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Geological Society, London, Special Publications 2011; v. 352; p. 27-36
doi: 10.1144/SP352.3

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Results of the struggle at ancient Ephesus: natural processes 1, human intervention 0

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Abstract: Coastal areas have been prime locations for habitation and commerce. Early authors such as Pausanias (second century CE), and Strabo (64 or 63 BCE–24 CE) noted the impacts of shoreline changes. Geomorphological and subsurface geological data, combined with archaeological excavation and ancient texts, indicate a long interplay between natural processes of estuarine infilling by sediments from the Küçük Menderes River (ancient Cayster River) and multiple attempts of human intervention to preserve the harbours of Ephesus. Strabo noted that harbour engineering efforts there, such as the construction of a mole to prevent siltation, instead created a sediment trap that made things worse. The pre-Holocene river valley was inundated by Holocene sea-level rise that formed the ancient Gulf of Ephesus. Extensive palaeogeographical studies, based on sediment coring, geomorphology, archaeology and history, have provided details of the problems the inhabitants faced in keeping vital harbours in operation. Dating and analysis of sedimentary deposits has allowed the description of shifting river courses, floodplain changes, human intervention, and anthropogenic deposits at Ephesus. During and following Classical times sediment deposition rapidly began to fill in the embayment, requiring the inhabitants to regularly shift the harbours westward. Ultimately, it was to no avail.

Coastal areas host a large percentage of the world's population. These areas have high energy available from wind and waves, so they are frequently sites of geomorphological change. In addition, sites that also are located in estuaries are in jeopardy of being overrun by alluvial deposition from riverine sources. Ancient Ephesus, on the Aegean coast of Turkey, is one such site. In this paper we describe the human reaction to the continual progradation of the ancient Cayster River delta floodplain past ancient Ephesus. Many efforts were made to interrupt or slow geological processes that were leading to the demise of the city and its important harbour.

The subsurface stratigraphic sections in river valleys and estuaries contain the fossil and sediment record of past environments and their geographies, as well as the record of local relative sea-level rise. From the study of these sediments and their included fossils we can determine with precision the loci of ancient river channels, floodplains, backswamps, deltas, lagoons, barriers, and other features commonly associated with the coastal zones of Greece and Anatolia. We have spent over 20 seasons and drilled over 200 cores to determine the palaeogeography of ancient Ephesus. This paper summarizes the data contained in approximately 20 of our publications, the most salient of which are referenced. Dating was provided by radiocarbon, historical texts, or in some cases archaeological artefacts. Our work at Ephesus was carried out under the aegis of the Österreichisches Archäologisches Institut (Austrian Archaeological Institute) excavations there.

Ancient Ephesus was located along the southern flank of a Neogene–Quaternary-age graben. Major archaeological excavations began there in the 1860s and have been continued for most of the past 100 years by researchers from the Austrian Archaeological Institute and their Turkish colleagues. The main archaeological sites occupy an irregular area roughly 6 km by 3 km. The long-term work at Ephesus by the Austrian Archaeological Institute indicates that archaeological remains vary in age from the Neolithic period to modern times. Throughout the early periods of occupation, the inhabitants had to adapt to the ever-changing morphologies of the ancestral Gulf of Ephesus, especially the overwhelming impact of the progradation of the ancient Cayster River. Here can be

From: Wilson, L. (ed.) *Human Interactions with the Geosphere: The Geoarchaeological Perspective*. Geological Society, London, Special Publications, **352**, 27–36.
DOI: 10.1144/SP352.3 0305-8719/11/$15.00 © The Geological Society of London 2011.

seen evidence of people adapting to ever-changing environments over the past 7000 years. The geomorphologically stable areas of Ephesus and the Derbent River (Fig. 1) (the ancient Marnas and Selinus rivers) were located along the southern flank of the graben where there were the limestone (marble) horsts of Panayirdağ (ancient Mount Pion) and Bülbüldağ (ancient Mount Preon), along with isolated smaller horsts.

Approximately 3000 years ago the Amazons are said to have dedicated a sacred site to the goddess Artemis, resulting in the construction of the earliest Artemision (a temple to the Greek goddess Artemis; Roman name Diana) on the shoreline of the ancient Gulf of Ephesus (Callimachus Hymn III, Callimachus 1973). From the time of the construction of the earliest temple of Artemis (*c.* 800 BCE) on a shoreline in ancient Ephesus to its destruction a millennium later by an earthquake, the inhabitants of Ephesus were engaged in a continuous struggle with the effects of colluvium derived from the uplands and, more seriously, alluvium from the prograding Marnas and Selinus rivers (Kraft *et al.* 2001; Brückner *et al.* 2008). In the two millennia since its demise the as-yet unexcavated city surrounding the temple (and later its ruins) was buried by 6 m of alluvium and colluvium (Brückner *et al.* 2008). The Artemision has now been excavated into the surface of the floodplain.

Figure 1 shows the present-day distribution of the various geomorphological elements of the lower Küçük Menderes River delta floodplain and the lesser impact of alluvium from the flanking rivers along the northern and southern sides of the area. In the lower regions of the delta are areas of seasonal swamp as well as marsh in the immediate coastal region. The abundant isolated meander loops indicate that the river has repeatedly changed course. The floodplain geometry was permanently altered by the construction of the Küçük Menderes Canal to alleviate flooding conditions as well as facilitate irrigation to the abundant agricultural areas now occupying the lower delta floodplain. Sandy barriers now occur along the shoreline of the Aegean Sea. The earliest evident remnants of sandy barriers as the delta prograded seaward are also shown. At the immediate coastal area the shore face drops relatively rapidly into the deeper and clearer marine waters of the Aegean Sea. Along the northern flank are two freshwater lakes surrounded by marsh that were originally marine embayments of the ancestral Gulf of Ephesus, as shown by marine fossils in our sediment cores.

Floodplains, backswamps, marshes, lakes, lagoons, barrier accretion plains, talus slopes, alluvial fans, and other such features are only the surface expression of 3D sedimentary environments of deposition. From floral and faunal elements we determined the nature of the sedimentary environments of deposition in three dimensions. To do this we drilled over 200 cores to determine the

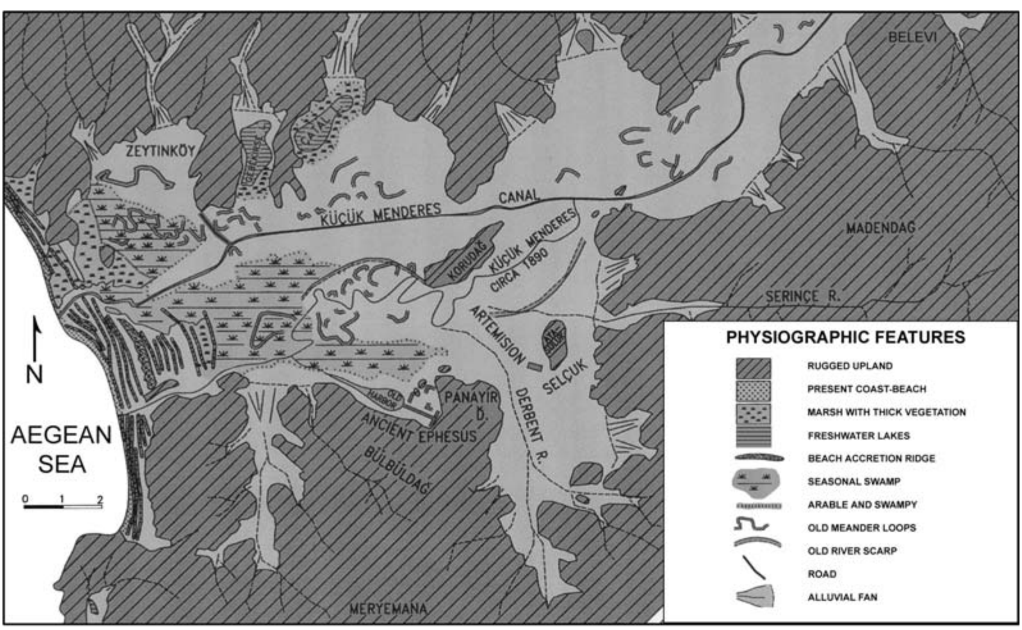

Fig. 1. Physiographic features of the Ephesus region of the Küçük Menderes floodplain and delta.

distribution and change of marine, coastal, and fluvial environments of deposition over the long term. Carbon dating provided us with the time frame. We used five coring units capable of extracting sediments from depths of 5–30 m.

From our palaeogeographical studies of the delta floodplain of the Küçük Menderes River (ancient Cayster River) we have been able to show that the earliest known archaeological sites (Neolithic, 7000 BP) in the region of ancient Ephesus lay along the southern flank of a relatively deep (30 m) clear water embayment of the ancestral Gulf of Ephesus. The initial Holocene sediments at the time of the Mid-Holocene sea-level highstand (*c.* ≥1 m above present sea level) consisted of sand with an abundant clear water marine molluscan fauna. Evidence from water wells across the plain nearly always shows an abundant and highly varied marine molluscan fauna. We identify two Neolithic sites (N) in Figure 2. The northern site lies on a pre-Holocene gravel fan with scattered shells of edible molluscs of varied clear water marine species. They are accompanied by fragments of red pottery that have been dated tentatively to the Neolithic. Along the southern flank, inland, and at higher elevation on a Neogene gravel fan between the two valleys of the Marnus and Selinus rivers, lies a newly discovered Chalcolithic site that was being excavated in 2008 by the Austrian Archaeological Institute. From drill-core evidence it appears that the site was initially occupied in Neolithic time. We do not have precise knowledge of the eastern landward extent of the ancestral Gulf of Ephesus in Neolithic time. However, it appears from the occurrence of bottom-set delta facies to have inundated the Quaternary graben valley to at least 18 km from the sea.

Figure 3 is a west to east geological cross-section from the present barrier accretion plain along the coastline of the Aegean Sea to the Belevi Gorge (Fig. 1). It should be noted that the greater portion of the marine sediment that has filled the valley consists of marine muds, as indicated by the molluscan assemblage, derived from the Küçük Menderes River. Of far greater importance are rates of deposition. In the first 2600 years of deposition, starting from 7000 years BP, there was clearly a much lower rate of deposition of marine muds than in the 200 years from Classical–Archaic time to the Hellenistic period. The rates of deposition since Hellenistic time appear to be much lower as the sea bottom of the ancestral Gulf of Ephesus has migrated seaward into the Aegean Sea. The river floodplain alluvium, as expected, thickens in a landward direction. One can speculate from this that human impact on the marine environment has

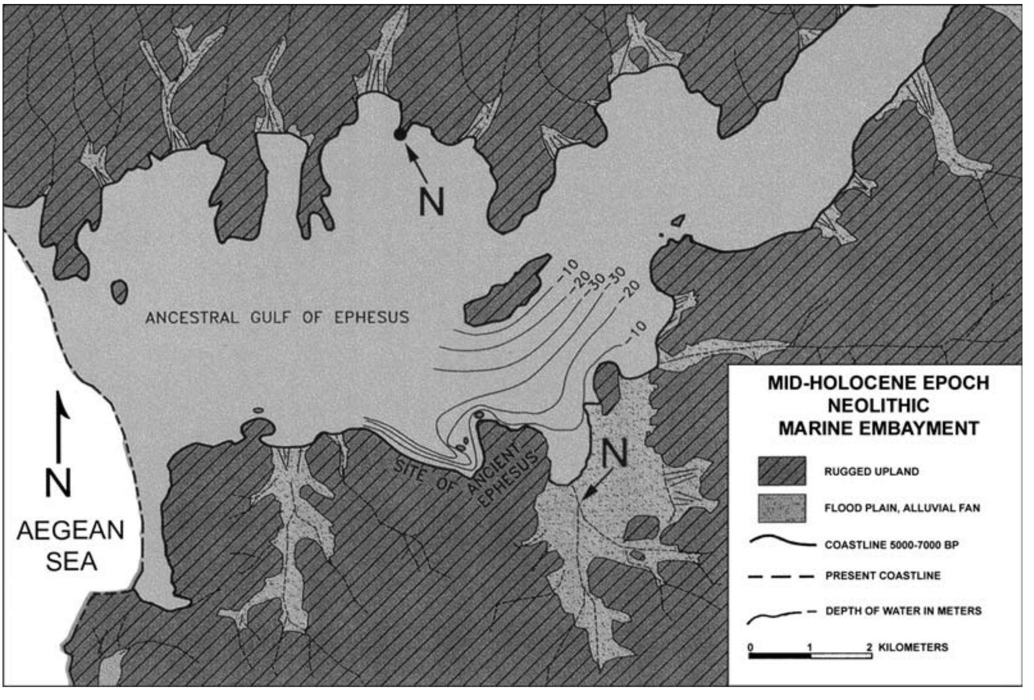

Fig. 2. Mid-Holocene Neolithic marine embayment.

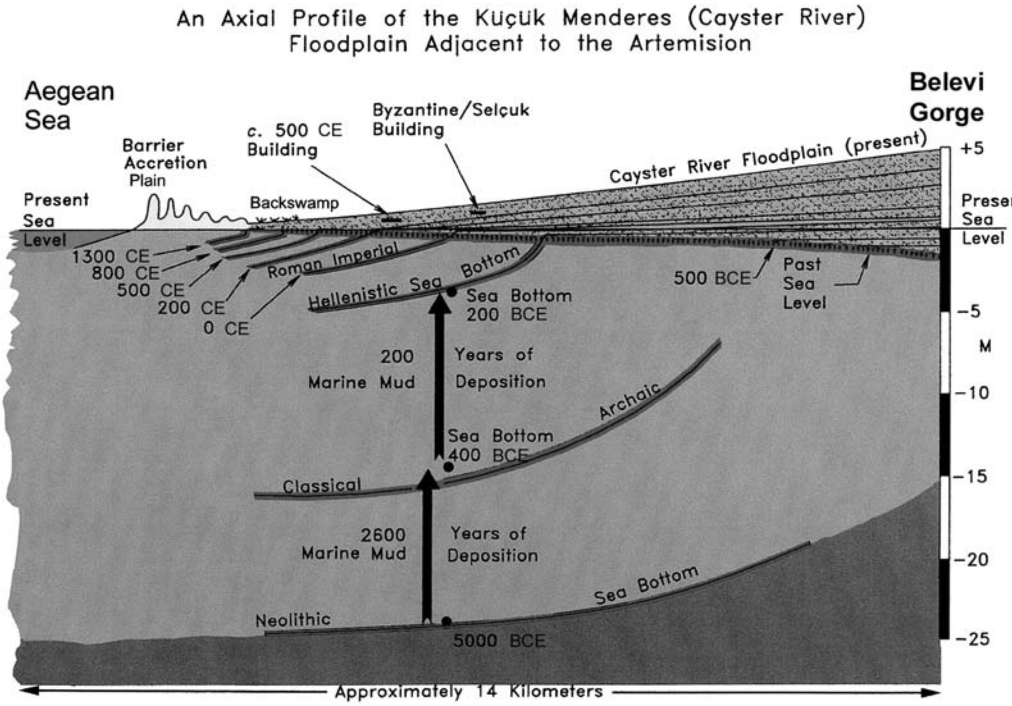

Fig. 3. Profile of the Küçük Menderes floodplain and the Neolithic embayment.

been profound since Neolithic time. The Neolithic expansion of agriculture across Anatolia and the even more intensive farming activities from Classical–Archaic time onwards to the present time have provided a driving mechanism for the high deposition rates.

Figure 4 illustrates shoreline and harbour configurations from *c*. 300 to 0 BCE. During the Hellenistic and early Roman time there was a prograding lower deltaic sequence between varied birdsfoot sandy distributaries of the ancient Cayster River. Such deltaic formations were rapidly changing. Between Mount Pion and Mount Preon lay an area of relatively deep water in Hellenistic times, with the strand or shoreline in the time of Lysimachus (360–281 BCE) lying very close to the immediate base of the flanks of the two mountains. The extent of the city of Lysimachus is shown. One of the more impressive structures in the entire history of the occupancy of ancient Ephesus is the massive defensive wall that stretches along the top of Mount Preon to the SE and then to the NE across Mount Pion and around to the northern flank where, based on more than 20 cores, we posit a series of sacred harbours that were forced progressively westward as the delta shoreline rapidly prograded. The sacred harbour of the Artemision, which at the time of construction would have been built in the immediate coastal zone, was thus gradually forced westward. This is perhaps the first series of major adaptations to the environment required of the people occupying the immediate coastal zone of the Artemision and of Hellenistic and earliest Roman Ephesus. Furthermore, in Hellenistic and Roman times the city was built into the floodplain surrounding the later Artemision, to be in turn buried under 5 m of alluvium until rediscovered a century and a half ago.

In the time of the earlier Lydian city (seventh–sixth centuries BCE), located in the valley between Mount Pion and Mount Preon, and through the initial occupancy of the city that Lysimachus built, the harbours were forced to move from the vicinity of the Artemision to this area, where ships could approach the shoreline near the base of the steep slopes along the flanks of Mount Pion and Mount Preon. However, as Hellenistic time progressed, rapid shoaling of this harbour area began as the prograding delta of the Cayster River continued to move to the west. By the time of Attalus II Philadelphus (159–138 BCE) the great mole (a breakwater built to enclose and protect the harbour) along the northern side of the harbour of Ephesus had been established. We have little knowledge of the early Lysimachan harbour other than that it would have started with ship access directly to the foot of the

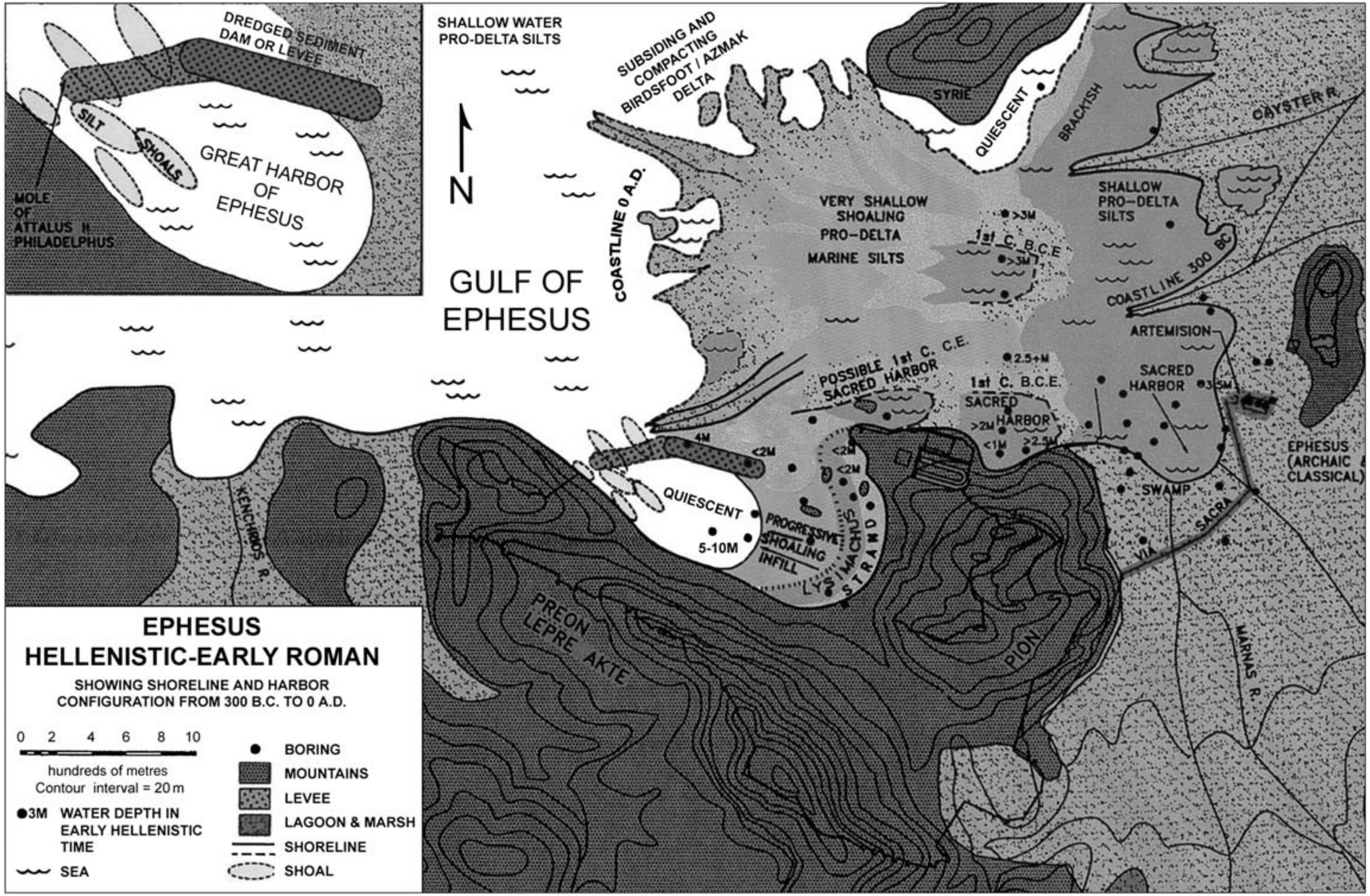

Fig. 4. Ephesus: Hellenistic–Early Roman times.

two mountains. By the time of Attalus II Philadelphus human impact plus that of the Cayster River on the environment of the harbour area had greatly accelerated. Indeed, as early as 190 BCE Livy (1997, Book 37, 14–15) commented on the nature of the entrance to the harbour of Ephesus as already having only a narrow entrance and that it was 'full of shoals'. Livy (59 BCE–17 CE) noted that a Roman, Rhodian and Pergamene allied fleet had tried to attack the fleet of the Seleucid King Antiochus III (242–187 BCE) that was trapped in the harbour of Ephesus. The Roman commander of the fleet proposed to sink ships to block the harbour. However, he was persuaded not to as it would have destroyed a great harbour; Livy noted 'because the mouth of the harbour was like a river: long and narrow and full of shoals'. We have schematically presented possible configurations of shoals with narrow channels in Figure 4; however, we have not yet been able to precisely delineate the configurations as described by Livy.

We can perhaps better understand a major environmental impact created by the engineers of Attalus II Philadelphus. Strabo wrote (Strabo 1924, Book 14, 1, 24), 'The city has both an arsenal and a harbour. The mouth of the harbour was made narrower by the engineers, but they, along with the king who ordered it, were deceived as to the result. I mean Attalus Philadelphus; for he thought that the entrance would be deep enough for large merchant vessels–as also the harbour itself, which formerly had shallow places because of silt deposited by the Cayster River–if a mole were thrown up at the mouth, which was very wide, and therefore ordered that the mole should be built. But the result was the opposite, for as the silt, thus hemmed in, made the whole of the harbour, as far as the mouth, more shallow. Before this time the ebb and flow of the tides would carry away the silt and draw it to the sea outside.' This quote describes a major engineering mistake, which created a quiescent settling basin out of what was earlier a deep-water major harbour. From then on, from Roman Imperial into Byzantine times, the great harbour had to be dredged continually.

From our drill cores in the harbour we determined that the greater portion of the sediments were beach anoxic silts. This confirmed that the harbour was cut off totally from the river, which distributed new silt with each spring flood.

The great mole was extended to allow ships to approach the great harbour (see Fig. 5). There also were at least five attempts to clean and maintain the great harbour of Ephesus in the times of Roman Emperor Nero (54–68 CE) and through the third century CE (Kraft *et al.* 2000). Apparently, numerous laws were passed to prevent using the harbour as a sewer, disposal area or dump. Many legal methods were tried to stop negative environmental actions. At times there were massive infusions of money to dredge the harbour and maintain the ever-extending narrow channel to the sea. The negative impacts of the works of Attalus II Philadelphus were thereafter compounded by three centuries or more of dumping of industrial and human waste into the harbour with major impact. In the middle of the third century CE the politician Valerius Festus enlarged the harbour. However, by this time, what had formerly been the open harbour of Lysimachus, with excellent access of ships to the shore, had now been filled with dumped materials and construction debris so that the harbour area progressively moved westward (Fig. 5).

During Roman Imperial times the Cayster River delta with its distributaries and marshes continued to prograde several hundred metres to the west. This necessitated continual dredging of the channel to the open sea and the construction of a large mole to prevent the channel from being filled by deltaic river deposits. Also during Roman Imperial times, in the early second century CE, Hadrian had a dam built to divert the Cayster River, to stop the sediment flow into the harbour. The location of this dam has not been determined. By High Byzantine time maintaining the channel to sea from the great harbour of Ephesus became extremely difficult. There are many references (see Foss and Meriç, cited by Kraft *et al.* 2000) to transferring cargoes from platforms near the sea to shallow draught barges or boats that could continue up the channel to the great harbour. Figure 5 shows possible locations of such platforms, but we cannot know of these features in any detail. Continued shoaling and the advance of the delta distributaries westward occurred. By Late Byzantine time the first sandy coastal barriers had formed and the great harbour at Ephesus was no longer in use. There is speculation that later harbours may have utilized areas between the mountains along the southern flank of the graben.

As noted above, by Roman time massive amounts of fill were being placed in the area of the former harbour of Lysimachus so that the lower city of Ephesus could be built. The great harbour of Ephesus was moved westward. Kraft *et al.* (2000), Brückner *et al.* (2008), and comments in the ancient literature have provided details of the environmental problems. These problems were compounded by Roman efforts to fill in the harbour area of Lysimachus to provide a foundation for the construction of public buildings and marble streets and columns from the vicinity of the great theatre of Ephesus to the harbour basin. Figure 6 delineates the nature and timing of the fill materials from an excavation trench. By 400 BCE coastal swamp sediments contained a metre of fill with

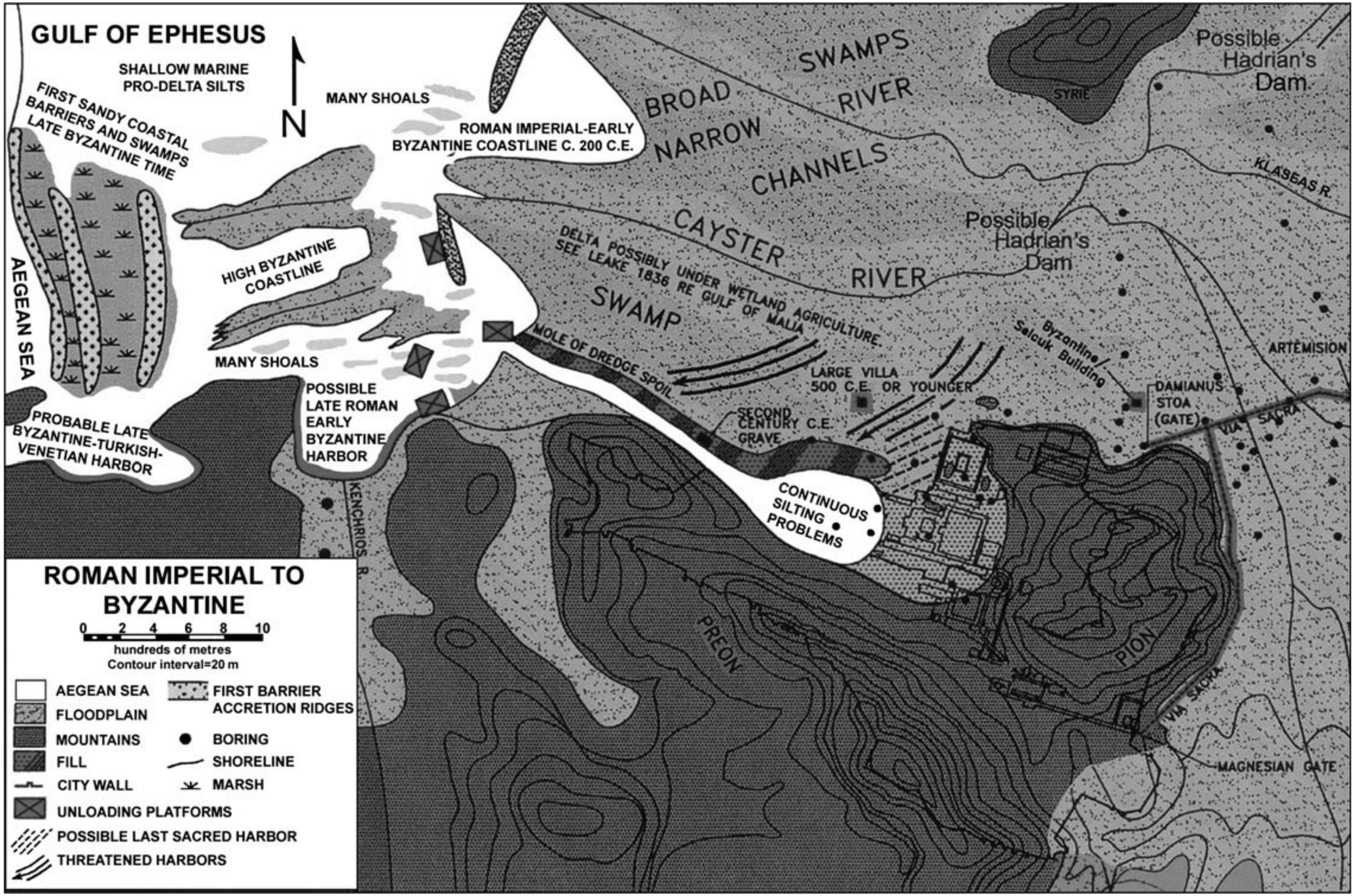

Fig. 5. Palaeogeographical map of the environs of Ephesus during Roman Imperial to Byzantine times showing the shoreline positions at three periods.

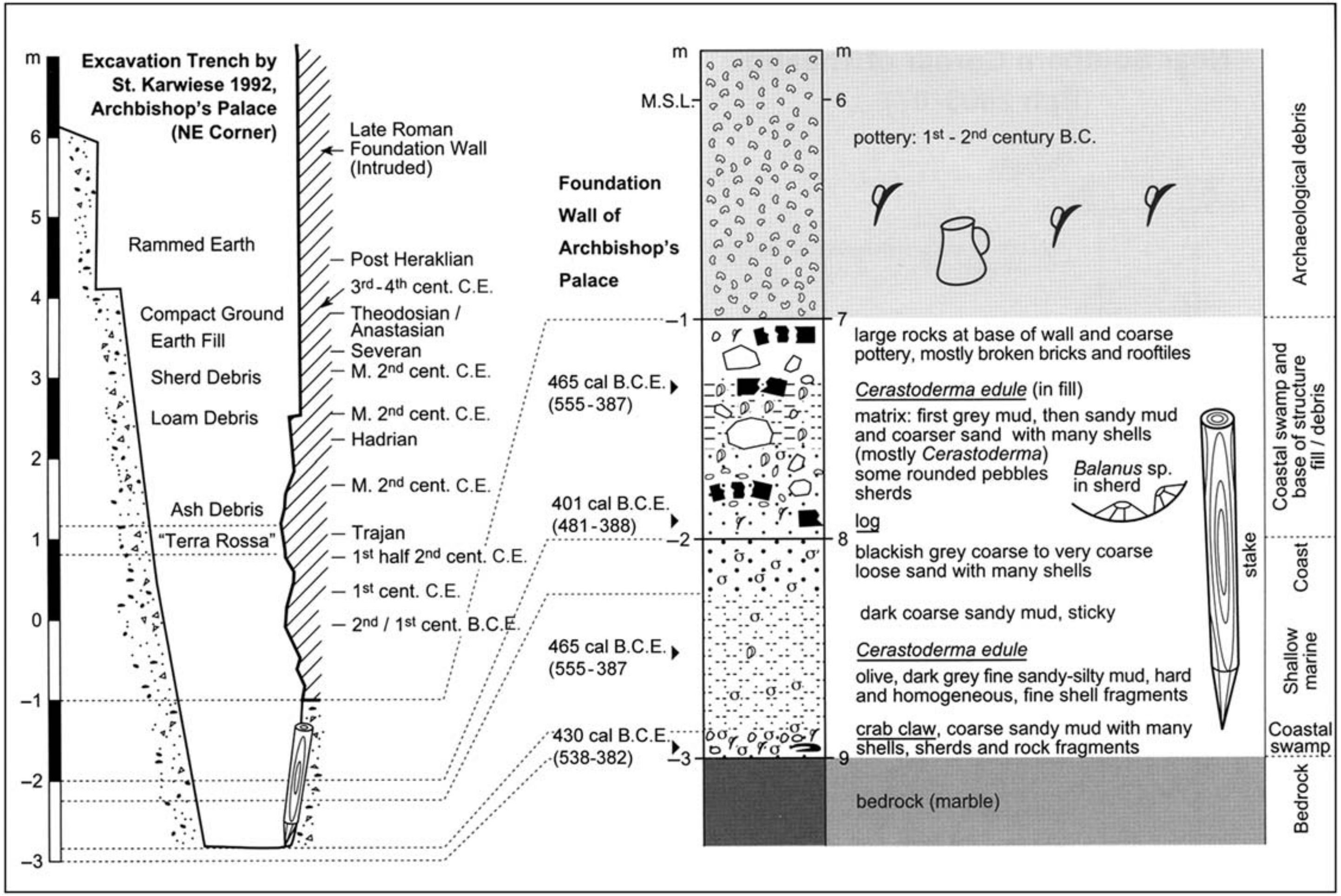

Fig. 6. Schematic diagram of the sediments encountered in an excavation trench, and a core from the bottom of the trench allowing us to locate the position of the shoreline in the time of Lysimachus.

abundant sherds and other debris extending into the edge of the sea. By the first century CE massive amounts of fill are indicated, and this continued throughout the second, third, and fourth centuries. During this time foundation walls were constructed to support a large number of public buildings in the lower city and its adjacent port facility. In addition, a temple and other public buildings were constructed along the northern mole of the great harbour. Archaeological excavation was able to delineate and date over 4 m of fill in the lower city. This contrasted with the centuries of effort to prevent people filling in the harbour as well as the dredging to clear the harbour to allow continuation of shipping.

The harbour of the Lydian (seventh–sixth centuries BCE) city at Ephesus as well as the harbour of Lysimachus (in the same location) in Hellenistic time was a natural deep-water harbour sheltered from westerly, southwesterly, easterly and northerly winds (Kraft *et al.* 2005). On the other hand, the sacred harbour of the Artemision for the Greek city of Androclus (*c*. 1000 BCE) as well as the Classical Greek city was located in the area of the modern city of Selçuk Ephesus. This was between Aya Suluk and the Artemision and the eastern slopes of Mount Pion, B in Figure 7, whereas A shows a possible but not proven early harbour. Throughout the earliest times the site of the Artemision had to be defended from inundation by

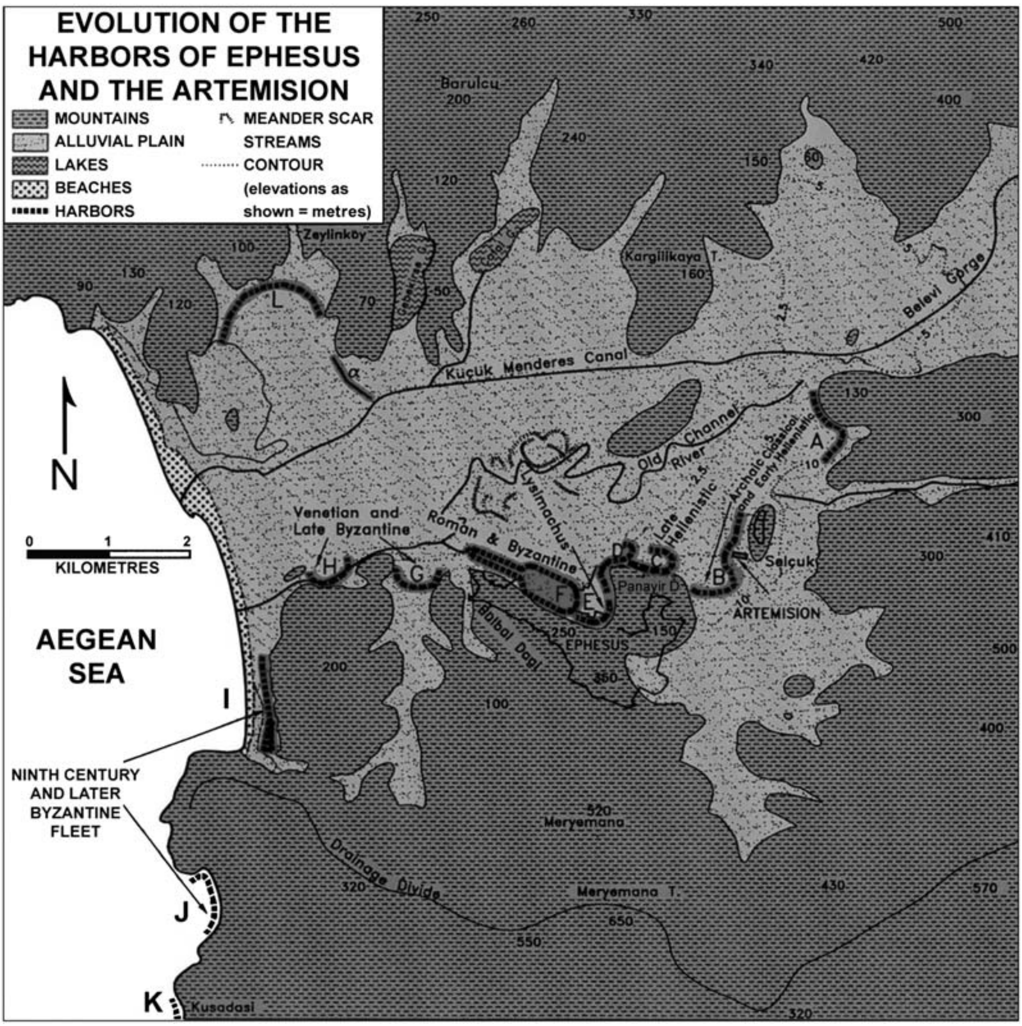

Fig. 7. Evolution of the harbours of Ephesus and the Artemision over two millennia from our core data, geomorphology studies, archaeological excavation and literature sources.

alluvium from the Marnas, Selinus and Serençi Rivers, as well as colluvium from the slopes of Aya Suluk. Indeed, the site of the Artemision throughout the history of its use was subject to flooding. C and D in Figure 7 show locations of later sacred harbours for the Artemision as the delta floodplain of the Cayster River continued to prograde seaward. E shows the location of the Lysimachus harbour, F locates the great harbour of Hellenistic and Roman times, and G and H are suggested locations of possible harbours of Late Byzantine and Venetian time. I, J and K indicate the locations of open sea harbours in later times. L indicates the possible location of the Panormus harbour, which was the last attempt at a commercial harbour for Ephesus but was no longer considered to be important. The excavated marble-block road to Panormus Harbour was constructed from the ruins of Ephesus in Selçuk time (1071–1299 CE). This was the last attempt by the inhabitants to utilize a harbour within the ancient embayment.

Conclusions

Over the past seven millennia humans have occupied the southern flank of the ancestral Gulf of Ephesus. Over time, they were forced to continually adapt to ever-changing coastal configurations created by the colluvial and alluvial sedimentary processes. As the main delta of the ancient Cayster River continued to fill in the ancestral gulf, people occupying the coastal zone of the various loci of the ancient cities of Ephesus had to continually adapt and change their patterns of occupancy. From the time of construction of the first Artemision, *c*. 1000 BCE, buildings, roads and harbour facilities were affected by the dynamic nature of the coastal environment. However, by the time of the Hellenistic construction of the greater city of Ephesus by Lysimachus the human actions came into direct conflict with the natural processes of progradation and aggradation of the Cayster River floodplain and delta. In the case of the Artemision, the sacred harbour was of necessity moved several times to the west along the base of Mount Pion. Indeed, in excavations at the Feigengarten and the Via Sacra(e) at the base of Mount Pion, deep-water conditions were shown to be rapidly filled in by the prograding deltaic sediments. The excavations by the Austrian Archaeological Institute indicate that two roads running from the Artemision to the lower city by the great harbour were buried by up to 5 m of a composite of colluvium, alluvium and structural debris. The area of the Artemision ruins was buried under up to 6 m of colluvium from Aya Suluk and alluvium of the Marnas and Selinus Rivers as well as the Cayster River delta floodplain. In these areas natural processes of deposition dominated (Brückner *et al.* 2008). On the other hand, at the foot of the western flank of Mount Pion and the northern flank of Mount Preon, in the area of the various harbours, over a period of five or six centuries human impact on the environment clearly dominated changes in landforms. In essence, from Classical times until High Byzantine times human actions and structures predominated. The struggle between the peoples of Ephesus and the natural alluvial and colluvial processes continued for over one and a half millennia. However, in the end, the natural processes of sedimentation prevailed. The struggle ended by Byzantine times with the score: natural processes 1, human intervention 0. Currently, the nearest harbour to the city of Selçuk Ephesus is the resort harbour of Kuşadasi far to the SW along the rocky coast of the Aegean Sea.

All seven figures in this paper are adapted and modified from Kraft *et al.* (2000). We thank C. Kubeczko, who adapted the figures, and H. Englemann for his intensive analysis of the ancient literature. Also, we are indebted to two anonymous reviewers, who made many worthwhile suggestions.

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