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Neolithic settlement sites in Western Turkey — palaeogeographic studies at Çukuriçi Höyük and Arvalya Höyük

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ABSTRACT

Çukuriçi Höyük and Arvalya Höyük are two prehistoric settlement mounds (tells) located in parallel striking valleys in the environs of Ephesus, W Turkey. They were studied with geoarchaeological methods in order to reconstruct their environmental setting, areal extension and distinct settlement phases, as well as the vegetation history. Both tells are situated on small ridges flanked by rivers and their alluvial plains which were suitable for cultivation. The Neolithic coastline was located at a distance of c. 1.5–2 km to the north. Çukuriçi Höyük covers an area of c. 200 m × 100 m; its strata have a total thickness of at least 8.50 m. The oldest remains, dating from the 7th millennium BC, represent an advanced Neolithic culture closely linked to the sea. The oldest foundations reveal that the site was intentionally chosen on the ridge within the still naturally wooded vegetated landscape. Other than Çukuriçi Höyük, Arvalya Höyük has not yet been excavated. However, geophysical measurements and corings revealed that it covers an area of c. 100 m × 60 m, and that it is constructed of several settlement layers with a total thickness of at least 3.50 m. Radar and geomagnetic images show building structures including fireplaces and pits, surrounded by a rampart-ditch construction as a potential enclosure.

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1. Introduction

Several Neolithic settlement sites have been excavated in Western Anatolia, especially in the last two decades (Özdoğan et al., 2012, 2013). However, until recently, systematic research concerning the prehistory in the broader area has been lacking. With the excavations of the Neolithic sites of Dedeçik Heybelitepe, Ege Gübre, Ulucak, Yeşilova, and Çukuriçi Höyük in the İzmir region (e.g. Çilingiroğlu, 2011; Çakırlar, 2012; Derin, 2012; Lichter and Meriç, 2012; Sağlamtimur, 2012), broader extensive studies of early farming cultures are possible for the first time in this particular region. It has been argued that these partially contemporaneous settlements make up a regional cluster in the 7th millennium BC, and are defined as a Neolithic group at the centre of the Anatolian Aegean coast (Horejs, in press). Systematic prehistoric research has just recently been initiated around the ancient metropolis of Ephesus with excavations and interdisciplinary investigations at Çukuriçi Höyük and its environment starting in 2006. Due to extensive agricultural land use, this settlement mound (tell) was already partially destroyed when research started.

Several studies and excavation reports about the tell have been published (e.g. Galik and Horejs, 2009; Horejs et al., 2011; Galik, 2014; Horejs, 2008, 2012, 2014). Neolithic occupation started in the early 7th millennium BC with several radiocarbon-dated settlement phases; the chronological sequence continues until the early 6th millennium BC. From excavations at Çukuriçi Höyük it is known that agriculture was practised already from the Neolithic period on in the surrounding alluvial plain (approximately 10 km^2; Horejs, 2014). Archaeobotanical remains are represented by finds of barley and wheat as well as lentils, flax and figs (Thanheiser, 2008; Horejs et al., 2011). Moreover bones of domesticated animals were found (Horejs et al., 2011; Galik and Horejs, 2009; Galik, 2008, 2014). These results combined with other elements of the 'Neolithic package' (Horejs, in press) indicate a fully developed farming community. Finds of fish bones, echinoid spines, crabs as well as many molluscs from sandy and rocky habitats have proven that the inhabitants used the sea intensively (Galik, 2008; Galik and Horejs, 2009; Horejs et al., 2011). The coastline was located 1.5–2 km north of the tell site (Stock et al., 2014).

The neighbouring Arvalya Höyük has neither been excavated nor studied in detail yet. It is located 1.5–2 km south of the coastline (Stock et al., 2013) within am alluvial plain about 3 km^2 (Horejs, 2014). Only Evren and İcten (1998) published surface finds of the site,

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and Stock et al. (2013) investigated the potential tell based on a drill core and described a few survey finds.

Geoarchaeological and geophysical research has been conducted on both settlement sites and their environs since 2008. For this study, drill cores were analysed according to sedimentological and geochemical properties. Georadar and geomagnetic measurements were conducted on Arvalya Höyük. In addition, a first palynological examination of a core from the Belevi swamps close to Ephesus reveals the early vegetation history for this area. The chronostratigraphy relies on AMS-^{14}C ages from the drill cores and relative chronological dating of the survey finds by comparison with artefacts of the excavated Çukuriçi Höyük.

This study aims (i) to reveal the geoarchaeological context of the mounds by determining the thickness, extent and age of the settlement layers throughout the periods of settlement; (ii) to reconstruct their palaeoenvironmental setting; (iii) and to detect the vegetation history including the human impact during Neolithic and Bronze Age times.

2. Study area

The settlement mounds of Çukuriçi Höyük and Arvalya Höyük are located close to the ancient city of Ephesus in the two parallel N–S-striking valleys of the Derbent (max. 3 km wide) and Arvalya (max. 1 km wide) rivers (Fig. 1). Both tells lie at a distance of about 2 km to the main fault system which created the Küçük Menderes graben. The latter developed over pre-Miocene basement rocks of the Menderes Massif along an E–W-trending syncline. It has been filled with mostly continental deposits since Miocene times (Rojay et al., 2005). Both the Derbent and the Arvalya valleys are bordered by mountains up to 358 m a.s.l. (above sea level), composed of mica schist, dolomitic marble and bedrock from the Menderes gneiss core (Vetters, 1989).

With the rising sea level at the end of the last glaciation, a marine embayment formed reaching at least 20 km inland up to the swamps of Belevi (Brückner, 2005) (Fig. 1). Stock et al. (2013, 2014) proved

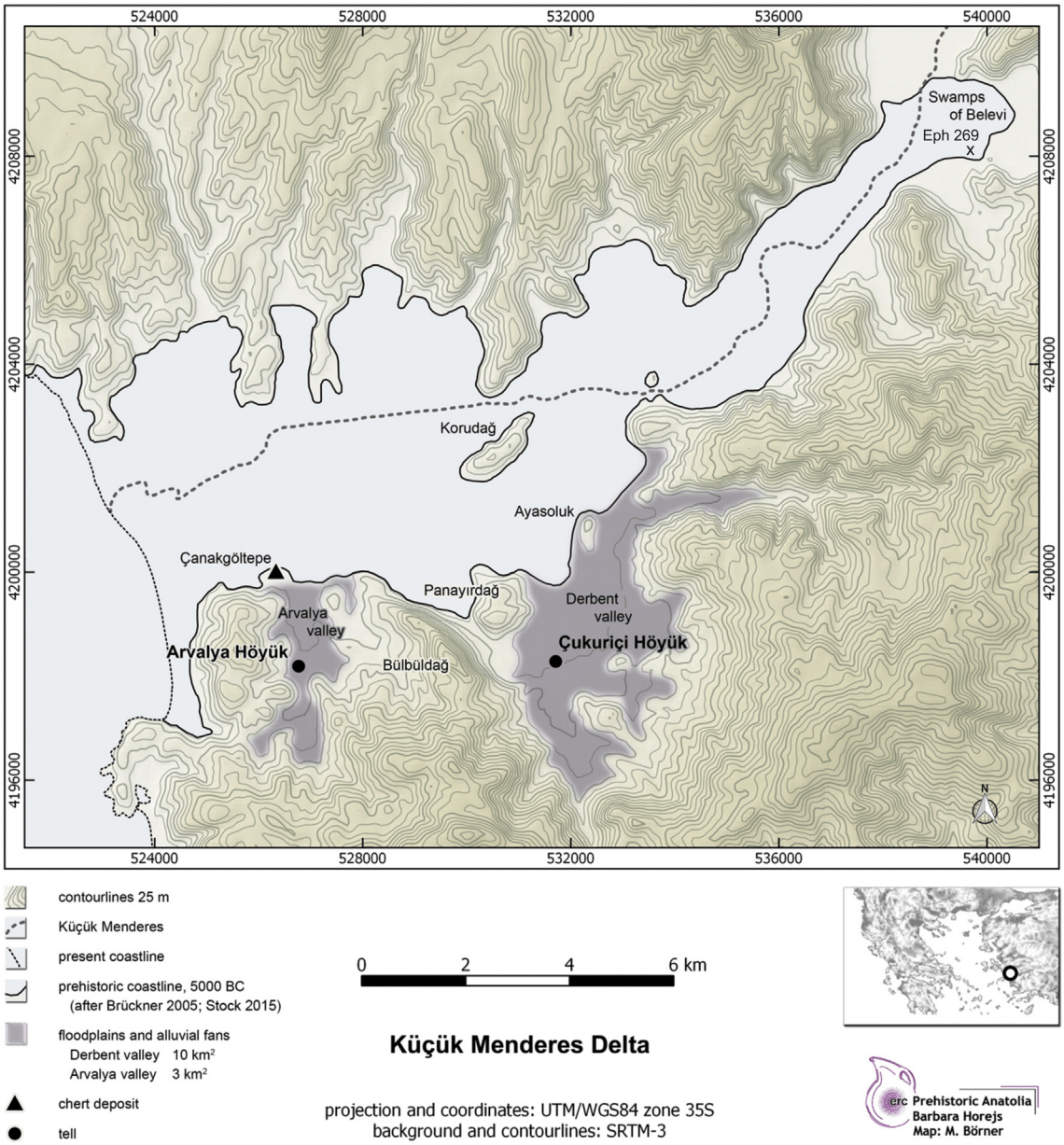

Fig. 1. Neolithic settlements and chert source within the lower Küçük Menderes basin. Reconstructed prehistoric coastline according to Brückner (2005). Location of drill core Eph 269 from the swamps of Belevi Map: ERC Prehistoric Anatolia/M. Börner.

that the maximum marine ingression reached max. 500 m into the Arvalya and Derbent valleys during Neolithic times. Thereafter, the continuous delta advance of the Küçük Menderes river and its tributaries since the 5th/4th millennia BC lead to a complete siltation of the marine embayment (Brückner, 1997, 2005; Kraft et al., 1999, 2000, 2001, 2005, 2007, 2011). Until the 1st millennium BC the siltation in the environs of the Çukuriçi Höyük was dominated by the rivers Derbent Dere and Derbent Çayı, and in the environs of the Arvalya Höyük by the river Arvalya Çayı. When the Küçük Menderes delta reached the study area during the 1st millennium BC the settlements had already been abandoned (Horejs et al., 2011, 2012; Brückner, 2005; Stock et al., 2013, 2014).

Çukuriçi Höyük is located in the western part of the Derbent valley (Fig. 2a). It has partly been destroyed, because the terrain was levelled and planted with fruit trees (Horejs, 2012). In 2006, its surface area was presumed to be 100 m × 80 m (Horejs, 2008). On satellite images of the 1960s and 1970s, several river channels are visible in the vicinity of the tell site (Kurtze et al., 2012). The channel of the Derbent is located east of the street to Camlık, another former river channel can be made out directly to the west of the tell.

Arvalya Höyük is a gently elevated area in the Arvalya valley, located mainly west of the new road to Kuşadası which destroyed most of the original surface (Fig. 3a). The tell is confined on the northern side by a Safari park and on the western side by a man-made edge. The Arvalya Çayı river channel flows to the west of the mound (Fig. 3b).

3. Methods

Both mounds and their environs as well as the swamps of Belevi were investigated with half open and closed drill cores (percussion corer Cobra pro, Atlas Copco Co., diameters of auger heads 5 and 6 cm) up to a maximum depth of 8 m at the mounds and 15.40 m at Belevi. In the field, the sediments were described in terms of grain size, colour (Munsell Soil Color Charts), carbonate content (with diluted hydrochloric acid) and other characteristics (e.g. macrobotanical and -faunal remains, potsherds and lithic fragments, angular stones). All coring sites were measured with a DGPS (Topcon HiPer Pro; precision: 2 cm; altitudes refer to present mean sea level). In the laboratory, selected samples from the cores obtained at the tells were dried and sieved (<2 mm). They were analysed for grain size (see Stock et al., 2013), calcium carbonate content (Scheibler apparatus), total organic carbon content (TOC with a C/N Analyser, vario EL cube, Elementar) and element measurements with an Atomic Absorption Spectrophotometry (AAS iCE 3000 series Thermo Scientific). Geophysical measurements were conducted on Arvalya Höyük to investigate the subsurface of the tell. Geomagnetic measurements were performed on 6027 m^2 using a Foerster FEREX® Fluxgate magnetometer with 4 sondes. The processing of the data (subgrid shifts, line shifts, displacements, moving of the spikes and noise) and the visualisation were carried out using the APMAG software (developed in ZAMG) and georeferenced for GIS implementation (Seren et al., 2004). 2787 m^2 were prospected with a Sensors & Software NOGGIN® georadar (250 Mhz antenna), processed and visualised with the APRADAR software (developed in ZAMG; Seren et al., 2004).

The archaeological objects (pottery, lithics, small finds) from the drill cores (Çukuriçi and Arvalya Höyük) and the surface finds (Arvalya Höyük) were documented and analysed. Pottery was categorised according to shapes and fabrics to be compared with the excavated assemblages from Çukuriçi Höyük.

Thus, together with radiocarbon age estimates, diagnostic pottery reveals the chronostratigraphy of the mounds and the swamps of Belevi.

Palynological studies were conducted with 2–4 cm^3 sediment following Eisele et al. (1994). Identification of the pollen grains was carried out after Beug (2004), Moore et al. (1991) and Reille (1992).

4. Results and discussion

4.1. Drill cores at Çukuriçi Höyük

In order to study the thickness and the extent of the cultural layers and the palaeoenvironment, 19 drill cores were obtained on the tell and in the surrounding area. They reached a maximum depth of 8 m and were arranged in cross sections.

4.1.1. North–south cross section

Eph 277 and 332 were drilled on top of the tell site. Eph 204 and 214 are located below the man-made edge within the excavation zone. Eph 215, 320, 313 and 335 were retrieved up to 100 m north of the edge. The southern cores comprise Eph 333, 334 and 336, located up to 60 m south of the southern edge of the mound (Figs. 2b, 4).

The base of the cores within the tell area is characterised by dark yellowish brown sandy silts mostly consisting of weathered angular stones (mica schist, quartz) up to 3 cm (Eph 332, 277, 204, 214, 215; Fig. 5). Geochemical analysis revealed low phosphorous and total organic carbon (TOC) contents and no trace of carbonate (Fig. 6). Within the upper part of this unit, there is a slight decrease in grain size and an increase in iron. A distinct unconformity to the overlying strata (sandy silts) is especially expressed in the colour change from yellowish brown to brown (Fig. 5). There is a noticeable rise in carbonate, carbon and phosphorous contents directly above the boundary. Settlement remains (charcoal, shell fragments, burnt clay, bones, potsherds, stone tools) are found in the following strata up to the top. At Eph 277 the still preserved settlement layers have a total thickness of 5.65 m, while they are reduced to 3.50 m in the northern cores due to bulldozing. 7 radiocarbon ages from drill cores north of the man-made edge (5 charcoal pieces, 2 bone fragments) date to the 7th millennium BC (time span: 6592–6216 cal BC).

The lowermost sediments of the drill cores from the environs of the mound (Eph 336, 334, 333, 320, 313, 335) revealed similar characteristics: yellowish brown silts and sands with angular stones. South of the tell (Eph 333 and 334) the overlying sediments are characterised by the presence of archaeological remains of individual settlement periods.

North of the tell, a transition unit of 1.30 m is composed of light greyish silts with laminations (Eph 320) and silty fine sands with coarser components ranging from fine sand to gravel, which is partly rounded (Eph 335). Up to the surface, all cores are composed of sandy silts with abundant archaeological remains which, according to results from the diagnostic pottery, date from the Pottery Neolithic period to the Early Bronze Age.

4.1.2. West–east cross section

Eight drill cores were retrieved up to 80 m to the west (Eph 317, 316, 315, 314) and 60 m to the east (Eph 309, 312, 310, 311) of the tell (Figs. 2b, 4). With the exception of Eph 314, the yellowish brown layer with angular clasts (see 4.1.1) was reached at a depth of 4–5 m b.s. (below surface). In all drill cores, the sediments up to the present surface consist of sandy silts with scattered weathered archaeological remains. The latter comprise mudbrick fragments and potsherds; only few could be determined and assigned to the Late Neolithic and Chalcolithic periods.

In the eastern cores Eph 312, 310 and 311, a specific stratum is intercalated: a brown greyish layer with fining upward sequence (gravel to sandy silts). In Eph 312 this layer containing several archaeological remains is especially thick (2.50 m greyish clayey silts).

4.1.3. Interpretation of the cored strata at Çukuriçi Höyük

The lowermost sediments can be interpreted as an alluvial fan from the Late Pleistocene/Early Holocene (Figs. 4, 5, 6). This is indicated by the common occurrence of weathered angular stones and by the dark yellowish brown colour. The angular components indicate a short

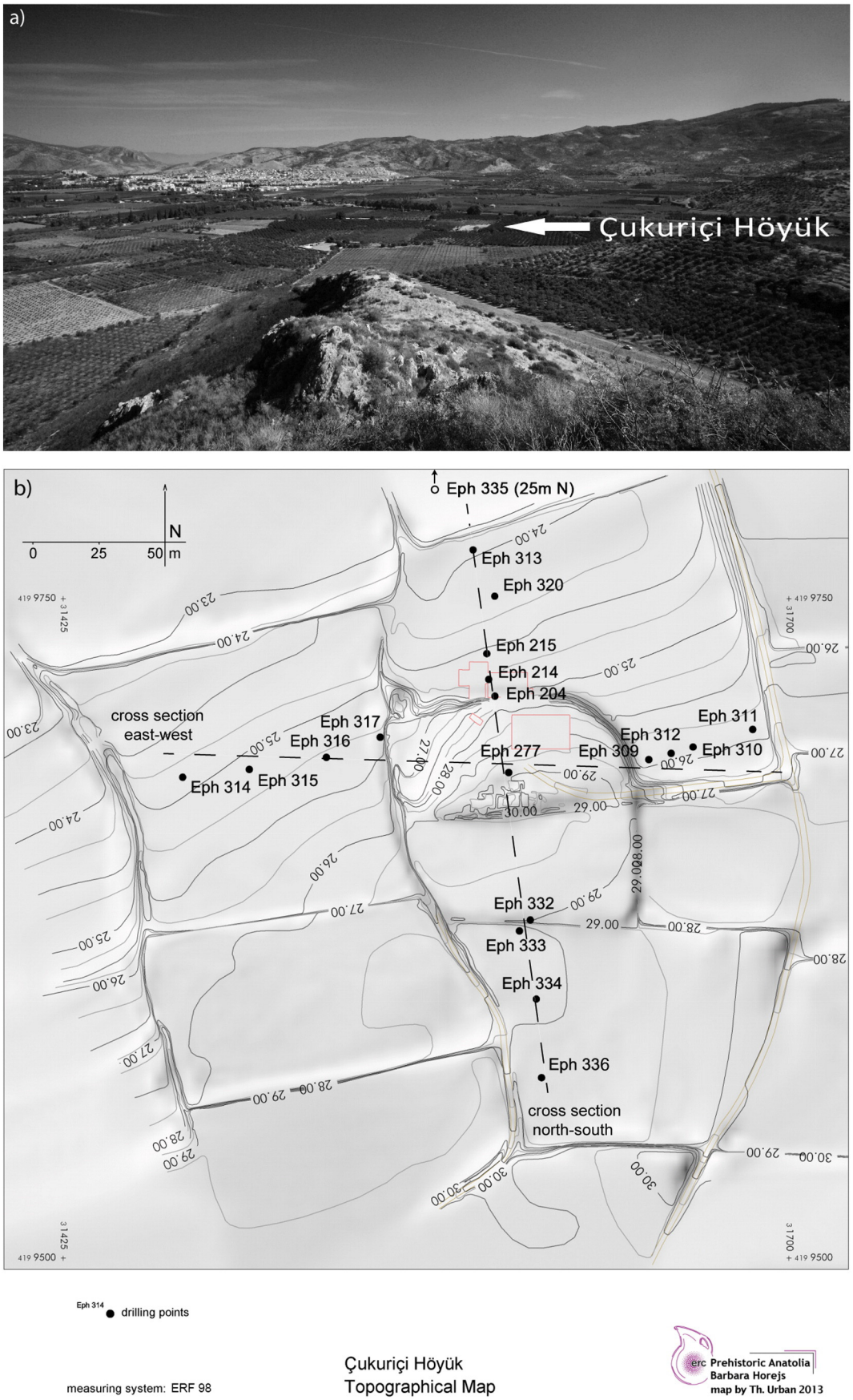

Fig. 2. a) View of Derbent valley and Çukuriçi Höyük. b) Topographical map of Çukuriçi Höyük (ERC Prehistoric Anatolia/Th. Urban).

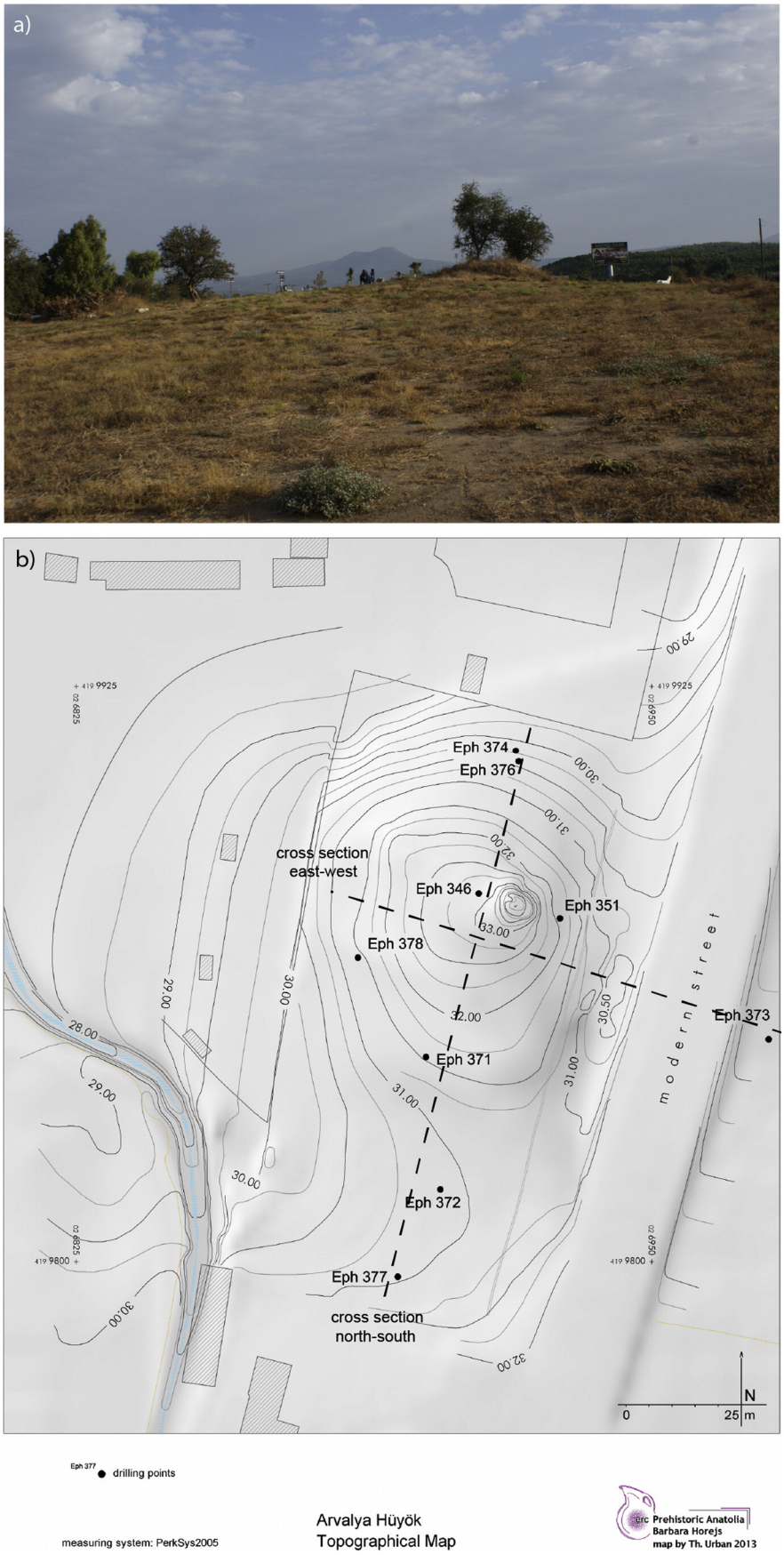

Fig. 3. a) View of Arvalya Höyük. b) Topographical map of Arvalya Höyük (ERC Prehistoric Anatolia/Th. Urban).

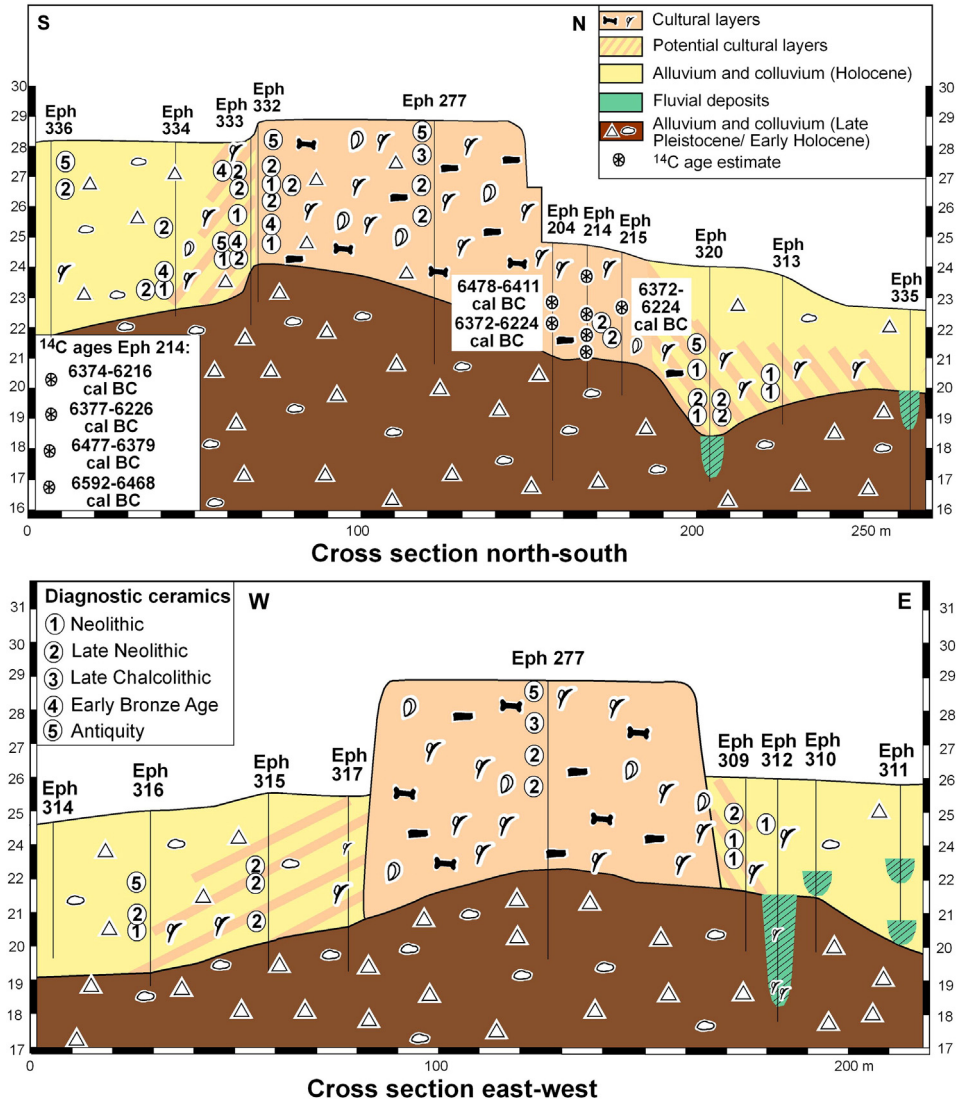

Fig. 4. North–south and west–east cross sections of Çukuriçi Höyük with facies interpretation and diagnostic ceramics. The maximum size of the mound is not known and can only be estimated. In order to get more precise information, further excavations are necessary. Parts of this tell have already been lost due to extensive bulldozing.

transport from the nearby mountains. Since these strata are void of archaeological remains, the deposition must have taken prior to an initial settling at the site. A palaeosol has developed in the upper alluvium in the middle and the northern part of the tell area. It is decalcified and shows an enriched iron content. The alluvial sediments are topped by cultural layers, the maximum thickness of which was 5.65 m in drill core Eph 277. However, they were originally up to 8.50 m thick with visible archaeological remains on top of the tell site (Horejs, oral comm.). Besides the abundant occurrence of artefacts and charcoal there are many more indications of human impact: high contents in phosphorous (Holliday and Gartner, 2007; Gauss et al., 2013) and TOC (Schlezinger, 2000). Cultural layers were also detected in cores adjacent to the tell (Eph 309, 317, 333 and 334, 320 and 313). The higher density of finds in the northern cores may indicate the extent of the tell in this direction. However, this can also be due to the northwards sloping topography (see Fig. 4) with alluvial and colluvial processes having transported and redeposited the artefacts. An excavation could bring about clarity how far the tell actually extents in this direction.

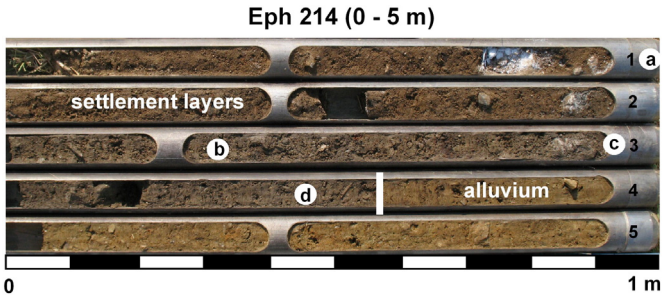

Fig. 5. Çukuriçi Höyük. Photo of coring Eph 214 with location of ^{14}C samples. Top of the coring in the upper left corner, end of the coring at 5 m below surface in the lower right corner. Diameter of augerheads: 6 cm. The gap in the 2nd and the 4th metres is due to the coring process. a) 7374–6216 cal BC; b) 6377–6226 cal BC; c) 6477–6379 cal BC; d) 6592–6468 cal BC.

Several drill cores in the vicinity of the tell and only a sparse occurrence of archaeological remains are of alluvial/colluvial origin; they can, therefore, not be referred to as cultural layers. Nevertheless, the artefacts allow to design these strata to the Holocene period.

The intercalated layers with fining upward sequences identified in Eph 310, 311, 320 and 335, can best be interpreted as fluvial channels. Shifts in the fluvial system of the river and its affluents were a common phenomenon. In Eph 312 predominantly fine-grained clastic deposits indicate low energy depositional conditions, or a stillwater environment. An excavation could clarify whether the deposit is of natural or man-made origin, such as hydrologic measures like damming.

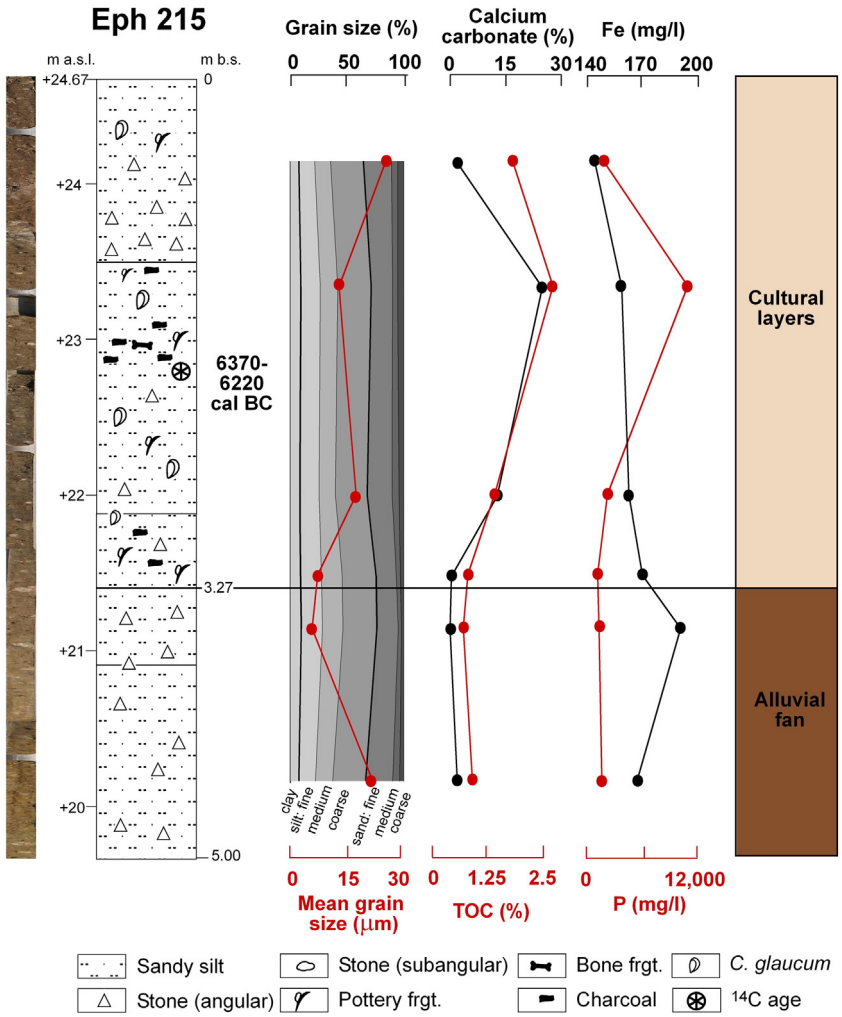

Fig. 6. Çukuriçi Höyük. Stratigraphy of core Eph 215 and results of geochemical and sedimentological analyses.

4.2. Arvalya Höyük

Since Arvalya Höyük has hitherto not been excavated yet, different methods were applied for studying the tell site. The geophysical investigations were conducted in order to obtain a large image of the tell. These results were verified and extended with drill cores. Together with the analyses of diagnostic ceramics from the drill cores, the archaeological survey on top of the tell complete the intensive study of this mound.

4.2.1. Geophysical investigations

The magnetogram shows in the northern and eastern parts a modern conduit and several recent iron objects (Fig. 7; very bright anomaly). This area is disturbed; no clear archaeological structures are visible. In the southern part there is a potential rampart-ditch construction or enclosure with an entrance area. In the magnetogram, the ditch appears as a positive anomaly in dark colour (Seren et al., 2004). The ditch or enclosure is up to 7 m wide, the wall c. 6 m. It is identifiable at a length of 50 m and disappears about 13 m west of the street, where it was probably destroyed during road constructions. Linear light bright structures occur north of the rampart-ditch. They may indicate houses within the enclosure. Several pits and fireplaces were also detected.

The interpretation of the radar data is presented in Fig. 8 at a depth range of 0.2 to 1.3 m. Many structures are visible, except in the southern area, but identifiable only within the 1–2 m depth range. These typically dark structures may be interpreted as walls (Goodman, 1994). In the centre of the measured area a distinct round structure with a diameter of 3.5 m appears. South of it a 12 m × 14 m ground plan can be identified as well as more walls further to the south. The structures in between can be vaguely determined; they are possibly walls as well. The presumed rampart-ditch cannot be detected with the radar technique. Fig. 9 shows a synoptic interpretation of the magnetic and radar images.

4.2.2. Drill cores

To verify and extend the geophysical research and prove the period of settlement, 9 drill cores with a total depth of 6 m were retrieved from the settlement and its surrounding areas (Figs. 3b, 10). All of them reveal a consolidated layer of clay and loam with small stones at the base. Overlying is a max. 2.90 m thick stratum, with lithics, bones, potsherds, burnt clay and shell fragments as well as charcoal. Only Eph 377, located at the southern border of the field, and Eph 373, drilled east of the street, are void of settlement remains.

In addition to Eph 346 from the centre of the tell (3.50 m settlement layers: Stock et al., 2013), Eph 351 was drilled within a round structure obtained on the radar. The upper 2.80 m of this core is composed of silty sands with archaeological remains. On the northern part of the tell site (Eph 374 and 376) abundant settlement remains occur within the upper 1.65 m. Eph 378, drilled on the western part of the mound, shows human impact within the upper 2.80 m. In corings Eph 371 (inside a house structure) and Eph 372 (within the ditch), only scattered anthropogenic remains were found in the uppermost 2 m of the cores. In general, the pottery fragments date from the Neolithic period to the Early Bronze Age.

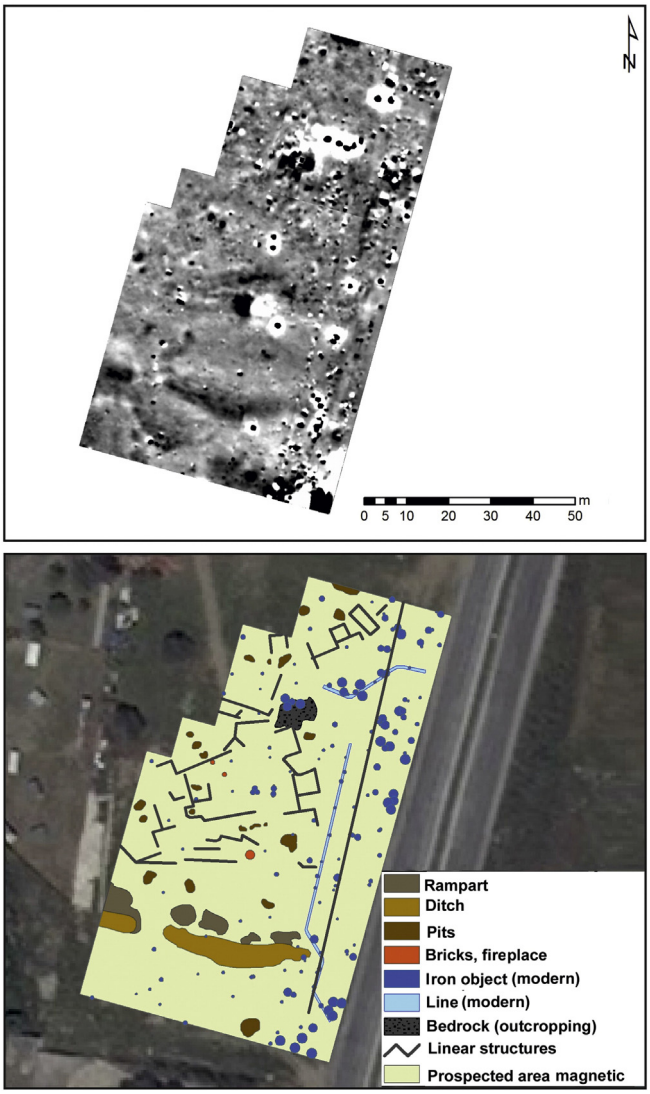

Fig. 7. Arvalya Höyük. Geophysical investigations. a) Magnetogram (ZAMG/ÖAI); b) Archaeological interpretation of the magnetogram (ZAMG/ÖAI).

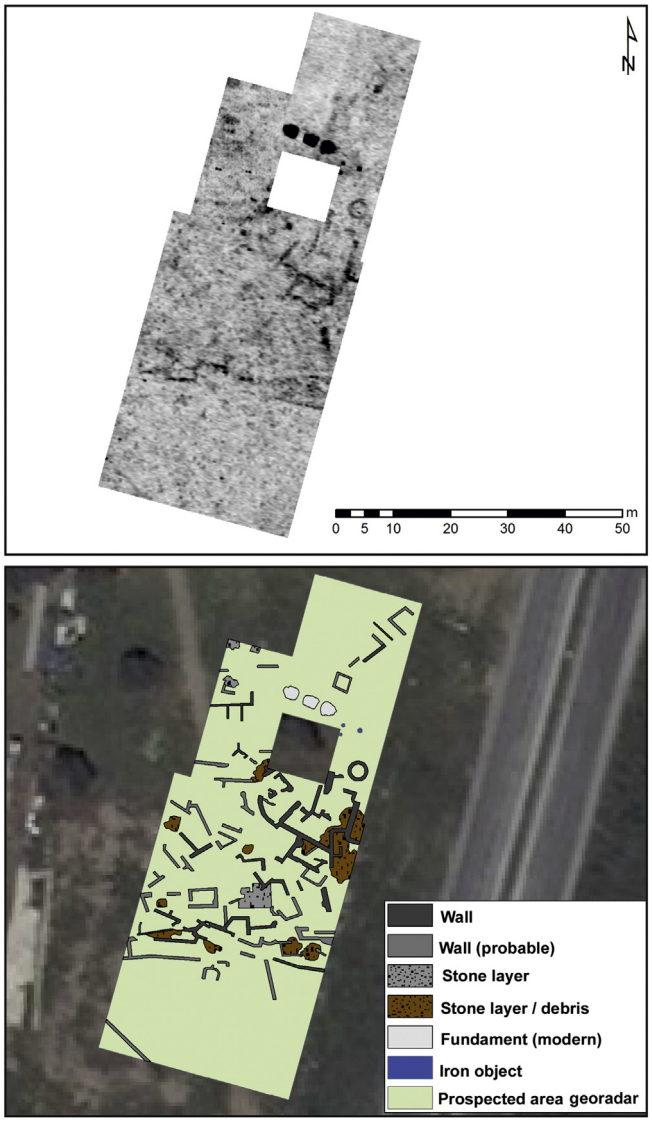

Fig. 8. Arvalya Höyük. Geophysical investigations. a) Georadar (depth profile 0.2–1.3 m) (ZAMG/ÖAI); b) Archaeological interpretation of the georadar data (ZAMG/ÖAI).

Four ^{14}C dates give a rough estimate of the chronostratigraphy (Table. 1): two samples from the deepest settlement layers date to the 7th millennium BC, the others to the 3rd millennium BC.

4.2.3. Interpretation of drill cores of Arvalya Höyük

The base of the drill cores may be interpreted as the top parts of an alluvial fan, probably deposited during the Late Pleistocene/Early Holocene (Fig. 8). The overlying settlement layers have a max. thickness of up to 3.50 m (Eph 346, 351 and 378). The centre of the mound was probably in the northern and western parts of the investigated area which is suggested by the high number of finds; it may, however, have shifted over time.

4.2.4. Archaeological surveys and material studies

The site Arvalya Höyük was registered and surveyed already by colleagues from the local museum of Selçuk in the 1990's, before the massive modern destruction took place (Evren and İcten, 1998). They provided some general information of a potential tell without detail discussion of materials and presumable chronology of the site. Therefore an additional collection of surveyed materials appears necessary and has been conducted parallel to the geoarcheological investigations. This intensive, but non-systematic survey could provide small assemblages of pottery, lithics and a few small finds. Due to the state of preservation, all observable objects have been collected to achieve at least a few information of chronology, raw materials and archaeological–cultural relations. Of the 58 gathered pottery fragments only very few are diagnostic pieces, like rims or base fragments. The analysis of their fabrics and wares reveal similarities to excavated Çukuriçi material, making it possible to use the same classification system and allowing assumptions in terms of chronology. 33 ceramics are corresponding to already defined and well-known pottery wares, which are characteristic for specific chronological periods in the neighbouring valley. Their distribution show a clear dominance of Neolithic wares (Fig. 11b, c, e, f; phases ÇuHö X-VIII; 64%) followed by Late Chalcolithic wares (Fig. 11d; phase ÇuHö VII; 30%), and only rarely Early Bronze Age pottery (Fig. 11a; EBA, phases ÇuHö IV-III; 6%). The lithic material consists of obsidian and chert artefacts, also comparable to already known types and raw materials of the Neolithic period. Of particular interest is the chert assemblage of retouched tools, flakes cores and debris (Fig. 12). It should be pointed out that the only material source of local chert known so far is Çanakgöltepe located near the entrance to Arvalya valley (Fig. 1). The Neolithic material spectrum of lithics and pottery can be integrated very well into the supposed archaeological group of the centre at the Aegean Anatolian coast that include Ulucak, Ege Gübre, Yeşilova, Dedecik-Heybelitepe and Çukuriçi Höyük (Horejs,

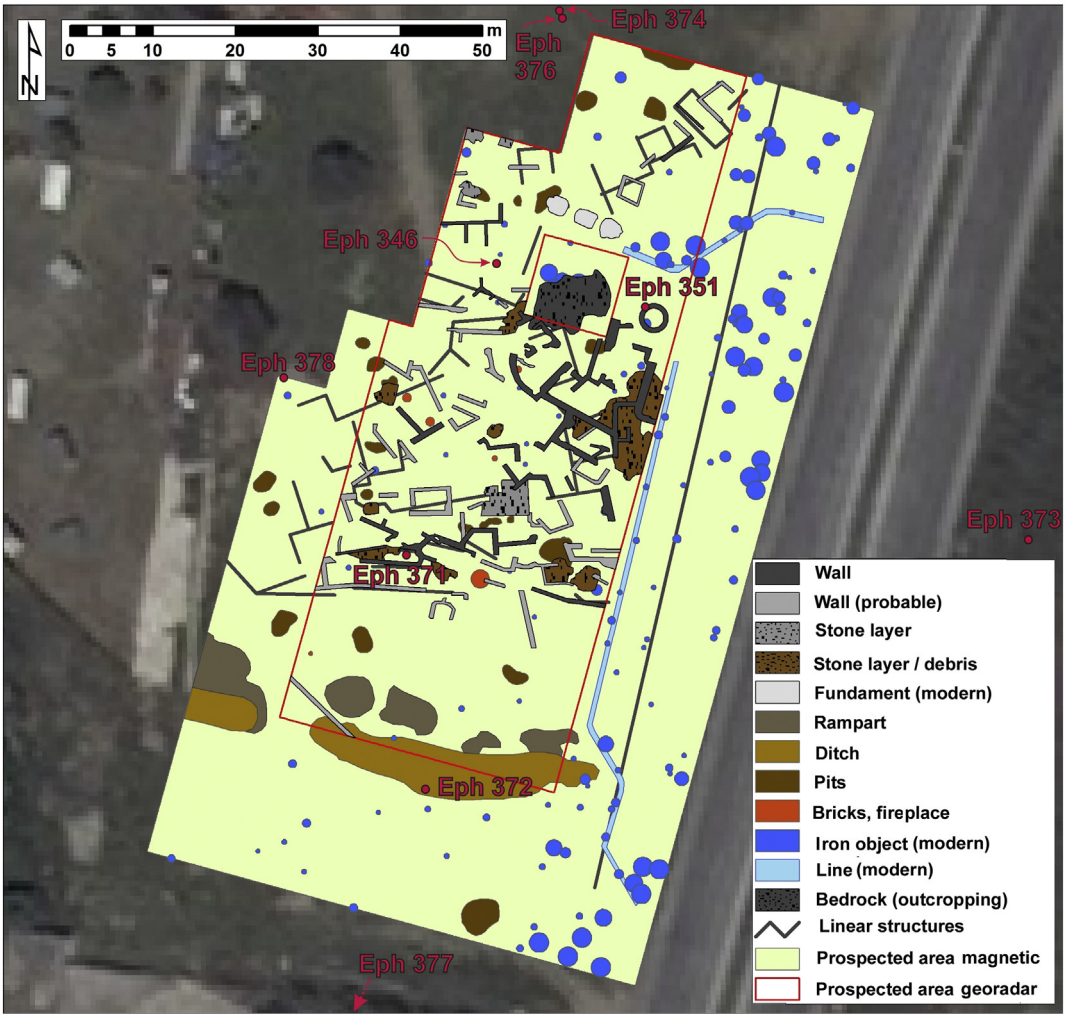

Fig. 9. Arvalya Höyük. Geophysical investigations and drill cores from the tell area. Synopsis of the geophysical prospection. Combined interpretation of magnetic and georadar results (ZAMG/ÖAI).

in press). Arvalya Höyük appears as another 7th millennium tell settlement integrated in this archaeological group of Pottery Neolithic period. This result corresponds to the radiocarbon-dated drill cores. Although there are no ^{14}C ages indicating a 4th millennium occupation, the pottery also hints to a Late Chalcolithic site. Finally, the singular EBA ceramics can be related to ^{14}C ages of the 3rd millennium, indicating a settlement which is contemporaneous to at least phases Çukuriçi Höyük IV and III.

4.3. Palynological analysis

A palynological study has been carried out for drill core Eph 269, retrieved from the swamps of Belevi (Figs. 1, 13) for obtaining a better knowledge of the vegetation in the environs of the mounds during the settlement periods. The lower 7 m comprise the period from the 7th to the 3rd millennia BC (15.40–8.06 m b.s.; below surface). The base (15.40–9.78 m b.s.) reveals silts with an intercalated sand lens (13.33–12.46 m b.s.) dating from the end of the 7th to the beginning of the 5th millennium BC. Microfossils at the base indicate freshwater to brackish conditions, followed by a brackish-marine environment still connected to the sea (unpublished data). The palynological analysis revealed a high number of indeterminate pollen grains and *Isoetes* spores (pollen assemblages zones (PAZ) 1a + b). The indeterminates, *Isoetes* spores and a large part of the palynomorphs were probably transported by the Küçük Menderes river into the marine embayment. This part of the profile indicates a natural vegetation dominated by deciduous oak (*Quercus robur/cerris*-type). However, more than 5% of Cerealia type pollen may suggest early agricultural activity and human impact on the landscape already at the beginning of the 7th millennium BC.

The overlying stratum (9.78–8.06 m b.s.) is characterised by pale yellow sediments of a lake, rich in calcium carbonate, with brackish and freshwater ostracods and foraminifers (unpublished data). Thus, the connection to the sea was interrupted as early as during the 5th millennium BC. PAZ 2 is dominated by a rapid decline of indeterminates and *Isoetes* spores and now indicates the absence of sediments transported by the Küçük Menderes river. The macro remains are represented by the swamp and water plants *Typha*, *Najas* and Characeae. Deciduous oaks (*Quercus robur/cerris*-type) still dominate the tree pollen with up to 50% of the terrestrial pollen. In the direct vicinity of the swampy environment, crop cultivation is rather unlikely. The discontinuation of *Polygonum aviculare*-type pollen (common on areas with trampling stress) also confirms this assumption.

5. Palaeoenvironmental reconstruction

The results prove the existence of two settlement sites in parallel striking valleys dating back to the Neolithic period. At Çukuriçi Höyük, the AMS-^{14}C ages from the drill cores roughly correspond to the samples from the excavation area going back to the early 7th millennium BC (Fig. 4; Table. 1) (Weninger et al., 2014; Horejs, in press). As Arvalya Höyük is not excavated yet, only diagnostic pottery and ^{14}C age estimates from the drill cores give evidence of different settlement periods.

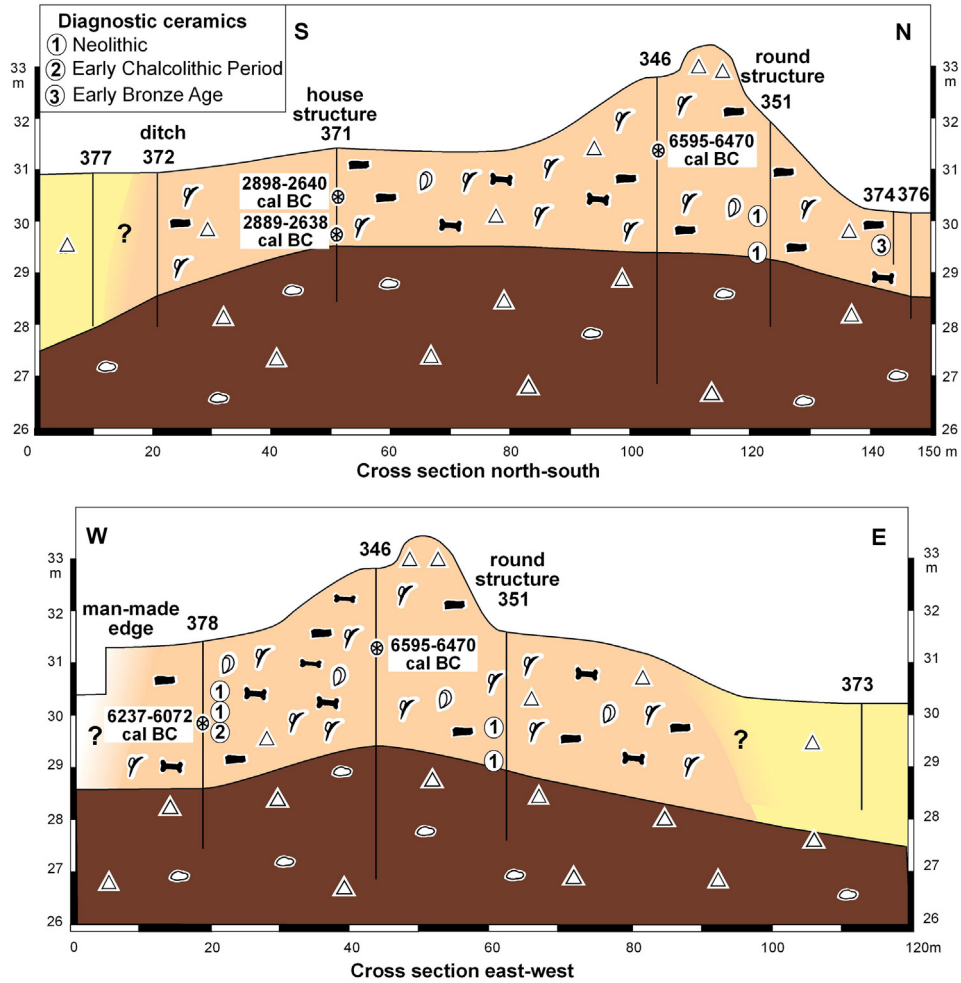

Fig. 10. North–south and west–east cross sections of Arvalya Höyük with facies interpretation. Legend in Fig. 4. The maximum size of the mound is not known and can only be revealed by excavations. Parts of this tell are already lost due to bulldozing and construction works.

Combining these archaeological and chronological results with drill core analyses and geophysical interpretations (s. above), it can be stated that Arvalya Höyük comprises several layers of occupation dating to different periods from the Neolithic to the Early Bronze Age. This massively destroyed tell site was probably larger in its original extension (Fig. 12). The various architectural and domestic remains detected by means of geophysics (Figs. 7–9) show differing orientation and settlement patterns covering each other. Although a proper chronological classification of these structures cannot be established without an excavation, it has been suggested that although the significant enclosure (rampart-ditch) could be correlated with all detected periods, it appears similar to the Late Chalcolithic ditch at Çukuriçi Höyük VII (and other sites), which is 4–5 m wide and up to 2.5 m deep (Horejs, 2014; Horejs and Schwall, 2015). However, a comparison with massive enclosures known from the 3rd millennium BC, e.g. Bakla Tepe or Liman Tepe, could also be made (e.g. Erkanal, 2008a,b).

Table 1
Radiocarbon data chart. The AMS-^{14}C ages are calibrated with Calib 6.0 (Reimer et al., 2009) and are presented here with 2 sigma standard deviation (95.5% probability). The shells are corrected with the marine reservoir effect of 390 ± 85 years (Siani et al., 2000). b.s. below surface, b.s.l. below sea level, a.s.l. above sea level. ^{14}C measurements were performed at the Applied Center for Isotope Studies at Athens, Georgia, USA (UGAMS), ^{14}Chrono Centre for Climate, the Environment and Chronology at the Queen's University Belfast, UK (UBA), AMS ^{14}C-laboratory in Erlangen, Germany (Erl), and at the Klaus-Tschira Laboratory for scientific dating in Mannheim, Germany (MAMS).

Sample code	Lab code	Material	Depth (m) b.s.	Depth (m) a.s.l./b.s.l.	δ^{13}C	^{14}C age	Age cal BC/cal AD (2σ)
Eph 371/12 HK	UBA-26795	Charcoal	148	30.057	−24	4183 ± 33	cal BC 2889–2638
Eph 378/9HK 160	UBA-26796	Charcoal	160	29.783	−24.8	7311 ± 40	cal BC 6237–6072
Eph 371/5HK 80	UBA-26797	Charcoal	80	30.737	−28.9	4199 ± 38	cal BC 2898–2640
EPH 346/4HK147	UGAMS 13058	Charcoal	147	31.322	−26.1	7700 ± 30	cal BC 6595–6470
Eph 204	UGAMS 6040	Charcoal	194	23.902	−26.8	7590 ± 30	cal BC 6478–6411
Eph 204–259	UGAMS 6042	Charcoal	259	22.44	−25.6	7400 ± 30	cal BC 6372–6224
Eph 215–195	UGAMS 6041	Charcoal	194	22.613	−26.1	7400 ± 30	cal BC 6372–6224
Eph 214–345	UGAMS 6043	Charcoal	345	21.301	−26.4	7690 ± 30	cal BC 6592–6468
Eph 214–100	UGAMS 6044	Charcoal	100	23.751	−25	7390 ± 30	cal BC 6374–6216
Eph 214 297	Erl-14521	Bone	297	21.781	−19.9	7568 ± 39	cal BC 6477–6379
Eph 214 232	MAMS-10878	Bone	232	22.431	−23.2	7409 ± 33	cal BC 6377–6226
Eph 269 10,21 Cg	UGAMS 13570	Shell (*Cerastoderma glaucum*)	1021	−6.75	−4.6	6440 ± 30	cal BC 5095–4880
Eph 269/M 1315	UGAMS 13568	Marine shell	1315	−9.69	−8.7	6760 ± 30	cal BC 5441–5281
Eph 269/1 Pf. 1496	UGAMS 13569	Plant remain	1496	−11.5	−27.4	7320 ± 30	cal BC 6234–6085

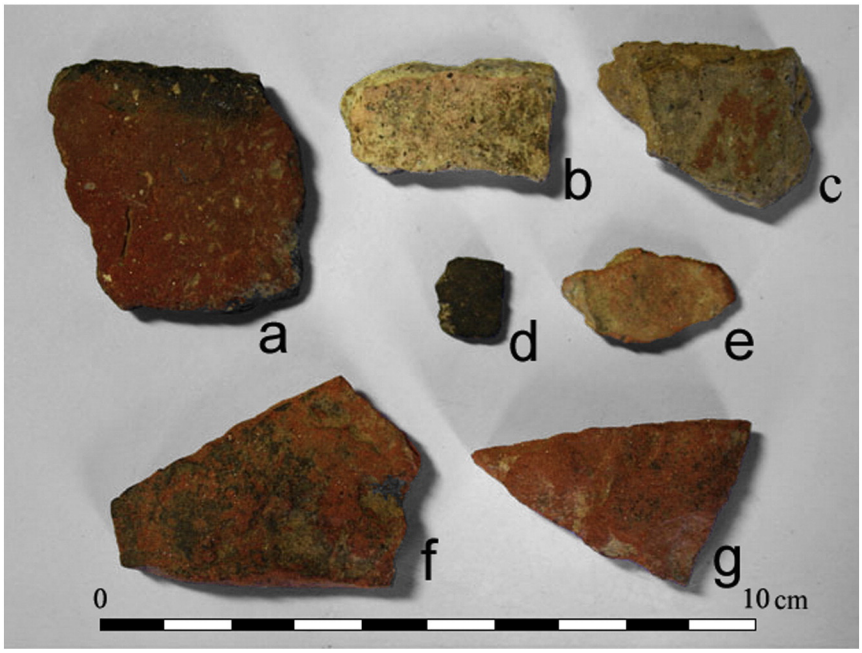

Fig. 11. Neolithic (b, c, e, f), Late Chalcolithic (d) and Early Bronze Age (a) pottery from the surface of Arvalya Höyük. (ERC Prehistoric Anatolia/photo: J. Traumüller).

The size of the tell sites can be estimated thanks to the drill cores: Çukuriçi Höyük had a maximum N–S extension of 200 m and E–W extension of 100 m, i.e. roughly 16,000 m^2, if a quasi-ellipsoidal shape is assumed. It is evident, however, that the maximum extent of the tell varied considerably for each settlement phase from the early 7th to the 3rd millennia BC. Taking all the results of Arvalya Höyük into account, a minimal N–S extension of 100 m and an E–W extension of 60 m can be estimated, with an overall quasi-ellipsoidal surface of at least 5000 m^2. However, it appears more likely that the settlement area was considerably larger, which could not be confirmed because no coring could be carried out further to the north and west. The declining topography seems to confirm this assumption (Fig. 3).

The inhabitants intentionally seem to have chosen the locations due to the advantageous topography in the early 7th millennium BC, located on small elevations (Çukuriçi Höyük 1–4 m, Arvalya Höyük c. 1–2 m above surface; Figs. 4, 10) at a distance of about 1.5–2 km from the coast, surrounded by alluvial plains. At Çukuriçi Höyük, the palaeosol underneath the tell site seems to represent the exposed land surface. It was not preserved in the environs of the tell. This may be explained by a strong modification of the environs of the site (e.g. by changing river channels and truncation).

During the time of occupation, several rivers flowed in the direct vicinity of the tell sites. The elevated terrain provided safety from the torrents. Today, there are river beds noticeable to the west of both mounds (Fig. 3). A multi-temporal study of aerial photographs and satellite images since the 1950s indicates that the torrential streams have changed their courses several times (Kurtze et al., 2012). It can be assumed that at one point the torrential streams flowed directly to the west and east of the tell sites. The diversity of the fluvial layers is the result of discharge fluctuations due to climate variations (e.g. rapid climate change of 8600–8000 BP in the Aegean region; Mayewski et al., 2004; Weninger et al., 2014) or seasonality on the one hand and lateral migration of the stream channels on the other.

From excavations at Çukuriçi Höyük it is known that agriculture was practised already from the Neolithic period on. This is also attested by finds of Cerealia-type pollen in a drill core in the swamps of Belevi. Although the swamps of Belevi are located up to 16 km to the east of the mounds and many pollen may originate from the hinterland, this archive is relatively untouched by human impact. 5% Ceralia-type pollen hint to agricultural activities although little is known about the hinterland and its settlements. Taking all the information into account, it is well probable that the Neolithic people at Arvalya Höyük also started to practise agriculture.

However, despite human impact in this early period, a natural vegetation cover with deciduous oaks on the surrounding slopes was still present during the time of occupation (Knipping et al., 2008). Thus, stronger human impact with stronger deforestation activities does not date back to the Neolithic period or the Bronze age.

6. Conclusion

The geoarchaeological study of early settlement sites in Western Anatolia reveal a colonisation of the Arvalya and Derbent valleys south of the Küçük Menderes graben by the early 7th millennium BC. Several different methods were used for reconstructing the palaeogeography of the coastal mounds Arvalya Höyük and Çukuriçi Höyük. Çukuriçi Höyük was larger than Arvalya Höyük (roughly 16,000 m^2 vs. 5000 m^2) with altogether more preserved settlement layers (8.50 m and 3.50 m, respectively). The study highlights that both sites were settled from the Neolithic period to the Bronze age. Detailed archaeological excavations at Çukuriçi Höyük provided valuable information about different settlement phases. Our multidisciplinary approach at Arvalya Höyük including geophysics, drill cores and archaeological survey together with diagnostic ceramics (partly random) and ^{14}C ages, yield preliminary promising results but requires further investigations to unravel the different phases of human occupation of the tell.

Both mounds lie upon small elevations surrounded by several river channels within fertile alluvial plains. In order to date and better understand the shift of the river channels, a more detailed study of these sediment archives is necessary.

Agricultural practise, attested for Çukuriçi Höyük, is also supported by finds of Cerealia-type pollen in a drill core in the swamps of Belevi. The similarities to Çukuriçi Höyük let assume that Arvalya Höyük also belonged to the archaeological group at the Aegean coast, that people practised agriculture and used the sea intensively. Only excavations can solve this assumption. However, it seems that they have been the perfect spots for first sedentary farming and herding villages. Although human impact is already detectable in this early period, a natural vegetation with deciduous oaks still dominated the landscape. However, a comparison between the swamps of Belevi with an archive from the

Fig. 12. Chert artefacts from the surface of Arvalya Höyük (flake cores, flakes and debris). (ERC Prehistoric Anatolia/photo: B. Milić).

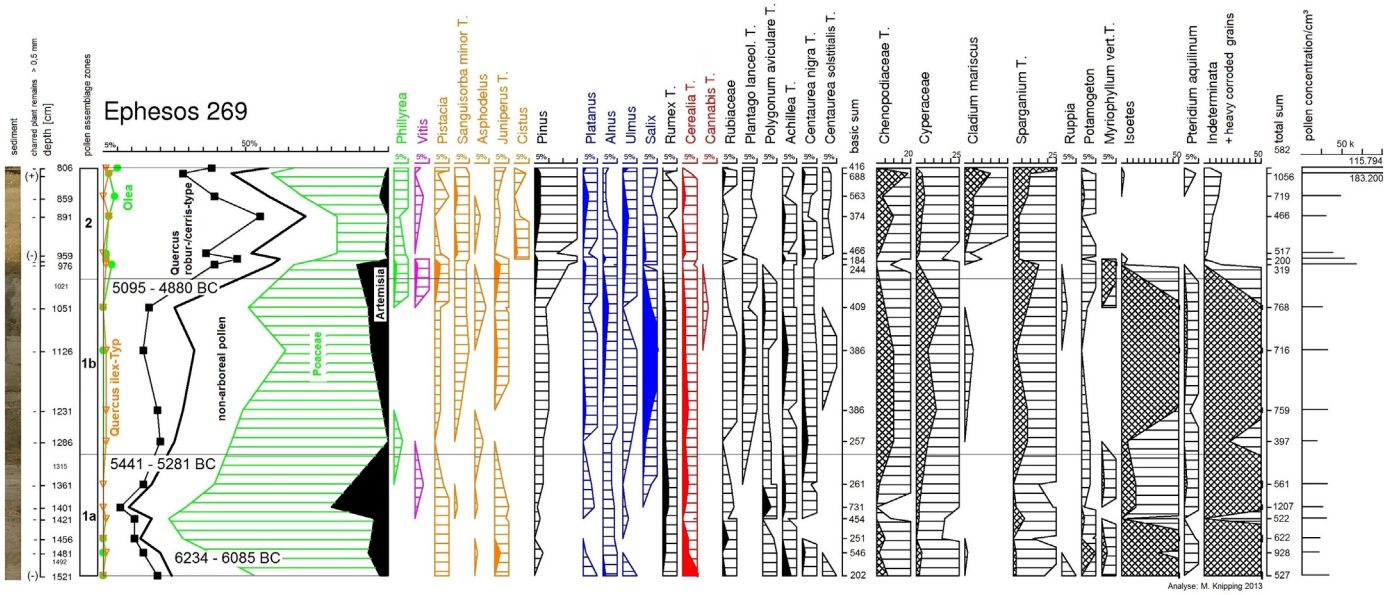

Fig. 13. Palynological analysis of the lower part of core Eph 269 from the swamps of Belevi. (Palynology: M. Knipping).

direct environs of the tell is necessary to gain a better understanding of the surrounding vegetation and the initiation of human impact on the landscape.

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