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ARTIFICIAL PORTS AND WATER ENGINEERING AT TROY: A GEOARCHAEOLOGICAL WORKING HYPOTHESIS

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ABSTRACT

Discoveries of hydraulic installations in Egypt, Syria, Palestine, Greece and Hittite Asia Minor and have shown that already during the Late Bronze Age a great deal of knowledge existed with respect to optimizing hydrological environments. During the 2nd millennium BC, engineers devised systems to drain lakes and wetlands, channelize and divert streams, build reservoirs, and dig artificial port basins on a massive scale. They also invented systems to keep basins sediment-free by flushing them with fresh water. In this paper the authors look at the example of the Port of Nestor at Pylos to propose a generic hydraulic system for an artificial seaport with clean-water flushing. This approach is then applied to the remains of artificial interferences with the landscape still visible in the floodplain below Troy. In this way, we develop a working hypothesis as to how a human-made hydraulic system at Troy could have functioned. We argue that Troy may well have possessed an artificial fresh-water-filled port basin that was connected to the Aegean Sea via a dry slipway. By being pulled over 150 meters of land and the sliding down another 300 meters, eastbound vessels would have avoided a 50 kilometer-long detour all the way around the island of Gökçeada and thus eased the hazardous entry into the Dardanelles. From this artificial Port of Troy basin, ships could slip directly into a counter-current running along the south coast of the Dardanelles, significantly mending their journeys towards the Black Sea.

Keywords: Troy, Pylos, artificial ports, hydraulic engineering, Late Bronze Age, navigation, Dardanelles.

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Hydraulic Installations

Water management was first successfully practiced in Mesopotamia and Egypt. A relief from Upper Egypt dating to the middle of the 4th millennium BC depicts a pharaoh opening an irrigation channel. Constructing and maintaining canals was a major endeavor in ancient Egypt, where a system of dikes extended across the Nile delta. Such installations made it possible to control the annual floods of the Nile and turn what used to be a threat into a blessing for the economy. Strict laws regulated people's obligation to contribute to the maintenance of the system. Some of the embankments thus remained functional for over 1,000 years, and are partly still visible today.

By the 14th century BC, the wealth and power of the pharaoh, and engineering skills, had evolved to such an extent that Amenhotep III could order the construction of a port basin, 1.5 kilometers long and 1 kilometer wide, in western Thebes. The perimeter and spoil heaps are still clearly visible at present-day Birket Habu.

A great deal has recently been found out about hydraulic engineering in Mycenaean Greece (Fig. 1). The German hydro-engineer Jost Knauss spent many years investigating the remains of human-made constructions at well-known sites¹. One of the most impressive feats was draining Lake Kopais in Boeotia². Knauss investigated the Late Bronze Age drainage of Lake Kopais and concluded that an artificial canal was built to drain 700 million cubic meters of water every year. This system functioned for a few hundred years during the Mycenaean period. Knauss also studied a dam below Mycenae that was built to create a water reservoir, but which was previously assumed to have merely been a bridge.

Experts in ancient hydraulic engineering have recognized remnants of hydraulic systems at numerous other Mycenaean sites. During studies in the Argive Plain in the 1980s, the senior author too arrived at the conclusion that Lake Lerna was artificially drained, and that this engineering feat might well have been reflected in the legend of Heracles fighting the Lernaean hydra³. In this case, the ever-regenerating heads of the hydra would reflect the streams feeding the lake. Whenever one was cut off, a new one would spring up elsewhere.

Another major achievement – in fact the oldest hydraulic installation on the European continent that still functions – is the stream diversion near the Late Bronze

¹ E.g. Knauss 1996, 157–164; Knauss 2001. – It should be emphasized that recognizing these remains requires the trained eye of an experienced hydro-engineer.

² Strabo, *Geography* 9.2.40: “They say that the place now occupied by Lake Kopais was formerly dry ground, and that it was tilled in all kinds of ways when it was subject to the Orchomenians, who lived near it. And this fact, accordingly, is adduced as an evidence of their wealth.”

³ Zangger 1991, 1–15.

Age citadel of Tiryns⁴. The lower town of Tiryns repeatedly suffered flash floods. As a consequence, the people there built a dam, and redirected the entire stream through a 1.5 kilometer-long canal (Fig. 2). At about 100 meters long, 10 meters high, and 40 meters wide, the dam is a structure of considerable size. Jost Knauss⁵ found out that the dimensions of the dam exactly met the requirements for managing maximum runoff.

It is now certain, that an “enormous know-how”⁶ of water management was also available in Hittite Asia Minor. The Hittite dam and reservoir at Gölpınar in Alaca county (Çorum province) was excavated by Aykut Çınaroğlu between 2002 and 2007.⁷ It was built during the reign of Hattuşili III, about 100 by 110 m in size and could contain 25 000 m³ of water. The reservoir was designed in such a way that sediment-free clean water would exit from it across a shallow gravel-plastered spillway. – In the urban area of Hattuša two large-scale ponds existed and have been excavated since the 1980s⁸. The silted East Ponds could store 36,000 m³, the South Pond 20,000 m³. Other known dams in Hittite Asia Minor include Karakuyu in the vicinity of Kayseri Pınarbaşı and Köylütölu in Konya Kadınhan. Hittite laws and official circulars in cuneiform provide clues to the importance of protecting dams from littering and the need to clean artificial canals at least once a year. Farmers who damaged irrigation canals were punished. – The highly sophisticated hydraulic installations of Urartu also indicate that the knowledge of water management must have had a long tradition in Anatolia.

The Port of Nestor

In April 1991 the senior author of this paper, Eberhard Zangger, gave a lecture at the Troy Project in Tübingen at the invitation of the former excavator of Troy, Manfred Korfmann. Zangger presented the findings on the stream diversion at Tiryns. Two months later, he visited Korfmann at Troy, examined the silted-up basin and the artificial trench at Kesik, and together with the excavator looked at spoil heaps in the Karamanderes floodplain a few hundred meters west of the modern village of Kalafat. A few days after this visit, Zangger was on the Peloponnese in Greece for a pilot reconnaissance of the Pylos Regional Archaeological Project (PRAP), a project conducted by the University of Cincinnati under the direction of Jack L. Davis. At Pylos, too, artificial interferences in the landscape exist that are quite comparable with those at Tiryns, and even more so with those at Troy. As co-

⁴ Zangger 1993, 1994, 189–212.

⁵ Knauss 1996, 158.

⁶ Klinger 2007, 93; Hüser 2007.

⁷ Çınaroğlu 2004; 2005; 2006.

⁸ Wittenberg 2013, 692; Schachner 2013.

director and chief physical scientist of PRAP, Zangger was able to investigate the hydraulic system below the Palace of Nestor over a number of years.

The royal residences of Pylos and Troy have much in common with respect to their environmental setting. Both sites are located on east coasts facing potential markets across the sea in the west. Both palaces lie approximately 5 kilometers inland from the coast, giving them a strategic and pleasant view of a wide region and distance from the noise, pollution and danger of the coastal surroundings. Both are right next to perennial streams and a fertile coastal plain. And both landscapes contain deep artificial trenches and thus show clear signs of human interference.

At Pylos, geoarchaeologists John C. Kraft and George Rapp had begun investigating the area during the 1970s⁹. They discovered that the Selas stream passing west of the Palace of Nestor suddenly entered a bed that did not seem to be entirely natural (Fig. 3). This Holocene change in riverbeds might well be due to anthropogenic interference, as Kraft and his coworkers suggested: “At some time the river was diverted into its present flow pattern to the west. The authors consider it a possibility that man caused a diversion of the river by cutting a gap north of Romanou.”

The topographic contour pattern of the coastal plain north of Osmanaga lagoon has the shape of an alluvial fan, suggesting that a massive amount of sediment was deposited there in recent times. Between Romanou and Koryfasio, where the coastal plain reaches elevations of 14–20 meters above sea level (masl), Kraft and his coworkers found up to 24 meters of early to middle Holocene floodplain deposits. The existence of such massive deposits can only be explained if there was a river feeding the fan and floodplain with sediment. Today, however, the only large stream in the area, the Selas River, exits into the Ionian Sea, completely skipping the alluvial plain north of Osmanaga lagoon. The floodplain has even become inactive, and is now an erosional rather than a depositional environment.

Evidently, during the first half of the Holocene, when large quantities of sediment were deposited, the stream must have used a different channel, one that ran south to exit into the Bay of Navarino (Fig. 3). No later than 800 BC, when Osmanaga lagoon formed, the Selas River must have changed its direction and assumed its present course; otherwise the lagoon would have filled in long ago.

Kraft and his colleagues suggested that the diversion of the Selas River was brought about by Mycenaean engineers, whose goal may have been the removal of all major flood problems in the coastal plain to make the plain more habitable and improve its agricultural potential.

During our investigation of the stream diversion we found that because of the relatively steep gradient of 5%, no more than 25–35% of the floodplain would have

⁹ Kraft et al. 1980b, 187–210.

been under water, even during major floods. Hence, there was no real threat of flooding to anyone who might have lived on the plain. On the contrary, inundations during the winter would have enhanced the agricultural value of the land. An artificial diversion of the river to prevent floods was therefore unnecessary.

A topographic cross-section of the northern section of the floodplain between the Palace of Nestor and Osmanaga lagoon shows the old stream path during the early Holocene, when the river was feeding the floodplain (Fig. 4). It also shows that the present stream actually passes over a ridge consisting of conglomerate – the hardest stone in the entire area. The stream was indeed forced to go right through the top of the conglomerate knoll. Such a river path can only be artificial. The canal is in fact still well visible today. It is about 10 meters deep, and has almost perpendicular walls. People therefore did interfere with the landscape, and they clearly did so to adapt the landscape to their needs.

The canal exited into a rectangular plain, 330 by 230 meters in size and about 500 meters inland from the Ionian coast, which did not seem to be completely natural either. The working hypothesis during PRAP was that this plain represented a silted-up artificial basin, which most likely was built to function as a human-made port. In that case, the stream diversion must be somehow related to the basin.

During the 1990s, the elements of the hydraulic system were still well discernible in the landscape. Today, the Costa Navarino Hotel Resort occupies this area, and the formerly rectangular plain southeast of the former Kokevis estate building, whose ruins are still in place, is largely covered by the driving range of the hotel's golf course.

Back in 1994, Zangger made drill holes into the plain to determine the subsurface stratigraphy. The stratigraphy revealed clay deposits with marine and brackish microfossils at the bottom of the Holocene sequence, covered by coarse gravel and floodplain alluvium. This means that the basin was indeed artificially made, because there is no reason for such a pool to form naturally in the middle of the landscape.

Continuing the inquiry at this stage required the expertise of a hydraulic engineer. For this reason Jost Knauss was asked to join the project. Not long after he set foot in the study area, Knauss discovered yet another basin upstream from the first one. This second basin, a now silted-up lake of 180,000 square meters, was more irregular in shape. It was connected with the proposed port by an artificial canal adjacent to the Kokevis estate (Fig. 5).

As it turns out, it would have been pointless to excavate a cothon-type port by itself, because the long shore current would have silted up the entrance to it very quickly. The engineers who constructed the port had to think of ways to prevent the sediment from entering the basin. To keep the basin sediment-free, they constructed a clean-water flushing mechanism. The clean water had, of course, to be derived

from a river that would, however, also carry a sediment load. Directing a river into an artificial basin means that the basin will quickly fill up with sand and gravel. That is why another basin was needed further upstream. This upstream reservoir was built by simply blocking the river with a dam. The stream lost its energy when entering the reservoir and thus dropped its sediment load, so that water at the lake surface was clean and sediment-free. This clean water was then diverted through the artificial canal into the actual port basin (Fig. 5). In this way, the port basin was continuously provided with fresh water. The fresh water exited towards the sea, and its pressure prevented marine water and sediment from entering the port.

This solution shows how sophisticated hydraulic engineering was during the Late Bronze Age. Radiocarbon accelerator dates from auger cores have proved that the port was functional during the peak of the Mycenaean era, between about 1400 BC and 1200 BC¹⁰. It is thus the earliest known artificial port in prehistoric Europe. Its discovery proves that the hydraulic expertise required for complex domestic meliorations was also applied to maritime installations.

A Generic Artificial Sea Port

The knowledge gained at the Port of Nestor can be used to develop a generic model for an artificial port to reconstruct the experience that was evidently available during the Late Bronze Age. It is likely that very few engineers possessed this expertise, and those experts may even have been foreigners who were called in for a limited time to oversee the construction, much like internationally renowned architects today. All that was required, in addition to the engineering know-how, was the authority to command a few hundred slaves and the supplies to feed them.

In addition to this, a suitable environmental setting was also imperative. What was needed was a river and an alluvial plain running more or less parallel to a section of the coast and divided from it by a low ridge. This is exactly the environmental setting at Pylos and Troy. At Pylos, the Selas River runs from north to south, and at Troy the Karamanderes River from south to north. Apart from that, the settings are virtually identical. Engineers would then have determined a suitable location for an artificial basin between the floodplain and the coast. It could be relatively near to the coast, but in any case needed to have a narrow entrance. It could also be on the edge of the floodplain, as long it had distinct banks. In addition to the basin, the river that used to feed the floodplain needed to be dammed to create a reservoir. Those were the major constructions; the only other things needed to make the system work were one canal between the reservoir and the port basin and one between the latter and the coast. The first canal carried clean water from the uppermost layers of the reservoir into the port basin and made sure it was filled with fresh water,

¹⁰ Zangger et al. 1997, 622.

which would help remove worms and algae from the wooden ships. It would also produce pressure inside the port and thus a permanent run-off preventing seawater and sediment from entering the artificial basin. The second canal, connecting the port basin and the coast, had to be as narrow as possible to prevent seawater from entering the system, but obviously wide enough to allow the passage of ships. The clean-water flushing mechanism already applied during the Late Bronze Age represents a standard solution that was re-invented and widely used in medieval Europe.

The Plain of Troy

Troy ranks as the most important stratified archeological site in the world. No other city's fate has aroused so much general excitement and scholarly interest in Old World history as that of ancient Troy. The earliest surviving written accounts in the Western world, Homer's poems, revolve around the demise of this legendary city 3,200 years ago. At first, the popularity of the oral traditions describing the end of the Heroic age may have helped 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 19th century, the discovery by Philip Barker Webb, Charles Maclaren, Frank Calvert and Heinrich Schliemann of an extensive stratified settlement on the mound called Hisarlık, 25 kilometers southwest of Çanakkale in North-West Turkey, brought an end to the quest for lost Troy¹¹. 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 until that time, for bringing about the end of the Heroic Age¹² – 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 honor its memory, and sought to trace their family lineages back to Trojan ancestry. In medieval times, the war over Troy stood at the center of many popular novels, despite the fact that knowledge of the Homeric epics was temporarily lost.

Since large-scale excavations began at Hisarlık in 1871, the site has been subjected to an unusual degree of archaeological scrutiny, involving five research projects encompassing 40 individual years of excavation.

The major questions surrounding the ancient city are as unresolved as they were shortly after Calvert and Schliemann first set their spades to it. Controversy, for instance, still surrounds the actual size of ancient Troy. The former president of the German Archaeological Institute and excavator of Hattusa, Kurt Bittel, argued that “the so-called sixth city of Troy is in reality a fortified chieftain's estate without any

¹¹ E.g. Allen 1999.

¹² E.g. Plato, *The Laws* 3.678; Thucydides, 1.12; Strabo 1.3.2

lower town surrounding it”¹³. The excavator Manfred Korfmann also characterized Troy as a pirate fortress¹⁴. Later on, however, he considered Troy to be “a former large residential and trading city of oriental style”¹⁵ and indeed “one of the largest Aegean cities of its day.”¹⁶

Scholarly debate also surrounds the ports of Troy and the potential campsite of the Greeks during the Trojan War¹⁷. Understanding the current discussion revolving around these issues requires a brief 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 Beşik Bay, apparently aiming to revive German archaeological research in the Troad after World War I. Dörpfeld was accompanied by the archaeologist Martin Schede and the Bavarian geologist and fund-provider Oscar Mey. All three men published the results of their investigation in individual reports¹⁸, complementing the work produced by Alfred Brückner¹⁹ and Walter Leaf²⁰. Re-examining these reports shows that many of the approaches taken by the excavation campaign under the direction of Manfred Korfmann are reminiscent of ideas developed 70 to 80 years earlier. These include approaching Hisarlık via an investigation of Beşik Bay, first conducting excavations on Beşik Tepe, establishing the site of the port of Troy during the initial stage of the investigation, and arguing that the port was located in Beşik Bay. Even the existence of a Late Bronze Age graveyard in Beşik Bay, announced as a surprise discovery during the 1980s, was, in fact, nothing new, as it was already known earlier this century²¹. 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 these marshes with the Aegean Sea²². Brückner suspected that the distinctly-shaped Kesik plain (Kesik düzlüğü, Lisgar marsh) used to be the port basin of the classical city of Sigeion. This idea was revived by Zangger, who argued that the Kesik plain may well hide the long sought-after port of Bronze Age Troy, including the “naval station” of the Greeks during the Trojan War²³. The excavator (Korfmann) rejected this theory, alluding to “strong argu-

¹³ Bittel 1976, 138.

¹⁴ Korfmann 1986, 13: „I might not be far wrong should I describe Troy as a pirate fortress“; Korfmann 2003, 8.

¹⁵ Korfmann 1996, 30.

¹⁶ Korfmann 1995, 179.

¹⁷ E.g. Kraft et al. 1982, 11–41; Luce 1984, 31–43, Luce 1995; Rapp – Kraft 1994, 69–90; Zangger 2003, 317–324.

¹⁸ Dörpfeld 1925, 115–121; Mey 1926; Schede 1930, 358–368.

¹⁹ Brückner 1912, 616–633, Brückner 1925, 230–248.

²⁰ Leaf 1912; Leaf 1923.

²¹ Brückner 1925, 247.

²² Brückner 1925, 246.

²³ Zangger 1992, 211.

ments” from ancient philologists without specifying those²⁴. And yet the ancient philologist John Victor Luce was sufficiently impressed to present the Kesik harbor site as his idea²⁵.

Artificial Interferences with the Landscape at Troy

Obviously, the most promising approach to reconstructing human interference with the hydrological environment at Troy is by cooperating with hydro-engineers, preferably 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, achieved using common techniques, are bound to lead to common solutions. Such a collaboration with hydro-engineers was unfortunately never attempted during the many years of excavations at the royal citadel.

The landscape around Hisarlık abounded in lineaments, abandoned channels, river quays, an artificial canal, bridges, numerous sand heaps and man-made ditches according to the topographic map produced by Thomas Spratt and Peter Wilhelm Forchhammer in 1839²⁶. Unfortunately, these elements are today, after a century of tractor-driven deep ploughing and the large-scale regulation for the Karamenderes River, hardly recognizable. Nevertheless, these are strong indications that hydraulic installations of some kind used to be in place. To recognize these elements and determine how they may have functioned together at some point in the past, one has to see the landscape through the eyes of an engineer who wanted to optimize it over 3,000 years ago, because never, at any point since then, did this area play such a pivotal role that a complex hydraulic system would have been needed. But a technical reconstruction requires many years of experience and the skill to interpret and extrapolate the remains, since the Late Bronze Age surface is virtually nowhere intact today. In general, elevated knolls have been eroded, often several meters below their Bronze Age levels. Thousands of years of ploughing have greatly accelerated this process. Material that came loose was transported to lower elevations, thus burying the Late Bronze Age levels in the floodplain under several meters of gravel and mud. What is more, between the 15th and early 19th centuries AD, what used to be considerable architectural remains above ground were quarried to obtain building stones. In 1819, Cambridge geologist Philip Barker Webb²⁷ visited Hisarlık and saw the last vestiges of the Bronze Age city being carried away to build a fort at the

²⁴ Korfmann 1992, 299.

²⁵ Luce 1995, 211.

²⁶ See also Kraft et al. 1982, 28; fig 11.

²⁷ Barker Webb 1822, 59.

Dardanelles. He remarked that in the future travelers will not be able to see even the scanty remains of the famous city that he met thanks to a merciful fate.

The most recent excavation project led by Manfred Korfmann was, intellectually speaking, primarily driven by the ancient philologists in the team. They tended to look for parallels between the landscape and its description in Homer's work. However, the approach to reconstructing the Trojan landscape on the basis of the *Iliad*²⁸ entails many risks. Even if Homer existed as an 8th- or 7th-century BC individual, it would have been impossible for him to comprehend a hydraulic system which had collapsed 500 years before. Homer never mentioned the Port of Nestor, the river diversion at Tiryns or the melioration of Lake Kopais.

Several writers from classical times until the 19th century AD also indicate that people interfered with the landscape at Troy²⁹. Pliny (1st cent. AD) spoke of the navigable Scamander.³⁰ For instance, the river passing through the plain bore two names in antiquity³¹: Gods called it Xanthos ("yellow river"); but later, the people of Troy are said to have artificially diverted the stream, which is why it was ever thereafter called *Skamma andros*, equivalent to "man-made trench"³².

Below follows a brief discussion of the major potential elements of a hydraulic system that are still visible in the Trojan floodplain today.

Yeniköy canal: Between the Yeniköy plain and Beşik Bay, the coastal ridge drops to about 10 meters above sea level. This low threshold is dissected by a canal, 4 meters wide and several meters deep,³³ running northeast/southwest. This canal was clearly not a navigable waterway, because it is too narrow and lies too high for that purpose. There is no doubt that it was designed to direct water from the Karamenderes plain to Beşik Bay. If its whole purpose was drainage, however, a channel to the Karamenderes River itself that is draining into the Dardanelles would have sufficed. The real purpose of this construction therefore remains enigmatic – and so does its date. The last use of the canal was to drive a 19th-century water mill in the Beşik plain. That such a massive construction was originally conceived and undertaken for this purpose is, however, economically irrational and rather unlikely. Peter Wilhelm Forchhammer saw the canal when it was functioning, and concluded that it must be of great antiquity. He hoped that nobody would assume that such a major construction was undertaken to drive "the wheel of a humble water-mill"³⁴. To him, it seemed far more likely that an existing, silted-up canal was cleaned and restored to

²⁸ Mannsperger 1995, 343–356; Korfmann – Mannsperger 2012.

²⁹ E.g. Mauduit 1840, 132; Forchhammer 1850, 20; Schliemann 1880, 98.

³⁰ Pliny, *Natural History* 5.30: „*amnis navigabilis*“.

³¹ Homer *Ilias* 20.74.

³² Eustathios, *Commentarii ad Homeri* 20.74.

³³ Lenz 1798, 21: „Man [mußte] dem Kanal, der Mitte zu, bis zu 30 Fuß Tiefe geben.“

³⁴ Forchhammer 1850, 20.

be used for the mill. 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”³⁵. The engineer himself dated it to the time of the Trojan War.

Yeniköy plain: East of Beşik Bay inside the Trojan plain the Yeniköy canal meets the Yeniköy plain. Drill core investigations revealed that this marsh used to be a marine embayment until the Early Bronze Age. During the subsequent progradation of the coast the area remained under water, supplied by the Pınarbası stream that rises at the south end of the plain of Troy³⁶.

Kesik cut: The cut at Kesik (Kesik itself meaning “cut” or “cleft” in Turkish), 400 meters long, 50 meters wide and 30 meters deep, is a most impressive construction, and as such best discerned from the air. It is an artificial trench into the coastal ridge, and somehow connects the Kesik plain with the beach at the Aegean Sea. Considering its exceptional size, one might be tempted to interpret the straight cut as a silted-up entrance to a port basin inside the plain. However, drill cores have revealed that its bottom lay as much as 13.7 meters above sea level at a distance of about 150 m from the sea, so that it was evidently neither navigable nor a drainage canal. Again, its function remains entirely enigmatic.

Kesik plain: The Kesik cut enters the Kesik plain in the floodplain of the Karamenderes. This basin is about 800 meters wide and partly surrounded by unnaturally steep scarps (e. g. on the north side of the Ballıkaya ridge),³⁷ indicating that they have been eroded by water at some point in the past. A lake still forms on the Kesik plain during some winters, when it protrudes somewhat into the Kesik cut. The latter was therefore clearly related to this silted-up basin.

Paleostreambeds: A number of travelers and scholars who visited the area during the nineteenth century described paleostreambeds and artificial canals within the Trojan floodplain³⁸. The Korfmann excavation team recognized these as indications of navigable watercourses in the floodplain, and regarded it as a possibility that a river port existed immediately below the citadel³⁹. This had been suggested before⁴⁰, but is nevertheless difficult to reconcile with other reconstructions by Korfmann, in which the sea was thought to have advanced all the way to the citadel. The map produced by Thomas Spratt and Peter Wilhelm Forchhammer in 1839 (German

³⁵ Lenz 1798, 22.

³⁶ Kayan 1995, 220.

³⁷ Kayan 2009, 108; fig. 3.

³⁸ Forchhammer 1850, 20; Schliemann 1880, 81.

³⁹ Kayan 1996, Kayan 2006, 320; see also „Der Spiegel“ 1997 (16): „Neben der Wasserader hatten die Trojaner eine große Plattform in den Fels gepickelt, die an eine Mole erinnert. Diese Formation, sagt Jablonka, „könnte als künstlicher Flußhafen gedient haben“.

⁴⁰ Zangger 1992, 146.

version 1850) shows a number of sand-heaps next to some paleostreambeds. These could be spoil heaps from canal excavations, but have also been interpreted as dunes. However, their sediment is completely unsorted, ranging from silt over fine and coarse sand to fine gravel. This excludes transportation by wind or water.

Trenches around the citadel: Finally, there are at least two artificial ditches, about 4 meters wide and 2–3 meters deep, which were detected on the plateau south of the Troy citadel during a magnetometer survey by the German geophysicist Helmut Becker⁴¹. The inner ditch lies about 400 meters south of the Troy VI fortification wall at an elevation of approximately 25 masl⁴². Obviously, because of their elevation and narrow width – they are considerably narrower than Bronze Age ships – these trenches are unrelated to the hydraulic system which may have existed in the plain.

Previous Investigations

The collaboration on the Holocene depositional history of the Troy plain between sedimentologists John C. Kraft, Professor at the University of Delaware, and İlhan Kayan began already in 1975⁴³. When Manfred Korfmann received permission to revive excavations at Hisarlık, he delegated the geoarchaeological investigations to the team that had already been working on the Holocene landscape evolution for over ten years. This had two consequences. Firstly, based on preliminary observations, it was assumed from the outset that Troy's port may have been at Beşik Bay⁴⁴. Secondly, for a whole 40 years the geoarchaeological investigation of the Trojan plain had in effect been monopolized; no second opinion was possible.

İlhan Kayan eventually became professor at Izmir University, and as such continued his studies of the Holocene sedimentological history of the alluvial plain below Hisarlık throughout his professional career. Between 1977 and 2006 he made 318 power drill holes, initially up to 75 meters in depth, after 1988 using a Unimog up to 20.5 m, to determine the depositional history⁴⁵. His core descriptions, however, were purely sedimentological, and did not follow international standards for color

⁴¹ Becker – Jansen 1994, 105–114.

⁴² Jablonka et al. 1994, 52.

⁴³ Kraft et al. 1980a, 776–782; Kayan 2006, 322; Kraft 2014, 703.

⁴⁴ Kraft et al. 1982, 40: „One must seriously consider the possibility that the Greek fleet was beached in the embayment at Besika“. Kayan 1991, 91; “It is obvious that the Besik bay could have been used as a harbor”. Korfmann 1991, 19; Rapp – Kraft 1994, 76.

⁴⁵ Kayan 2006, 322–323; Kayan 2014, 703.

and grain size⁴⁶. The core logs have never been published; neither were any of the many ceramic fragments found in the cores.⁴⁷

According to the results of the coring, however, there is no doubt that the floodplain used to be a marine embayment during the early Holocene. As for the coastline progradation after the maximum transgression, the Troy project's coastline reconstructions changed considerably over time (Fig. 6)⁴⁸. Using the eustatic sea level curve established by Dieter Kelletat⁴⁹, Kayan assumed a mid-Holocene sea level initially slightly above present and later at present⁵⁰. As a consequence, sea level would have dropped by about 2 meters 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"⁵¹. However, in his coastline reconstruction, the rapid drop had the same effect as the subsequent rise in sea level. Both caused a moderate seaward movement of the shore, due to the large amount of sediment deposited into the plain⁵². That the regression did not occur faster could point to 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 Kayan⁵³.

In the summer of 1991, fifteen years into the drilling investigations at Troy, Kayan also directed his interest to the marshes and cuts on the western side of the plain. The Yeniköy canal, according to Kayan, was cut through the bedrock to "bring fresh water to the Beşik plain"⁵⁴. Korfmann argued that the canal definitely dates to the 18th century AD⁵⁵. At this time, however, scholars already debated the date of the canal's construction⁵⁶.

The Kesik cut has been interpreted by members of the Troy project as an unfinished construction, an irrigation channel, a drainage channel and a play of nature. Kayan started making bore holes inside the canal and found a 2–2.5 meter thick layer of colluvium at the bottom of the trench. The highest point of the cut is at 13.7

⁴⁶ Kayan 2006, 324.

⁴⁷ It is quite possible to find characteristic pottery in cores that are only a few centimeters wide. See for example Zangger 1993, 83.

⁴⁸ Jablonka 2014, 218; fig. 10

⁴⁹ Kelletat 1975; Kayan 2001, 310.

⁵⁰ Kayan 2001, 310; fig. 321; Kayan 2014, 709; fig. 8.

⁵¹ Kayan 1995, 217.

⁵² Kayan 1995, fig. 8.

⁵³ Kayan 1995, 231.

⁵⁴ Kayan 1995, 221.

⁵⁵ Korfmann 1993, 28.

⁵⁶ Lenz 1798, 22.

meters above sea level, while the surface of the coastal ridge rises to an elevation of 30 meters in this area. So although the cut was impressive in size, its bottom never came close to sea level. Kayan believes that the cut was completely unrelated to maritime installations, something the British ancient historian John M. Cook concluded some years ago: “It seems to us clear that the work was never completed”⁵⁷. Kayan hypothesizes that the cut formed in a depression originally caused by a tectonic fault.⁵⁸ He argues that this natural passage was later so frequently used by people commuting between the shore and the plain that the original valley deepened and widened.⁵⁹ But tectonic movements are unlikely to have had a significant effect in the area, since bore holes in the Kesik plain have revealed coastal sand units from around 2000 BC at a depth equivalent to present sea level. Kayan points out that the lack of artefacts in trial trenches dug across the cut seems to indicate that it was not used as a hydraulic construction. He overlooks the fact that extensive commuter traffic would have produced a dense artifact scatter. Practical experience gathered during numerous intensive surveys in Greece show that the number of surface finds increases in the vicinity of ancient roads and tracks. Besides, during a visit to the field in April 2014, the senior author found a sizable prehistoric site in freshly ploughed field on the top of the Yeniköy ridge about 600 m south of the Kesik cut.

According to Kayan “one can easily imagine that the Kesik plain could have been an excellent harbor which was connected to the Aegean Sea by the Kesik ‘canal’”⁶⁰. The radiocarbon dates (from marine shells) seem to indicate that the marsh silted up before 1300 BC⁶¹, but this conclusion cannot actually be reconciled with Kayan’s drill holes⁶². In the stratigraphic cross-section through the plain, Kayan does not distinguish between “swamp” and “fine sandy flood plain delta sediments”⁶³. Swamp sediments, however, might well have originated in an ancient freshwater port basin. Finally, it is rather confusing that the Kesik plain appears as a marine embayment in the most recent reconstructions of Troy VI⁶⁴ if it had silted up over 1,000 years before. Kayan ends his study with the conclusion that there is “no evidence” that the natural embayments along the western edge of “Troia Bay” were arranged and used as principal harbours.⁶⁵ On many occasions he refers to the lack of “definite,” “clear,” or “most valuable or trustworthy” evidence. In the pursuit of reconstructing Bronze Age landscapes, the chances of finding obvious or irrevocable

⁵⁷ Cook 1973, 167.

⁵⁸ Kayan 2009, 124; 2014, 723.

⁵⁹ Kayan 2014, 724.

⁶⁰ Kayan 2014, 723. – *contra* Kayan 2003, 400: “Yeniköy and Kesik bays could not have been used as harbours during the Later Bronze Age, especially during Troia VI.”

⁶¹ Kayan 2001, 313; Kayan 2009, 105.

⁶² See also Luce 2003, 22.

⁶³ Kayan 2003, 396; fig. 6.

⁶⁴ Korfmann 2001, 19; see also Jablonka 2014, 236.

⁶⁵ Kayan 2003, 401.

evidence at the surface are minute. In previous years Ilhan Kayan, Manfred Korfmann, George Rapp and John C. Kraft have unequivocally favored the idea that the port of Troy was located in Beşik Bay – although there was never any “definite evidence” to support this notion.

As for the human-made trenches around the citadel on Hisarlık, these clearly did not belong to any hydraulic installations in the floodplain. Korfmann himself launched the guessing games regarding the function of these ditches by announcing to the global media that the anomaly found in 1993 indicates a fortification wall made up of mudbrick that was fired in a conflagration.⁶⁶ A year later it turned out that the anomaly was caused by an artificially dug trench – not even a trace of a wall was found. Although Siebler, a former member of the project, declares that the inner ditch was already filled in by the time of the Trojan War⁶⁷, the excavators regard it as an obstacle to approaching chariots, still visible during the 8th century BC⁶⁸. 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 fashion⁶⁹. One might argue that the material at the bottom of the trenches yields hints of their former surroundings and thus their function. Pollen and seeds of a large variety of exotic plants had gathered at the bottom of the trenches. A complete skeleton of a bull was also found there.⁷⁰ One might therefore think that the trenches were surrounded by a palace garden of which certain parts were also frequented by bulls. A very peaceful scenario; no traces of weapons, chariots or human bones were found. And yet for 15 years the excavation project concentrated primarily on tracing the void left by these trenches.

Hypothetical Reconstruction of the Port of Troy

Considering the complex hydraulic installations in Mycenaean Greece and Hittite Anatolia, it is highly unlikely that the plain of Troy was a wasteland controlled by the floods of the Karamenderes River⁷¹. More probably, the people at Troy stabilized their landscape to the extent that it could be optimally exploited for centuries.

The recent subsurface studies along the Yeniköy ridge now permit a refined theoretical reconstruction of the paleohydrology of the Trojan plain – one that might

⁶⁶ *The New York Times*, February 23, 1993; “Dr. Korfmann, leader of the new explorations, said a geomagnetic survey probing to depths of more than 20 feet detected clear signs of a thick clay wall more than 1,300 feet beyond the previously known inner city.” – Becker – Jansen 1994.

⁶⁷ Siebler 1994, 116.

⁶⁸ Mannsperger 1995, 350.

⁶⁹ Reconstruction in Korfmann 2001, 19.

⁷⁰ Ernst Pernicka, pers. com.

⁷¹ As stated by Kayan 1995, 232.

be used as a working hypothesis for future investigations (Fig. 7). The generic model for a freshwater port presented above yields valuable hints regarding the function of the elements visible in the Trojan landscape. In this case, the Yeniköy marsh would have been equivalent to the lake and sediment trap at Pylos, while the Kesik plain equals the Port of Nestor – a largely artificial basin that is filled with sediment-free fresh water derived from the reservoir upstream. The freshwater current continued to run from the port basin toward the sea and exited near Kumtepe. Thus saltwater – and the sediment carried by it – was prevented from entering the port system. In this way the port would function even without the two artificial canals at Yeniköy and Kesik.

The two canals, however, add new dimensions to the system. Evidently, the maximum runoff was so large that it may have flooded the port installations and the surrounding houses during the spring. The Yeniköy canal was therefore dug to channelize the lion's share of the Karamenderes run-off straight into Beşik bay. The engineers designed the canal to be quite narrow and extraordinarily deep to increase the speed of the water flow and thus make it drag as much sediment as possible towards Beşik Bay. This idea had already been advanced by the geologist Oscar Mey during his investigation of the sediments in the Beşik plain⁷². He found out that virtually all the sediments there are derived from the Karamenderes.

The freshwater basin at Kesik clearly was the “naval station” mentioned in the *Iliad* – what else would one have called such a construction? The Kesik cut could have functioned as a dry slipway for ships. Before the canal at Corinth existed, ships were dragged along a track over a distance of 8 kilometers⁷³ – the cut at Troy is only 0.5 kilometers long. We know that the ships at Troy would have had to wait for favorable sailing conditions if they wanted to continue their voyage upstream through the Dardanelles. The dry slipway to the port would have offered a number of advantages. The most important is related to the current conditions in the Dardanelles. Ships sailing towards the mouth of the Dardanelles face an extremely strong current that is equally fast all across the straits. Entry is only possible if ships coming from the south sail clockwise all the way around the island of Gökçeada and then enter the Dardanelles travelling sharp along their northern shore (Fig. 8). In 1984, British historian Tim Severin rowed and sailed from northern Greece through the Dardanelles using a 16.5-meter replica of a Bronze Age galley that was based on a detailed scale model of the “Argo” and powered by twenty oarsmen. Severin was forced to make the 50 kilometer detour around Gökçeada to be able to enter the Dardanelles. Hence, the main purpose of the port basin at Kesik was to provide a convenient and risk-free entrance into the Dardanelles. Ships dragged a few hundred meters across land and into the basin at Kesik were able to first enter the freshwater

⁷² Mey 1926, 19–20.

⁷³ Werner 1997, 109.

current flooding the basin that took them to the Dardanelles, where a counter-current picks up on the southern side approximately in the middle of the coastal plain at Troy. This counter-current then took them upstream like an escalator.

Once again, this function of the Kesik cut has been recognized before – as the German engineer and major Müller suggested in his report on the locality of the *Iliad*, published in 1798⁷⁴:

“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 – they were actually cuts into the coast – which gradually dipped towards the sea, and through which ships could easily be pulled without risk of becoming damaged.”

Homer also hints at such a slipway when he says, that the ships of Odysseus and Agamemnon had been stationed on the shore of the grey sea a long way from the fighting, while those that had landed before them had been “pulled up into the plain”.⁷⁵

Accordingly, 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, the Kesik cut may have been used as an additional exit permitting Trojan warships to circumvent naval attackers besieging the north coast. In peaceful times, trading vessels 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 exchange between the Aegean Sea and the Black Sea. 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 near 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 favorable location of their city.

The Buried City of Troy

The question of the size of Troy will never be resolved as long as excavations exclusively concentrate on the limestone knoll that housed the royal citadel. The marshes and wetlands in the floodplain should be investigated archaeologically as well, since they produced several meters of artifact-rich layers in drill cores⁷⁶. Fig-

⁷⁴ Lenz 1798, 139.

⁷⁵ Homer, *Ilias* 14.32.

⁷⁶ Kayan 1996, 248: „From an archaeological point of view, the area along the foot of the northern slope of Troia is an important one... In the light of these findings we consider that it would be very useful to make an archaeological excavation about 7 m deep”. See also Kayan

ure 9 shows – for the first time – a schematic cross-section running west-east through the knoll of Hisarlık and extending beyond into the floodplain. Much of the Troy VI and VII citadel has been removed by levelling in Classical times and archaeological investigations, thus little Late Bronze Age material remains to be found on Hisarlık itself. In the floodplain, however, Kayan discovered in his bore holes a few meters of artifact rich layers, about five meters below the present surface⁷⁷. He interpreted the artifacts to have been eroded down from the citadel⁷⁸. However, some archaeological material⁷⁹ was found to the north of the former streambed.⁸⁰ The anthropogenic material could not jump across the stream – hence, it must have been deposited *in-situ* in the floodplain, where “some levels contain a great deal of archaeological material”⁸¹. It appears that the lost city of Troy (Fig. 10) may be hidden in the floodplain to the present day, as has been indicated all along by various sources ranging from antiquity to the 19th century⁸².

The Holocene depositional history in the floodplain shows how the area below the Hisarlık knoll used to be a marine embayment during the Neolithic (Fig. 9: Marine sediment). It was then filled in by river gravel and covered almost entirely with braided streams emanating from Mt. Ida in the south. Around 1500 BC the depositional system changed dramatically, possibly because the people at Troy had canalized the stream, thus making the plain itself habitable. Not just the citadels of Troy VIh and Troy VIIa fell victim to destruction but also the city itself being located in the floodplain. Since the water management system had been abandoned, the city’s ruins were buried under mud within a year’s time. A number of sources in antiquity say that Bronze Age remains of Troy disappeared under water and mud and are thus today covered by fields⁸³. More alluvium mixed with debris from the citadel buried these remains even further. As a consequence, archaeologists looking for the remains of the city of Troy may only need to make a 5–6 meter trench near Kayan’s bore hole 143 – and they are likely to make a breakthrough discovery surpassing that of Heinrich Schliemann.

2003, 391; fig. 4: Archaeological material consisting mostly of sherds and fire remains were found 4-6 m below the present surface.

⁷⁷ Kayan 2002, 998.

⁷⁸ Kayan 2014, 712 and 720.

⁷⁹ Kayan 2002, 1002 (and Fig. 7 Drilling Number 128): “Pieces of bricks, stones and mortar indicate the remains of a construction”.

⁸⁰ Kayan 2014, 701.

⁸¹ Kayan 2002, 1003.

⁸² Diodorus Siculus 4.75.3; Albert von Stade 1249, *Troilus* 6.5.841-854; Lenz 1798, 305; William Gell 1804, 120-121.

⁸³ Strabo 1.3.17; Dio Chrysostom 11.76; Quintus of Smyrna 14.646-652, Homer *Iliad* 12.16-33: “Poseidon and Apollo decided to destroy the wall by turning against it the united waters of all the rivers that run down from the range of Ida to the sea” (Rieu).

The idea that the actual Late Bronze Age city was located in the floodplain below Hisarlık is reinforced through a number of medieval description of Troy. Most notable among those is the one provided by the Sicilian judge Guido de Columnis in his Latin work *Historiae destructionis Troiae* dating to 1287⁸⁴. According to this account, the city contained subterranean navigable canals and its streets could even be intentionally flushed with river water to clean them from debris and fecal:

“For its [Troy’s] foundations were established in the depths of the earth, made with deep excavation and ample width. ... Its avenues extended in a long and straight line, in the midst of which the brisk and invigorating air of dawn poured forth sweet and varied breezes... Through the middle of this city ran a river called Xanthus, which, by dividing the city into two equal parts, in its unfailling course offered many conveniences to the inhabitants of that city. ... In addition, this river, flowing through hidden channels on account of the requisite abundant supply of water, purified the city by prearranged floods, by means of skillfully made canals and underground sluices, and by these baths the accumulated impurities were cleaned away.” (5.114-179; Meek)

Outlook

We believe that the engineering skills available during the Late Bronze Age have thus far been considerably underestimated. Therefore, already in 1999 the senior author proposed conducting a helicopter geophysics study in the plain of Troy to determine the subsurface stratigraphy without even touching the ground⁸⁵. This technique offers the advantage of covering the entire area of the coastal plain at Troy in a mere 10 days of fieldwork. In return, researchers obtain high-resolution subsurface information including the layers between 5 and 10 m below the present surface that are most likely to contain Late Bronze Age architectural remains. The helicopter of the German Federal Institute of Geosciences and Natural Resources (BGR) in Hannover would have been available for this investigation. The state-of-the-art system on board comprises a bird dragged by the helicopter holding electro-transmitters and receivers working at five different wavelengths. The electromagnetic beam produced by these transmitters creates a signal in the ground whose reflection is then measured by the receivers. Computer modeling allows the combination of the sequences of layers produced by the different transmitters. By using five different wavelengths and penetration depths, the system already gives very high resolution even for the upper layers. This method would be the ideal way to obtain a first impression of the geological stratigraphy as well as the subsurface shape of the basin

⁸⁴ Griffin 1936; Meek 1974.

⁸⁵ Zangger et al. 1997b, 9–32.

and canals at Troy. These data could then be shown in maps, cross-sections and 2.5D and 3D subsurface models.

With the help of the Turkish embassy in Bonn, an official application to conduct such helicopter geophysics at Troy was submitted to the Ministry of Culture in Ankara already in 1999. The ministry, however, neither acknowledged receipt of the application nor granted permission. As it turned out, the German Troy project director Manfred Korfmann was not anxious to utilize this technique to gain more information about the floodplain,⁸⁶ nor was his successor Ernst Pernicka. The offer to conduct this project is still on the table. The authors are hopeful that the leaders responsible for the new Turkish project are open to it.

“Destroyed for others, Troy remains, for me alone,
where the victor lives to plough with captive oxen:
there are fields now, where Troy once was, and the earth,
beneath the scythe, crops densely, rich with Phrygian blood:
half-buried bones of heroes are struck by the curving plough,
and grass conceals the ruined houses.”
Ovid, *Heroides* 1.53 (Kline)

⁸⁶ Korfmann 2003, 11: “In and around Troia there are really far more urgent matters to be addressed. In short: I want no part of this.”

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Fig. 1 Map of the Aegean indicating Bronze Age settlements mentioned in the text

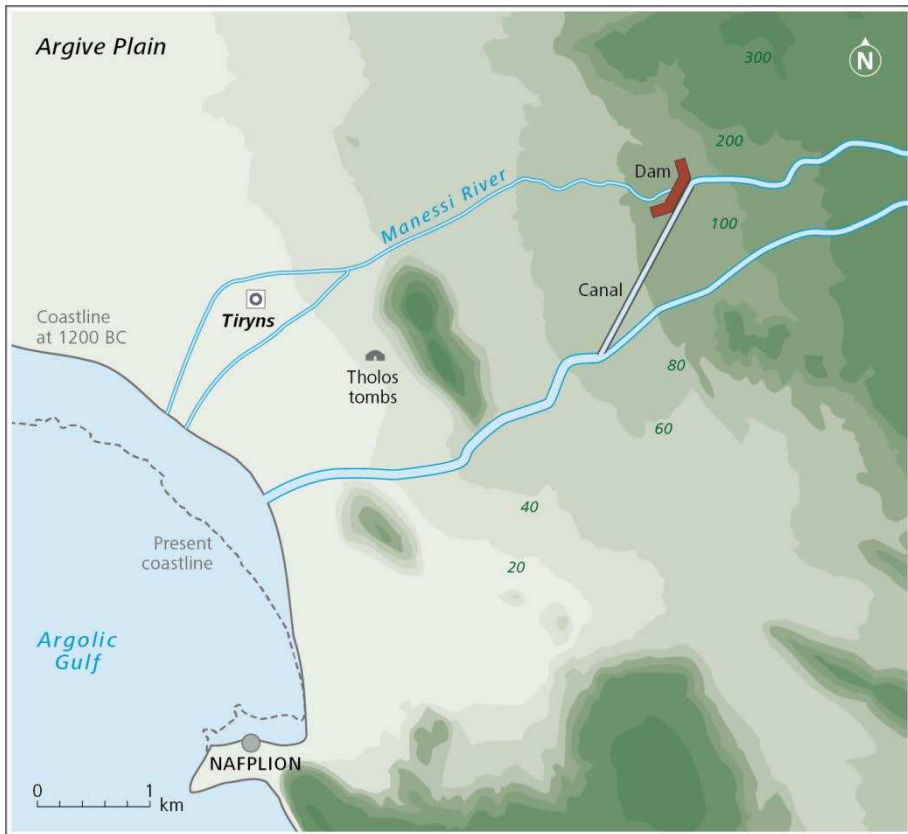


Fig. 2 Late Bronze Age stream diversion at Tiryns, Greece



Fig. 3 Floodplain south of the Palace of Nestor at Pylos, Greece

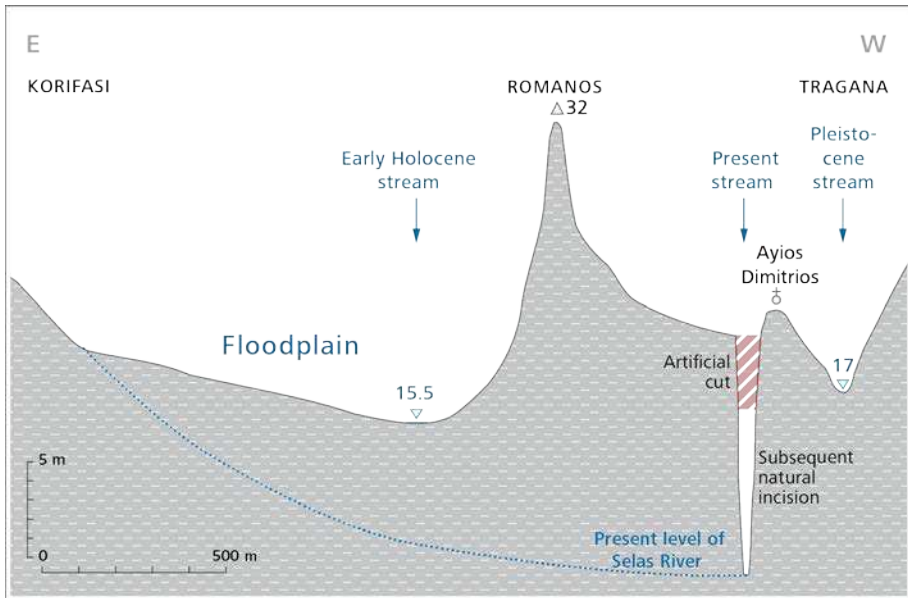


Fig. 4 Topographic cross-section across the floodplain of the Selas River, Greece; vertical exaggeration 50x

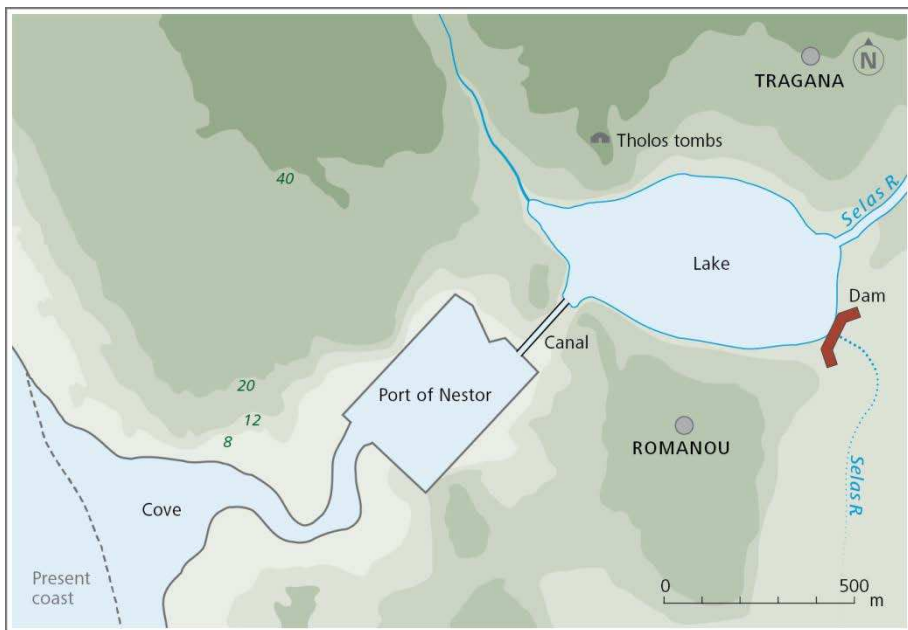


Fig. 5 Reconstruction of the now silted-up Late Bronze Age Port of Nestor

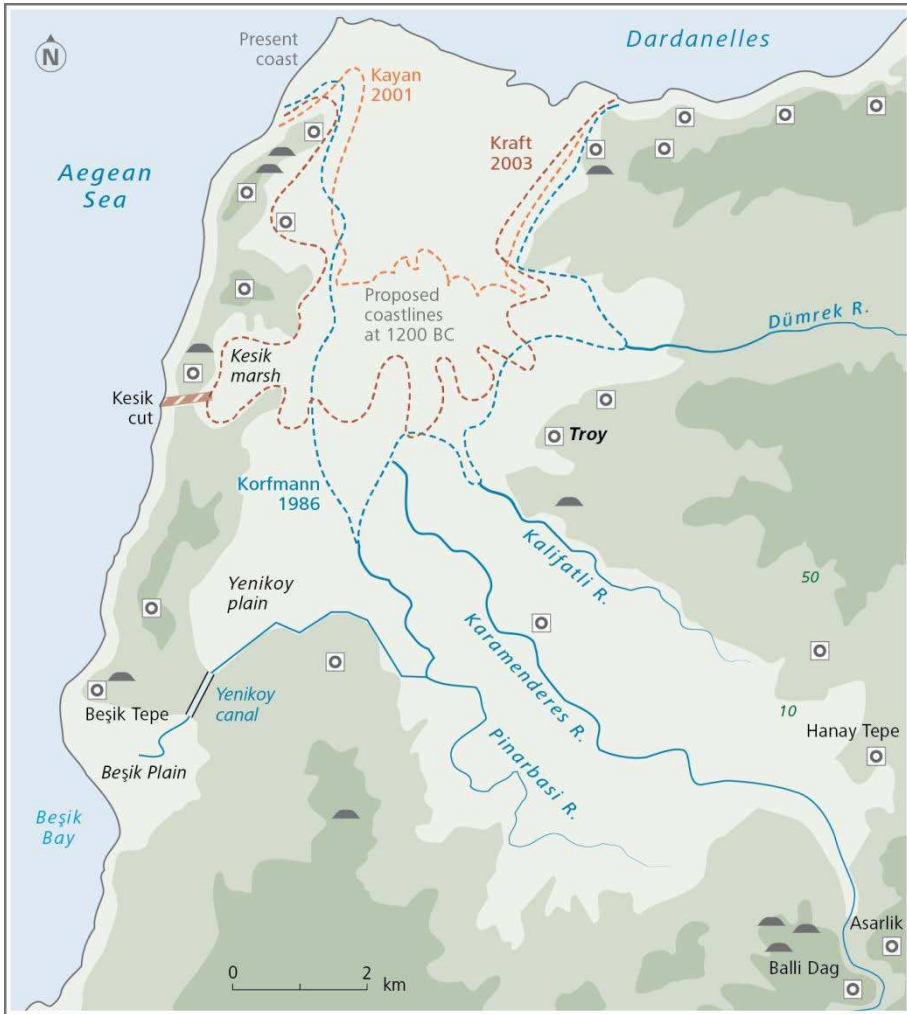


Fig. 6 Topography of the Karamenderes River floodplain at Troy today

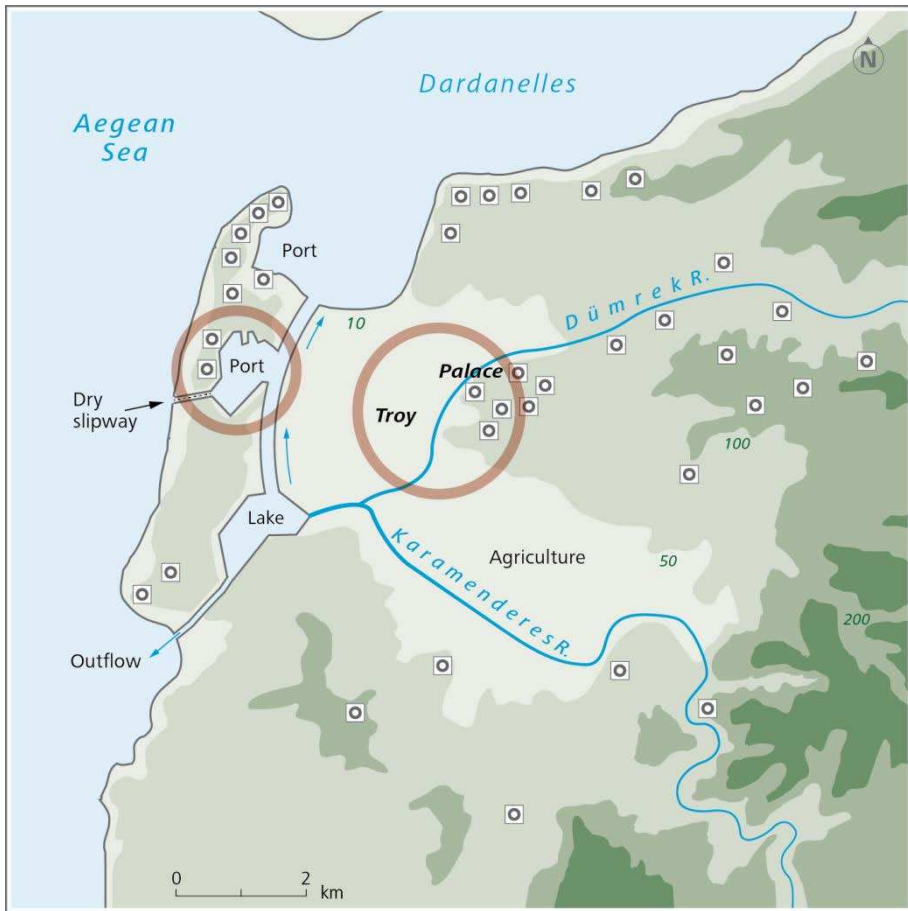


Fig. 7 Schematic system used for the Port of Nestor transferred to the plain of Troy

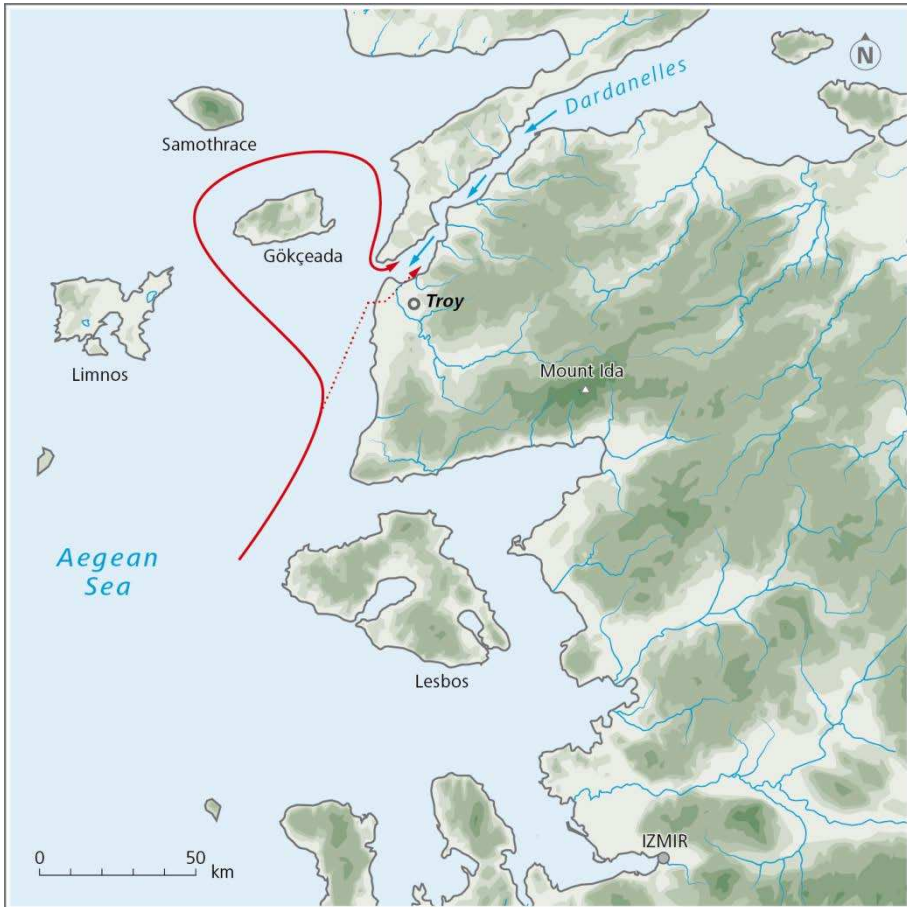


Fig. 8 The passage into the Dardanelles required a 50 km detour around Gökçeada – or a 500 m short-cut across land at Troy

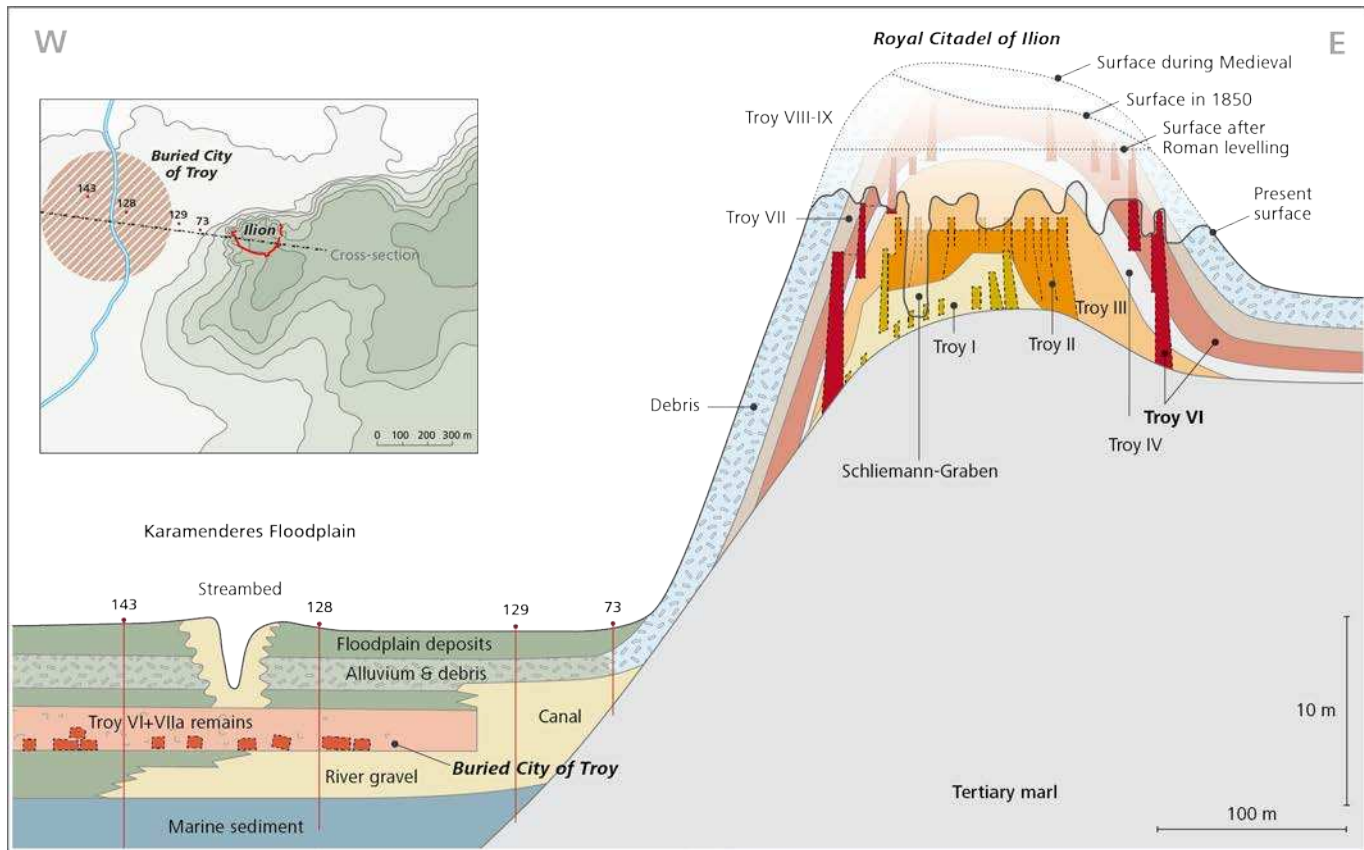


Fig. 9 Schematic cross-section through the settlement layers on Hisarlik and through the floodplain deposits



Fig. 10 Artist's reconstruction of the hydraulic system and ports at Troy during the Late Bronze Age (© Christoph Haußner)