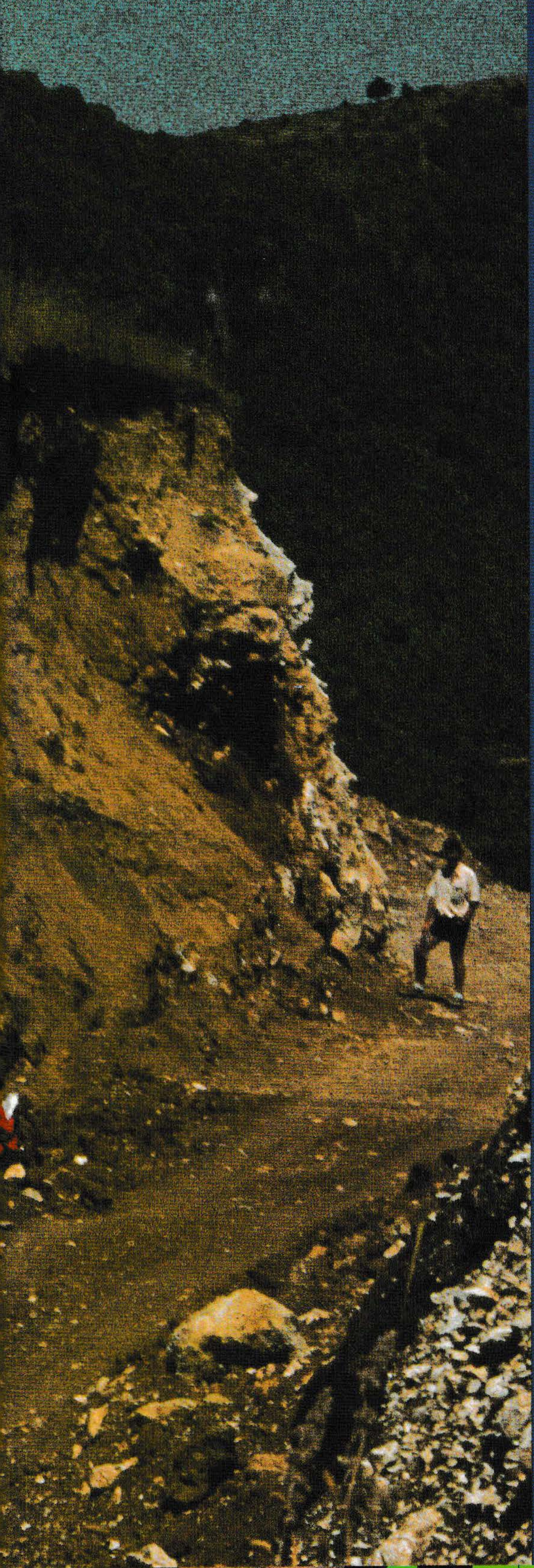
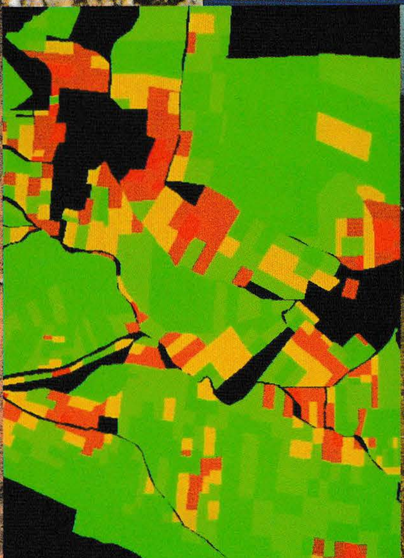
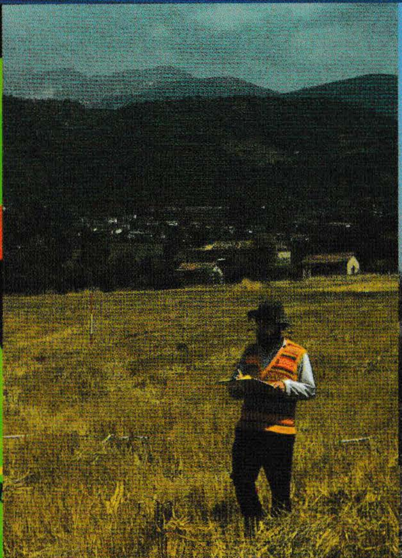


THE ARCHAEOLOGY OF
MEDITERRANEAN LANDSCAPES 2

Environmental Reconstruction in Mediterranean Landscape Archaeology

Edited by Phillipe Leveau,
Frédéric Trément,
Kevin Walsh
and Graeme Barker


The Archaeology of Mediterranean Landscapes

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10. Searching for the Ports of Troy

Eberhard Zangger, Michael E. Timpson, Sergei B. Yazvenko and Horst Leiermann

ABSTRACT

The paleotopography of the alluvial floodplain below the citadel of Troy (Hisarlik) is still disputed. Recently, it was suggested that one or several of the marshes and wetlands in the floodplain may represent silted-up basins which could have served as the long sought-after ports of bronze age Troy. To test this hypothesis and to generate the additional field data required to lead the discussion of the Trojan paleotopography towards a constructive solution, a short-duration, highly inter-disciplinary field study should be conducted. In this paper, the non-remote sensing, ground-based methods and components of such a project are discussed, including geomorphological mapping, systematic coring, micropaleontological analyses, identification of soils and their correlation through space and time, analysis of the paleoecology and paleoclimate, and technical reconstruction of the hydraulic system.

INTRODUCTION

No other city's fate has aroused as much general excitement and scholarly interest in Old World history as that of ancient Troy (Fig. 10.1). The earliest surviving written accounts in the western world, Homer's poems, revolve around the demise of this legendary city 3200 years ago. At first, the popularity of the oral traditions describing the end of the Heroic age may have helped to bolster the success of Homer's poetry, but soon the situation was reversed. The popularity of the *Iliad* and the *Odyssey* generated interest in the location and fate of the lost city. In the last century, the discovery by Charles Maclaren, Frank Calvert and Heinrich Schliemann of an extensive stratified settlement on the mound called Hisarlik, 25 km southwest of Canakkale in northwest Turkey, brought an end to the quest for lost Troy. This is the site generally identified with the city described by Homer – or at least parts of it. Many ancient Greek sources blamed the quarrel over Troy, apparently the biggest military engagement in the Aegean sphere at that time, for having caused the end of the heroic era – the watershed marking the boundary between the Bronze and Iron Ages. Greek and Roman generals made pilgrimages to the ruins of Troy, built temples to honour its memory, and sought to trace their family lineages back to Trojan ancestry. In medieval times, the war over Troy stood at the centre of many popular novels, despite the fact that knowledge of the Homeric epics was temporarily lost.

PERPETUAL PROBLEMS

Since large-scale excavations began at Hisarlik in 1871, the site has been subjected to an unusual degree of archaeological scrutiny, involving five excavation projects encompassing 26 individual years of excavation (up to 1997). Despite this impressive amount of scholarly dedication, the major questions surrounding the ancient city are as unresolved as they were shortly after Calvert and Schliemann first set their spades to it.

Some of the questions which emerged or re-emerged during the most recent excavations concern the size of the former city and the chronology of its settlement layers. The fall of Troy VIIa, marking the end of this once flourishing bronze age city, is a significant date for understanding the events during the so-called 'crisis years' around 1200 BC. At one point, the team of the current excavator, Manfred Korfmann, has stated that the fall of Troy VIIa might be placed around 1130 BC – considerably after the collapse of Mycenaean palatial society (Genz *et al.*, 1994: 341). Recently, however, this date has been adjusted to around 1180 BC (Brandau, 1997: 275; Zangger, 1994: 226).

Controversy also surrounds the actual size of ancient Troy. The British archaeologist John Bintliff (1991: 97), for instance, draws a picture of Troy VI as a fisherman's hamlet with a mere 100 inhabitants and no involvement in international commerce whatsoever, except as a fish market. According to Bintliff, Troy cannot be compared to a palatial

Fig. 10.1. Fortification walls of Troy VI.

residence such as Pylos, since the latter used to be a powerful administrative centre controlling an area many times larger than that belonging to Troy. In a similar vein, the former president of the German Archaeological Institute and excavator of Hattusa, Kurt Bittel, argues that 'the so-called sixth city of Troy is in reality a fortified chieftain's estate ("Fürstensitz") without any lower town surrounding it' (Bittel, 1976: 138). Korfmann too characterized Troy as a 'pirate's fortress' (Korfmann, 1986: 13) that was rather small in size. More recently, however, the excavators have considered Troy 'a residential and trading city of oriental style' (Korfmann, 1996: 30) and indeed 'one of the largest Aegean cities of its day' (Korfmann, 1995: 179). Since architectural remains of bronze age Troy emerge wherever archaeologists dig in non-erosional environments around Hisarlik, the 4th-century BC writer Hellanikos (F. Gr. Hist. 4,26a) may not have been entirely mistaken when he recalled that the city of Troy covered a number of different hills, with its citadel Pergamos crowning the tallest of them. Not surprisingly, the newly established National Park of Troy encompasses 61 known archaeological sites.

In 1992, the known extent of the city covered 100,000 m^2. Supposing that about one third of this area (= 33,000 m^2) was used for residential buildings (in addition to the citadel with its 5580 m^2) and taking into account the empirical value of 6.1 m^2 per person, Korfmann calculated a population of about 6000 (Korfmann, 1992: 138). Since 1992, however, the known extent of the city has at least doubled (to 200,000 m^2) if not tripled (to 300,000 m^2), but population estimates remained the same (Korfmann, 1995: 179). Provided the other parameters have not changed, the calculation of the population rate should now produce considerably higher numbers (12,000–18,000). The estimated population rate has not been raised, however, since it was previously argued that the available arable land around Troy was insufficient to feed the habitants of a large city (Korfmann, 1992: 138). The catchment of the city was estimated to have had a radius of seven kilometres, and an assumed 12.5% of this area was used for agriculture. Therefore, Korfmann calculated that the land could feed only about 6800 people. Supplies procured from the hinterland or conveyed by maritime trade were ignored. Moreover, the size of the catchment and the percentage of the arable land were taken from the work by John Bintliff, who estimated the total population of Troy to be a mere 100 – not a realistic figure from today's perspective. In his earlier work, Bintliff argued that today's fertile alluvial plains like the one at Argos used to be marshy grounds in the Bronze Age, unsuitable for agriculture (Bintliff 1977). More recent geoarchaeological studies have invalidated these ideas (Zangger, 1993: 84).

Considering the lack of investigations of late bronze age sites in western Asia Minor, the question of how large an area the city controlled and how significant its influence on international trade might have been is virtually impossible to answer. Korfmann's graduate students argue that contacts between Mycenaean Greeks and the Black Sea region are not confirmed by archaeological evidence (Genz *et al.*, 1994: 344). Korfmann himself, however, states that, first, Mycenaean swords have been found in Georgia, Armenia, Rumania and Bulgaria (Korfmann, 1988: 52); second, 'people around the Aegean have been interested in the Black Sea region long before the Mycenaean period', and third, that Troy's significance rested precisely on this interest (Korfmann, 1994).

Another unsolved problem regards the two artificial ditches, about four metres wide and 2–3 metres deep, which were detected on the plateau south of the citadel by the geophysicist Helmut Becker during a magnetometer survey (Becker and Jansen, 1994). The inner ditch lies about 400 m south of the Troy VI fortification wall at an elevation of approximately 25 m above sea level (Jablonka *et al.*, 1994: 53). The excavators believe that this ditch was accompanied by a fortification wall marking the outer circumference of the city. The second ditch lies even farther outside the citadel and appears to be identical to the first one, but, at least initially, it was interpreted in a different fashion: it was not thought to have been accompanied by a wall and suspected to have been outside the former city (reconstruction in Eberl and Romberg, 1995: 24–5). The function of these ditches is anybody's guess. Because of their elevation and small size, it is certain that they were unrelated to any navigable watercourses which may have existed in the floodplain (Zangger, 1992: 211). Although Siebler, a former member of the project, declares that the inner ditch was already filled in by the time of the Trojan War (Siebler, 1994: 116), the excavators now regard it as an obstacle for approaching chariots, still visible during the eighth century. BC (Mannsperger, 1995: 350).

THE QUEST FOR THE PORT

The most controversial questions, however, regard the locations of the coastline, the ports of Troy, and the potential camp-site of the Greeks during the Trojan War (e.g. Bintliff, 1991; Kraft *et al.*, 1982; Luce, 1984, 1995; Rapp and Kraft, 1994; Zangger, 1992). Understanding the current discussion revolving around those issues requires a look at the research history of Troy.

Thirty years after the conclusion of Dörpfeld's two-year excavation campaign, the architect returned in October 1924 to conduct a reconnaissance in Besik bay (Fig. 10.2), apparently aiming to revive the German archaeological research in the Troad after World War I. Dörpfeld was accompanied by the archaeologist Martin Schede and by the Bavarian geologist and fund-provider Oscar Mey. All three men published the results of their investigation in individual reports (Dörpfeld, 1925; Mey, 1926; Schede, 1930), complementing the work produced by Alfred Brückner (Brückner, 1912, 1925) and Walter Leaf (Leaf, 1912, 1923). Re-examining these reports shows that many of the approaches taken by the recent excavation campaign rest on ideas developed seventy to eighty years earlier. These include the approach of Hisarlik via an investigation of Besik bay, conducting excavations on Besik Tepe, establishing the site of the port of Troy during the initial stage of the investigation and arguing that the port was located in Besik bay. Even the existence of a late bronze age graveyard in Besik bay, announced as a surprise discovery during the 1980s, was, in fact, nothing new, as it was known earlier this century (Brückner, 1925: 247).

Other valuable ideas already introduced by Alfred Brückner regard the significance of the marshes on the western side of the Trojan plain and of the two artificial cuts through the Yeniköy ridge connecting those marshes with the Aegean Sea (Brückner, 1925: 246). Brückner suspected that the distinctly-shaped Kesik marsh (Fig. 10.2 and Fig. 10.3) used to be the port basin of the classical city of Sigeion. The prominent 400 m-long and 30 m-deep artificial cut through the coastal ridge would then have been its entrance (Fig. 10.4). This idea was revived by Zangger, who argued that the Kesik marsh may well hide the long sought-after port of bronze age Troy, including the 'naval station' of the Greeks during the Trojan War (Zangger, 1992: 211). The excavator rejected this theory, alluding to 'strong arguments' from ancient philologists (Korfmann, 1993a: 45). Yet the ancient philologist John V. Luce was sufficiently impressed to present the Kesik harbour site as his idea (Luce, 1995: 211).

RECENT INVESTIGATIONS

The idea to stimulate new research about potential harbour sites in the Trojan plain fulfilled its purpose. Fourteen years after drilling investigations had begun at Troy, the sedimentologist Ilhan Kayan at last directed his interest to the marshes and cuts on the western side of the plain. The results of this recent investigation were presented in combination with a coastline reconstruction which differs significantly from the one published before (Fig. 10.2) – but still leaves a number of open questions. According to his observation the sea level at Troy rose by about two metres between 1000 BC and 1000 AD (Kayan, 1995: 216). Despite this relative sea level rise, the coastline regressed, due to the large amount of sediment deposited into the plain. This is a common phenomenon that has been observed elsewhere in the Aegean (e.g. Zangger, 1993: 67). What is unusual at Troy, however, is that prior to this period the relative sea level had dropped by about two metres (between 3000 BC and 1000 BC). The sedimentologist states that this bronze age fall in sea level 'accelerated the deltaic progradation and that most of the plain changed into land during this period' (Kayan, 1995: 217). Surprisingly, in his coastline reconstruction the rapid

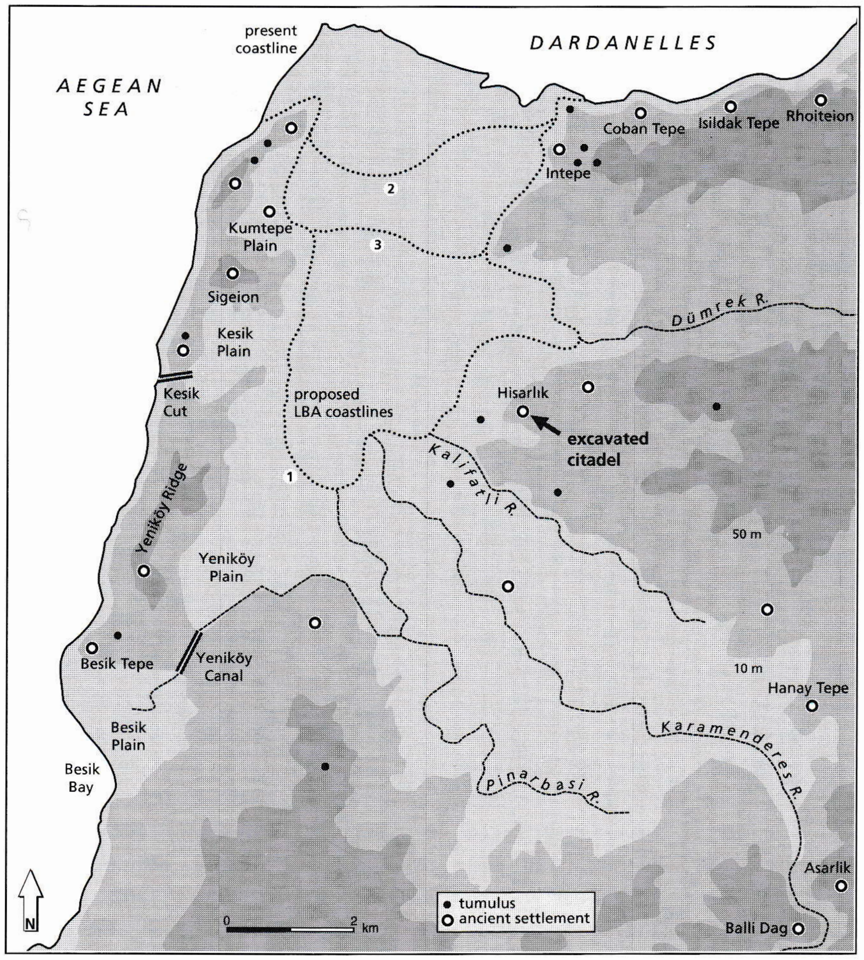

Fig. 10.2. Map of the plain of Troy with known archaeological sites, toponyms used in the text and river courses as recorded during the nineteenth century. Suggested positions for late bronze age coastlines are indicated as dotted lines and marked with numbers. 1. after Kraft et al. *(1982: 32), 2. after Zangger (1992: 211), 3. after Kayan (1995: 221).*

drop had the same effect as the subsequent rise. Both caused a moderate seaward movement of the shore (Kayan, 1995: Fig. 8). If, however, sedimentation rates are so high that they can compensate a sea level *rise*, a significant *fall* in sea level should have considerably accelerated the regression of the coastline. That such a fast regression apparently did not occur could be a hint at artificial interference with the hydraulic system. Anthropogenic control of the river sedimentation could have slowed down the sedimentation on the floodplain and thus the regression of the coastline. Another potential hint at the collapse of such an anthropogenic system could be the 'sharp change in the nature of sediments' in the floodplain observed by Kayan (Kayan, 1995: 231).

Inside the Trojan plain, the most landward possibility for a silted-up port is the Yeniköy plain, east of Besik bay. Kayan's drill cores revealed that this marsh was a marine embayment until the Early Bronze Age, and subsequently remained under water – even during the bronze age sea-level fall – since it was fed by the Pinarbasi stream rising at the south end of the plain of Troy (Kayan, 1995: 220). Between the Yeniköy plain and Besik bay, the coastal ridge drops to about 10 m above sea level. This low threshold is dissected by a canal running northeast/southwest. The canal was clearly not a navigable waterway, because it is too narrow and lies too high for that purpose. Kayan suspects that it was cut through the bedrock to drain the springs at Pinarbasi in order to prevent them from feeding the Yeniköy marsh (Kayan, 1995: 221).

There is no doubt that the canal was designed to direct water from the Karamenderes plain to Besik bay. If its whole purpose was drainage, however, a channel to the Karamenderes river would have sufficed. Thus, the real purpose of this construction remains enigmatic – and so does its date. Kayan cautiously states that the 'last use' of the canal was to drive a nineteenth-century AD water mill in the Besik plain. That such a massive construction was originally conceived and undertaken for this purpose is,

Fig. 10.3. During the 1960s the Kesik marsh (here seen from north) on the western side of the plain of Troy was drained and turned into arable land. Drill investigations have shown that the marsh used to be a marine basin during the Early Bronze Age. Later, it continued to be a depression filled with freshwater. Judging from its geographic position, this basin would have been an ideal port for bronze age Troy.

Fig. 10.4. The artificial Kesik cut dissects the 40-m high Yeniköy ridge. The bottom of the cut is now a field road, traversing the photograph from the lower right to the upper left corner. The light and dark macchia covers the north and south banks of the cut, highlighting its remarkable size.

however, economically irrational and rather unlikely. Peter Wilhelm Forchhammer, a geography professor at the University of Kiel, saw the canal when it was functioning and concluded that it must be of great antiquity. Rather optimistically, he hoped that nobody would assume that such a major construction was undertaken to drive 'the wheel of a humble water-mill' (Forchhammer, 1850: 20). To him, it seemed far more likely that an existing, silted-up, canal was cleaned and restored to be used for the mill. Korfmann, on the other hand, states that the canal definitely dates to the eighteenth century AD (Korfmann, 1993b: 28) – even though at that time, the date of construction was subject to debate as it is today. A Swedish engineer who examined the canal around 1790 remarked that 'everybody with even the faintest notion of engineering, would arrive at the conclusion that this construction is ancient' (Lenz, 1798: 22). The engineer himself dated it to the time of the Trojan War.

An outstanding candidate for a port inside the Trojan plain is the Kesik marsh due west of Hisarlik (Zangger, 1992: 207). Kayan states that before it silted up, this marsh could theoretically have been 'an excellent harbour', in particular since it appears to have been connected with the Aegean Sea through another artificial cut which dissects the coastal ridge (Kayan, 1995: 223). The surface of the coastal ridge rises to an elevation of 40 m in this area, while the highest point of the cut is at 13.7 m above sea level. Kayan's bore holes have revealed a 2–2.5 m thick layer of colluvium at the bottom of the trench. Thus, although the cut was an impressive 30 m deep, its bottom never came close to sea level. Tectonic movements are unlikely to have had a significant effect there, since bore holes in the Kesik plain have revealed coastal sand units from around 2000 BC at a depth equivalent to present sea level. Thus, Kayan believes that the cut was completely unrelated to maritime installations, something the British ancient historian John M. Cook (1973: 167) concluded some years ago: 'it seems to us clear that the work was never completed'.

Nevertheless, the cut could have been used as a dry slipway to transport ships between the Aegean Sea and the Kesik basin – as the German engineer and major Müller suggested in his report about the locality of the *Iliad*, published in 1798:

> 'Allein bey steilen, wenn gleich nicht hohen Ufern, war es eines Theils unmöglich, Schiffe von nur etwas beträchtlicher Grösse, so geradezu aus dem Wasser auf's Gestade zu ziehen, andern Theils würden selbige dabey sehr gelitten haben. Es wurden also Vorrichtungen erfordert, welche ersteres erleichterten, letzteres verhinderten. Dazu dienten Gräben, welches eigentlich in's Ufer gemachte Einschnitte waren, die allmählich (en pente douce) bis zum Wasser abliefen, und wodurch die Schiffe leicht, und ohne ihnen Nachtheil zuzufügen, heraufgezogen werden konnten.' (Müller, 1798: 139)
>
> (Translation: 'On low but steeply sloping coasts, it was almost impossible to beach ships without damaging them. Thus, installations were required which enabled the former and prevented the latter. For these purposes, channels were dug – actually being cuts into the coast – which gradually dipped towards the sea, and through which ships could easily be pulled without risk of becoming damaged.')

Kayan, however, points out that the lack of artefacts in trial trenches dug across the cut seems to indicate that it was not used in such a way. He advances the alternative explanation that the cut formed in a depression originally caused by a tectonic fault. Later, this natural passage was so frequently used by people commuting between the shore and the plain that the original valley deepened and widened. He overlooks the fact that such extensive commuter traffic would have produced a denser artefact scatter than the controlled lowering and rising of ships. Practical experiences gathered during numerous archaeological surveys tell that the number of surface finds increases in the vicinity of ancient roads and tracks.

The cut itself is too sharply defined, too straight, too large and too deep to be the result of some accidental trafficking. It is clearly a technical construction and was most likely designed to function as it now appears. It may not have been desirable to excavate the cut below sea level, to prevent saltwater from penetrating into the plain. The lack of artefacts in the buried paleosurface is not surprising, considering the degree of erosion that occurred in the area. Miocene sandstone is so prone to erosion that all remains of the classical city of Sigeion have disappeared from the coastal ridge.

Thus, despite the recent efforts to reconstruct the sedimentological history of the Kesik plain, many questions remain open. Kayan suggests that the Kesik plain could have been used as the port basin during the Early Bronze Age, but by the end of the Bronze Age it was probably silted up. Unfortunately, he does not discuss the depositional history of the plain after the Early Bronze Age. The radiocarbon dates (from marine shells) seem to indicate that it silted up after about 1300 BC In the stratigraphic cross-section through the Kesik plain, Kayan does not distinguish between 'swamp' and 'floodplain delta sediments'. Swamp sediments, however, might well conceal an ancient freshwater port basin. Finally, it is rather confusing that the Kesik plain appears as a marine embayment on the most recent reconstructions of Troy VI (Eberl and Romberg, 1995: 24–5), if it had silted up over 1000 years before.

Kayan ends his study with the conclusion that there is 'no evidence' that the basins on the landward side of the Yeniköy ridge have been used as ports in antiquity. On many occasions he refers to the lack of 'definite', 'clear', or 'most valuable or trustworthy' evidence. However, as always in archaeology, the absence of evidence is no evidence of absence – it should rather be taken as a challenge to change the methodology, the location of the search or the team of experts and to simply look harder. In erosional environments the chances of finding obvious or irrevocable evidence are minute. In order to even hypothesize how the now-destroyed landscape might have looked like in prehistoric times, one has to apply methods reminiscent of those used in forensic sciences.

In previous years Ilhan Kayan, Manfred Korfmann, George Rapp and John C. Kraft have unequivocally favoured the idea that the port of Troy was located in Besik bay (Korfmann 1991: 19; Kraft *et al.*, 1982: 40; Rapp and Kraft, 1994: 76), although there never was any 'definite' evidence to support this notion. Indeed, there is no 'conclusive' evidence that the archaeological site on Hisarlik is identical with the Homeric Troy. Only circumstantial evidence speaks in favour of this identification. Similarly, today there are numerous indications that the eastern side of the Trojan plain contained a complex hydraulic system, one that was most likely related to the ports of the city. These indications suffice to let the Besik hypothesis pale into insignificance. Kayan's closing remark that the theories advanced by Zangger (1992) lack 'the necessary proof' could be applied to any theory advanced by the excavators of Troy. Theories rest on arguments, not on proof. If new information arises which apparently contradicts existing theories, the latter have to be revised to fit the new data. As it turns out, the new data provided by Ilhan Kayan (1995) and insights gained during recent investigations of a late bronze age port system in Greece now permit a much more refined theoretical reconstruction of the paleohydrology of the Trojan plain.

ENVIRONMENTAL RECONSTRUCTION

In order to resolve the questions revolving around the canals and potential ports, it is clear that further paleoenvironmental studies are needed. We believe that after more than 120 years of traditional, palace-oriented, excavations at Troy, the time has come to supplement this work with a systematic investigation of its surrounding landscape, as has been so fruitfully applied elsewhere in the Mediterranean.

The sedimentological investigation of the plain of Troy began twenty years ago with a team composed of John Kraft, Ilhan Kayan and George Rapp – distinguished researchers whose pioneering work has paved the way for landscape reconstructions in the Aegean. Today, however, their approach resting exclusively on the sedimentological interpretation of drill cores no longer meets the standard required for landscape reconstructions. As these scholars themselves acknowledge, a wide array of new techniques is now available allowing far greater resolution and accuracy in landscape reconstructions. With respect to their investigation around Tiryns, Rapp and Kraft (1994: 85) conclude that 'the much more intensive study by Zangger (1991), based on a large number of drill cores, has provided a detailed picture of the environment and land use of Helladic people well beyond our previous work'. The same could be said about their study of the Gulf of Navarino, where they first detected an artificial stream diversion. A subsequent physical scientific study conducted in the framework of the Pylos Regional Archaeological Project was able to show that the redirected stream is just one component of a complex late bronze age port with a clean-water flushing mechanism (Zangger *et al.*, 1997a). It is quite conceivable that a succession of investigations by different geoarchaeological teams would lead to equally fruitful results at Troy.

At the outset of such a project, it is necessary to distinguish between the three different kinds of canals, cuts and trenches at Troy. First, there are the Yeniköy canal and Kesik cut dissecting the coastal ridge north and south of Yeniköy. Neither one of these constructions has ever been a navigable waterway. The Yeniköy canal is too narrow, while the bottom of the Kesik cut lies too high above sea level, as we now know. Second, there are at least two artificial ditches on the mound of Hisarlik which were found during a magnetometer survey (Jablonka *et al.*, 1994). Obviously, these narrow trenches are unrelated to the hydraulic system which might have existed in the plain. Why Manfred Korfmann consistently points out that Eberhard Zangger regards these as navigable watercourses remains enigmatic (Zick, 1997: 56) – they only have half the width of bronze age ships. Finally, there are paleostream beds and artificial canals inside the Trojan floodplain. These were described by many early travelers and scholars and still existed during the nineteenth century (Forchhammer, 1850: 20; Schliemann, 1880: 82; Zangger, 1992: 209). The senior author suggested that these now silted-up paleo-river courses inside the floodplain belonged to the port system at Troy – an idea initially rejected by Korfmann (1993a: 45). Meanwhile, however, the excavation team has also recognized the indications for navigable watercourses in the floodplain and now regards it as a possibility that a river port existed immediately below the citadel (Korfmann, 1997: 65). This interpretation is not new (Zangger, 1992: 146), but difficult to reconcile with earlier reconstructions, in which the sea was thought to have advanced all the way to the citadel.

To determine the purpose and possible interrelation of these features and to reconstruct the hydraulic system of the plain, a highly interdisciplinary study using state-of-the-art technologies from a number of natural scientific disciplines is necessary. This study must involve the application of several different remote sensing techniques at different altitudes, providing total-coverage information for the entire plain of Troy (Zangger *et al.*, 1997b). In this paper we concentrate on the ground-based methods to be considered, in particular on the contributions of geomorphology, soil science, paleoecology, geochemistry and hydraulic engineering.

GEOMORPHOLOGY AND PEDOLOGY

One of the first steps in a new investigation of the plain of

Troy would be the production of a geomorphological map which incorporates the information obtained by remote sensing, aerial photography, ancient and modern topographic maps, historic sources and ground checks. Based on this information, a team of earth scientists would conduct subsurface investigations, including coring and soil investigations, to determine the nature of the anomalies detected by radar and magnetometry surveys.

Recent landscape reconstructions in Greece and elsewhere have shown how much information about the paleoenvironment can be retrieved from examining the soils (e.g. Pope and van Andel, 1984; Timpson, 1992; Zangger, 1995). In order to obtain a detailed soil map, pedologists will examine the physical and chemical properties of the modern soils and the existence and degree of development of paleosols preserved in the alluvial sediments (e.g., Carter, 1993; Singer and Janitzky, 1986; Soil Survey Division Staff, 1993). Soil development involves a series of four interacting processes, consisting of additions, losses, translocations, and transformations, causing the differentiation of soil horizons. The quality and quantity of these processes depend on environmental factors including climate, parent material, and vegetation. Weathering and dissolution of primary minerals in the alluvial sediments result in mineral transformations and movement of the secondary weathering products to lower horizons. These processes manifest themselves in observable soil properties that can be determined in the field through close examination of the soils and sediments.

Describing soil horizons and their properties, therefore, not only provides initial insight into the processes and mechanisms involved in the development of soils, but also into the environmental conditions prevailing at that time. For example, weathering and movement of clay minerals from surface to subsurface horizons require many thousands of years. Thus, the observation of translocated clays in the soil B horizons implies long periods of landscape stability. The degree of soil development, the depositional environment, the nature of the soil parent material, and the physical processes involved in the formation of soils, can be determined through analyses in the particle-size distribution of the sediments and soils (Greenwood, 1969; Timpson and Foss, 1993). Because clay minerals weather in predictable sequences (Jackson *et al.*, 1948; Paquet and Millot, 1973), laboratory determinations of the clay fraction of the alluvial soils can be used to infer the conditions of weathering and therefore the regional climate (Timpson *et al.*, 1996). Subsequently, these soils will be correlated through space and time to determine – in relative terms – the periods of landscape stability and instability which occurred throughout the floodplain. Using this approach, it will be possible to develop a model of landscape evolution for the entire region (e.g. Foss et al., 1995; Mandel, 1994).

Since the Troad is known to have been seismically active in historic times (Rapp, 1982), the sedimentary record could also be examined for evidence of paleoseismic activity (Obermeier et al., 1990; Saucier, 1991). In the coastal plain region of South Carolina and in the New Madrid seismic zone of the central United States, subsurface injection features such as sediment dikes, and other seismically-produced sedimentary structures, including sand volcanoes and 'sand blows', have been found to document sediment liquefaction triggered by earthquakes (Obermeier et al., 1990).

Coring still represents an indispensable tool in environmental reconstructions, but it is important that core locations are established on a theoretical basis in order to reduce bias. An efficient way to investigate the subsurface stratigraphy of coastal plains utilizes cores that are placed at equal distances in straight lines across the floodplain (Zangger, 1993). Such cross-sections enable complete, unbiased coverage of the stratigraphy across the landscape. In the case of the plain of Troy, it is desirable to have several core cross-sections traversing the plain from east to west. To determine the paleoenvironment of subaqueous deposits found in those cores, it is essential to conduct detailed studies of the microfossil contents of the drill samples (e.g. Zangger and Malz, 1989). These investigations will be particularly useful to establish if and when the basins such as the one now concealed by the Kesik plain were once connected to the open sea.

PALEOECOLOGY

Archaeologists have long realized that knowledge of the vegetation history in their study areas is imperative to determine the degree of human impact on the natural environment, as well as past land use, and long-term changes in subsistence strategies. Obtaining continuous pollen records has therefore been a primary target of regional archaeological studies. The most recently investigated pollen cores from the Aegean are those taken from the Argive Plain in 1988 (Jahns, 1991, 1993) and from Osmanaga lagoon in 1993 (Zangger et al., 1997a). Both of these cores stem from regions of prime interest to Aegean prehistorians and both provide consecutive records of land use and vegetation changes extending back about 7000 years.

One of the challenges facing a palynologist in the Aegean is finding an appropriate site where continuous pollen preservation and sediment supply existed for a sufficiently long period of time. The most suitable depositional environments are marshes, swamps, lakes and coastal lagoons. In the dry and steeply sloping landscape of the Aegean, few such places exist. Gennett and Gifford (1982: 105) therefore postulate a hypothetical small, deep, spring-fed lake on the plateau 10 km east of Troy as the ideal source for recovering representative samples of the pollen from the vegetation of the surrounding countryside. There is no need, however, to establish such a hypothetical site, because wetlands abound within the alluvial floodplain of the Karamenderes and Dumrek rivers below Hisarlik. Even in historic times, the plain of Troy was regarded as swampy, and core analyses (Kayan, 1995; Kraft et al., 1982) have revealed that low-energy subaqueous environments existed within the plain at least since the Early bronze age. Considering the paramount interest in the archaeological history of the region and the rare presence of suitable pollen core sites, it is difficult to understand why a systematic paleoecological study has never been attempted. Given the abundance of marshes in the Trojan plain, several pollen cores might be taken, thereby enabling a reconstruction of spatial patterns of vegetation within the landscape as well as the discrimination between local and regional components in pollen diagrams.

The first and foremost task of pollen core analyses is the best possible identification of all pollen taxa found in the samples, combined with a thorough knowledge of ecological preferences of individual plant taxa. This aspect needs to be emphasized, because some previous pollen studies tended to focus on recognizing general groups of plants such as 'legumes', 'daisy-family' or 'oaks'. It is essential, however, to discriminate for instance between the pollen of deciduous and evergreen oaks, because these two species respond differently to human impact. Many crops (olive, walnut, flax, rye, corn) can be recognized in a pollen record and will therefore yield information about the extent and nature of agriculture and its historic development through time. Precise identification of weeds might help recognizing specific agricultural activities, such as grazing, farming and even crop rotation. It is interesting to note that inflorescences and roots of *Triticum durum* have been found in Troy I samples, possibly indicating that wheat was already cultivated at Troy during the earliest period of habitation around 3000 BC (Mulholland et al., 1982: 135).

An additional key element of high-resolution palynological analyses is dense core sample intervals providing high temporal resolution. Many important events in vegetation histories (for instance, forest fires and tephra layers from volcanic eruptions) have short time spans and might be overlooked, if the sample intervals are not densely spaced (see Bottema, Chapter 2). Furthermore, short sampling intervals help reduce the 'noise' and aid in extracting the main signals in long time-series. The anaerobic marsh environments in the floodplain are bound to contain ample remains of terrestrial plants that can be used to obtain a detailed radiocarbon chronology to date the vegetation history and to correlate changes in land use with historical events.

Another prerequisite of interpreting past vegetation changes on the basis of pollen records is a quantitative understanding of relationships between modern pollen production and the source vegetation. Thus far, interpretations of pollen counts in sediment samples from eastern Mediterranean countries are still problematic, since pollen counts do not necessarily reflect plant abundances in past vegetation. To establish relationships between the past pollen record and its source vegetation, modern pollen samples have to be examined quantitatively. In the temperate regions of Europe and North America, numerous studies have been conducted that quantitatively relate modern pollen assemblages to the source vegetation (Andersen, 1970; Bradshaw, 1981; Bradshaw and Webb, 1985; Heide and Bradshaw, 1982; Jackson, 1990; Webb, 1974; Webb et al., 1981; Yazvenko, 1991). Yet for the Aegean and, in fact, the whole of the eastern Mediterranean, the recent study of the landscape evolution of western Messenia (Zangger et al., 1997a) is the first attempt to quantify past vegetation – all previous studies have remained at a qualitative level (Bottema, 1974, 1980; Bottema and Barkoudah, 1979; Wright, 1972; Wright et al., 1967; van Zeist et al., 1970, 1975). Quantitative reconstructions of vegetation covers should provide a basis for assessing the proportion of land under cultivation and its changes through time.

Finally, fossil pollen samples should be compared with databases of regional vegetational records to find the closest modern analogs for the fossil assemblages and to accommodate pollen diagrams in the regional context. Such broad regional databases of modern pollen and vegetation data are available today, for instance for North America, central Europe, and the western Mediterranean.

GEOCHEMISTRY

Geochemical investigations are an essential part of the sedimentology, palynology, and pedology efforts. To test the hypothesis that some of the marshes in the plain of Troy may have been filled with water and connected to the sea, it will be necessary to determine and date the historical changes in the paleosalinity and paleoecology of the marsh deposits. The former depositional environment in the basins could be determined by measuring the sulphur and carbon contents of the sediments. If the marsh deposits conceal marine or brackish environments, the proportion of sulphur should be considerably above the values of the floodplain alluvium.

A coherent array of chemical testing, including determinations of carbon, nitrogen, and $\delta^{13}C$ should also be employed to analyze samples from the pollen cores (see Zangger et al., 1997a). Similar geochemical analyses can be conducted with soil samples. Organic compounds accumulate in the surface horizons of soils through the decay of plant remains, resulting in dark colours which mark the surfaces of buried paleosols. After burial, however, new additions of plant detritus cease and the organic compounds already present start to decompose, resulting in a gradual loss of the characteristic dark colour. Consequently, organic carbon content must be determined analytically to detect buried paleosurfaces more precisely.

Several other geochemical analyses have the potential of providing more information about the paleoclimate and environment in which a soil formed. For instance, quantifying the content and form of secondary iron minerals (such as hematite and goethite) can be used to assess the climatic conditions during soil formation (McFadden and

Hendricks, 1985). Also, determinations of the content, distribution, and composition of the primary and secondary carbonate minerals in soils can be utilized to model the processes and climatic conditions under which the soil formed (Mayer et al., 1988), because stable landscapes allow dissolution and movement of carbonates from surface to subsurface horizons. An initial assessment of the time frame needed for the soil's development can be obtained through field observations of the morphological expression of carbonate translocation (Gile et al., 1966). More precise information, however, requires laboratory analyses of these minerals.

Finally, insights into the paleoclimate and paleovegetation of the region may be obtained through measurements of the stable isotopic composition of carbon and oxygen in various soil components (Cerling et al., 1989; Grootes, 1993; Hays and Grossman, 1991; Kelly et al., 1991; Nordt et al., 1994).

URBAN PLANNING AND HYDRAULIC ENGINEERING

In traditional archaeological investigations, sites were considered as depositories of valuable artefacts to be retrieved from the ground. Today's regional archaeological projects have abandoned this approach (e.g. Cherry et al., 1991; Davis et al., 1997; Jameson et al., 1994; Snodgrass, 1987), and instead aim to consider sites as the settlement centres of dynamic and evolving societies whose fate and fortune depended largely on successful interactions with the natural environment. It is therefore necessary to incorporate the techniques of intensive survey and technical reconstruction of past urban planning in a regional archaeological study. However, no such study of the Trojan plain has been conducted since Forchhammer and Spratt surveyed and mapped the area in 1839. A century later, in 1924, many of the architectural remains recorded previously had already disappeared, including a 60 m-long stretch of what Thomas Spratt considered to be the fortification wall of Sigeion (Brückner, 1925: 242; Forchhammer, 1850: 22).

At Troy and Pylos, tumulus-shaped hills of bedrock have been identified, 'leftover'-remnants of the former surface which were spared destruction by modern agricultural practices (Kayan, 1995: 228; Zangger et al., 1997a). Considering the degree of surface destruction, many artefacts and architectural remains are likely to have fallen victim to erosion. Still, it would be better to conduct a systematic archaeological survey now: better late, than never. During this survey, particular attention should be paid to those areas where anomalies have been detected using remote sensing techniques to determine whether these lineaments correlate with structures visible on the ground.

Early hydraulic civilizations in Mesopotamia and Egypt were able to control annual river floods and turn them into a blessing for the economy long before the second millennium BC. Recent investigations of Mycenaean hydraulic engineering feats have shown that an impressive level of engineering expertise also existed in late bronze age Greece (e. g. Knauss, 1990, 1991, 1996). There is no reason to assume that ephemeral river floods limited the use of fertile alluvial soils in the floodplains around the Aegean. It is thus unlikely that the plain of Troy was a wasteland controlled by the floods of the Karamenderes river (as stated by Kayan, 1995: 232). More probably, the people at Troy stabilized their landscape to the extent that it could be optimally exploited for centuries. The large number of lineaments, abandoned channels, river quays, artificial canals, bridges, sand heaps and man-made ditches around Troy are strong indications that this was indeed the case. Even more, no other place has as many references to anthropogenic interferences with the hydraulic system as Troy – from classical times until the nineteenth century AD (e. g. Forchhammer, 1850: 20; Mauduit 1840: 132; Pliny, Nat. Hist. 5.30; Schliemann, 1880: 98). According to ancient mythology, the course of the Karamenderes River was actually determined by Heracles, thus its ancient name Skamander (skamma andros = 'man-made foam').

A WORKING HYPOTHESIS

The currently favoured approach of the excavation campaign to reconstruct the Trojan landscape on the basis of the Iliad (Mannsperger, 1995) bears many risks. Homer never mentioned the port at Pylos, the river diversion at Tiryns or the melioration of Lake Kopais. Even if Homer existed as an eighth-century BC individual, it would have been impossible for him to comprehend a hydraulic system which had collapsed five hundred years before. Therefore, the most promising approach to reconstruct the human interferences with the hydrological environment at Troy is through the cooperation with hydro-engineers – preferably those with a background in prehistoric technology. If modern engineers attempt to meet the goals of the past using the techniques available in the past, it may be possible to determine, at least approximately, the design of the infrastructure surrounding prehistoric and early historic cities. Common goals, fulfilled by common techniques, are bound to lead to common solutions. Prime examples for the methodology and potential of such technical reconstructions are the investigations of Mycenaean hydro-engineering (e.g. Knauss, 1991) and early iron age ports (e.g. Raban, 1997).

During the Pylos Regional Archaeological Project the collaboration between hydro-engineers and physical scientists from several different disciplines has unveiled the earliest thus far known artificial port in prehistoric Europe (Zangger, et al. 1997a). The system is highly sophisticated and reflects a level of engineering skill surpassing that of classical times. Its discovery proves that the hydraulic

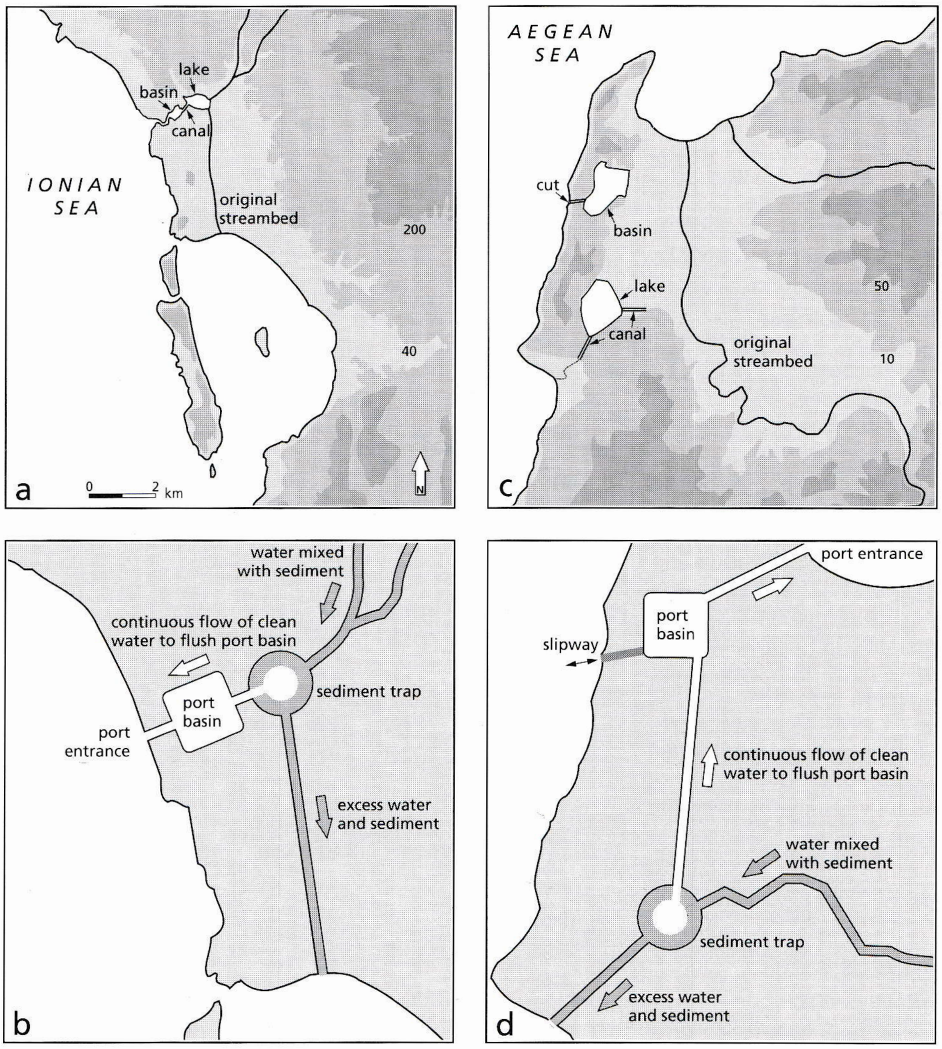

Fig. 10.5. During a recent geoarchaeological investigation around the Palace of Nestor on the southwestern Peloponnese, a complex hydraulic system was discovered (a). In one area a river was dammed to create an artificial lake. Sediment tranported by the river was deposited in the lake, while the clean water from the upper layers of the lake was used to flush an artificial port basin, thereby preventing it from silting-up by sediment derived from the sea (b). The remains of hydraulic installations at Troy (c) could have been components of a similar system (d).

expertise required for the complex domestic meliorations was also applied to maritime installations. About 4.5 km southwest of the 'Palace of Nestor' at Pylos, a cothon-type basin, 330 by 230 m in size, was artifically excavated about 500 m inland from the Ionian coast, connected to the sea by a paleochannel of a Pleistocene streambed (Figs. 10.5a, 10.5b). By itself, the entrance to the basin would have silted up after a few seasons – due to the large amount of sand transported along the coast by the longshore current. The architects who designed the port therefore constructed a flushing mechanism that prevented large amounts of saltwater (and sediment) from penetrating into the basin. The water required for the flushing current was derived from the nearby Selas River – by far the largest perennial stream of the region. Since the river itself also transports large amounts of sediment that would have filled the port basin, a sediment trap had to be constructed first. The river was thus dammed to form a lake 180,000 m^2 in size. When the river water reached the lake, it lost its energy and dropped the suspended sediment and bed load into the reservoir. From the surface of the lake a small current of clean water was directed through an artificial canal into the port basin, while the remaining water left the lake through the original streambed.

This system obviously demanded control of how much clean water was directed into the basin and how much dirty water was allowed to escape. When control was abandoned after the Mycenaean demise, the river, left to itself, chose the shorter course through the port basin, thereby filling it up almost immediately. Radiocarbon accelerator dates from auger cores have shown that the port was functional during the peak of the Mycenaean era,

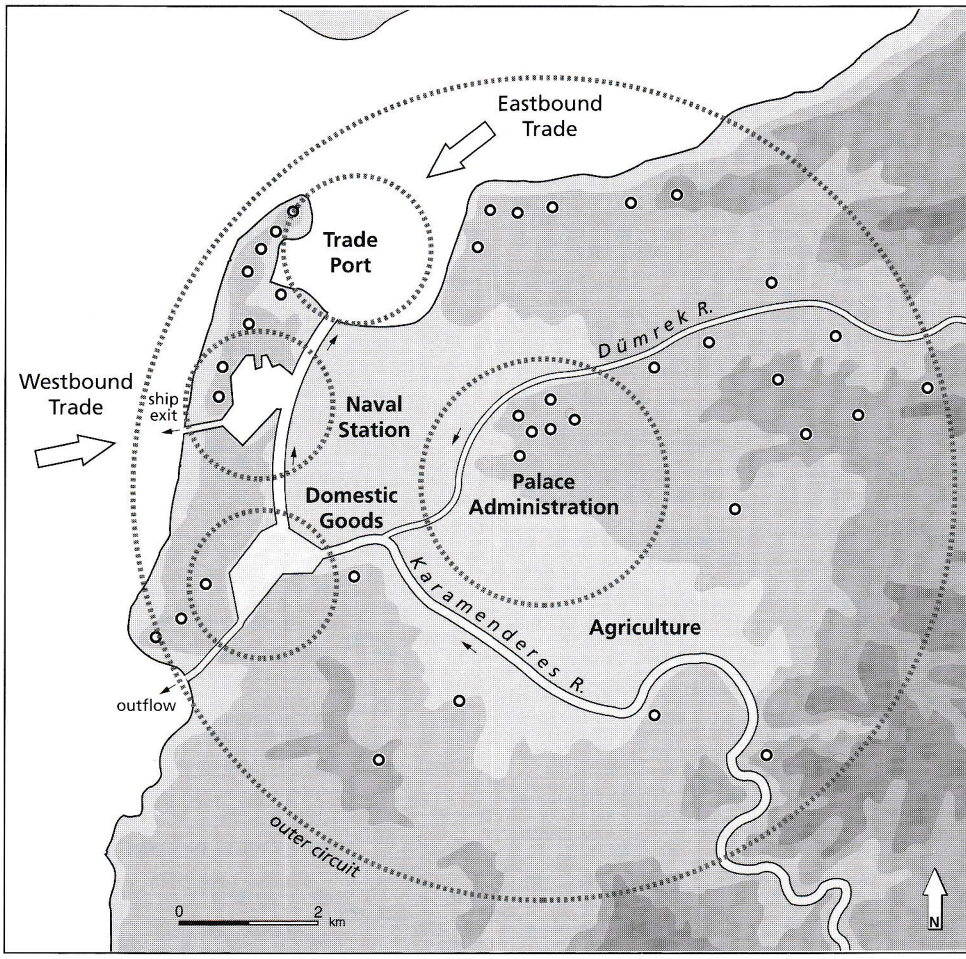

Fig. 10.6. This schematic model for the city of Troy illustrates how the floodplain below the citadel of Troy could have been used for port installations. The sediment-rich Dumrek and Karamenderes Rivers jointly exited into a lake at Yeniköy which could have been used for river traffic and for handling domestic goods. The canal toward Besik bay served as an outflow for excess water and sediment. Clean, sediment-free water was taken from the upper layers of the lake and directed north toward the basin at Kesik, which served as a 'naval station' either for military vessels or for westbound trade goods. Finally, the freshwater exited into the sea at Kumtepe, where there may have been the main port for trade with the Black Sea.

between about 1400 BC and 1200 BC. Its clean-water flushing mechanism, however, represents a standard-solution that was re-invented and widely applied in medieval Europe. All that was required to build such a naval installation was a floodplain, a stream feeding the floodplain and a low coastal ridge isolating it from the open sea – a typical landscape setting in the countries around the Aegean. A few engineers and about two hundred workers would have been able to build the system at Pylos in one to three years. Artificial port basins in Egypt, like the one of Birket Habu built under the rulership of pharaoh Amenhotep III., bear witness that constructions of this kind – even twenty times bigger than the basin at Pylos – were feasible using fourteenth century BC know-how and technology.

The knowledge about the port of Pylos, combined with the information provided by the recent subsurface studies along the Yeniköy ridge, now permit a refined theoretical reconstruction of the paleohydrology of the Trojan plain – one that might be used as a working hypothesis for future investigations. The port system at Pylos shows many similarities to the landscape at Troy and the remains of its hydraulic installations (Figs. 10.5c, 10.5d). The Yeniköy and Kesik plains represent silted-up basins and indeed remained wetlands until the 1960s. The former function of one basin, which now is the Yeniköy marsh, could have been equivalent to the lake and sediment trap at Pylos (Fig. 10.6). From this lake, sediment-rich water was directed through the artificial canal to Besik bay – an idea already advanced by the geologist Oscar Mey during his investigation of the sediments in the Besik plain (Mey, 1926: 19). At the same time, this lake may have been used as a river port for domestic goods. After all, most hydraulic installations fulfill more than one purpose (Leiermann, 1994: 18). Sediment-free water from the upper layers of the lake was directed towards a second basin, the 'naval station' at Kesik. This basin served as an interior freshwater port. It was generally preferred to keep vessels in freshwater to repulse worms and algae from the wooden hulls. The freshwater current continued to run toward the sea and exited near Kumtepe. Thus, saltwater – and the sediment carried by it – were prevented from entering the port system. Ships could enter or leave the Kesik basin by two ways. They could either sail into it from the north, or they could be pulled through the dry Kesik cut. In times of war, this additional exit permitted Trojan warships to circumvent naval attackers besieging the north coast. In peaceful times, ships travelling from and to the west were raised and lowered through the cut. Such a special service warranted extra high charges – and permitted a complete separation of the trade between the Aegean and Black Seas. Trade goods coming from and going to Aegean destinations were processed in the Kesik basin, while those from and to Black Sea cities were handled on the coast at Kumtepe. Keeping the suppliers separate from each other allowed the Trojans to dictate prices for goods in transit. In this way, the rulers of Troy would have ideally benefited from the favourable location of their city.

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