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THE FIRST LAKE-DWELLERS OF LITHUANIA: LATE BRONZE AGE PILE SETTLEMENTS ON LAKE LUOKESAS

Summary. Lake Luokesas in Lithuania has become the centre of attention in northern European wetland archaeological research after the discovery of two Late Bronze Age/Early Iron Age pile dwellings. Their unique location, chronology and building techniques have the potential to revolutionise our understanding of important aspects of wetland communities in later prehistoric Europe.

INTRODUCTION

The transition from Late Bronze Age to Iron Age (seventh–sixth century BC) is a critical period for wetland settlements in various parts of Europe. It is, in fact, within this time span that the long-lasting lake settlement tradition known as the ‘lake-dwelling phenomenon’ in the Alpine region started to disappear (Menotti 2001a). More than 3,600 years of occupation (although with periodic interruptions) around the numerous lakes of the Circum-Alpine area came to a close at the end of the seventh century BC. Although it has been possible to bridge some of the major occupational gaps within the Alpine lake village tradition (Menotti 2002, 2003a, 2004), the reason why they vanished completely before the Iron Age remains unknown. The mystery becomes even more intriguing because neither the climate (Magny 2004), nor other major aspects of culture and way of life underwent major changes at this time, which might have disrupted such an enduring tradition. An even more interesting observation is that wetland sites outside the Alpine region continued to be occupied well into the Iron Age – for instance Poggiomarino near Naples (Menotti 2003b), Biskupin in Poland (Kostrewski 1938; Coles and Coles 1989), Glastonbury in England (Coles and Minnitt 1995), the crannogs in Ireland and Scotland, and finally the various lacustrine settlements of the Masurian Lake region in Poland (see below).

The discovery of the Luokesas lacustrine settlements in western Lithuania has the potential to shed important light on the persistence of wetland occupation into the Iron Age, even though there was a long-term decline in their use, and their eventual disappearance seems to have been inevitable. The strategic geographical as well as chronological position of the Luokesas lake villages allows us to address crucial questions on climatic, environmental and cultural aspects of this transformation, which may have influenced patterns of human occupation within wetland communities of that period. These results will eventually be compared with changes in contemporary wetland sites in other parts of Europe to assess the balance between

environmental and social or cultural factors in this general trend. The final goal is to explain why people chose to become more and more 'terrestrial' as prehistoric times were coming to an end.

The paper explores past and current research into wetland sites in north-eastern Europe in order to set the Luokesas sites in a larger geographical context. The two Luokesas settlements are then considered in greater detail: from their discovery to the results of current excavations (which are still continuing), and also the results from some of the scientific analyses employed. A special emphasis is placed upon ^{14}C dating techniques and environmental investigations including micromorphology, in particular thin-sections of the lake sediments (see below).

WETLAND SITES IN THE EASTERN BALTIC REGION

Archaeological data obtained from wetland areas¹ play an important role in the overall understanding of prehistory in the eastern regions of the Baltic Sea. The typology of archaeological sites found in this kind of environment varies considerably according to their immediate environmental settings, in terms both of terrain and hydrology: wetland settlements can be constructed on stilts surrounded by water (either all year around, or only seasonally); or they can be built directly on the ground near the water (Menotti 2001b). In addition to sites formally recognised as settlements, there is also a great quantity of archaeological material from wetland environments in the Baltic regions, which consists of isolated and randomly collected artefacts, often with no precise excavation context.

Chronology and geography

The earliest wetland sites (mainly seasonal camps) in the eastern Baltic region date back to the Mesolithic (eighth–sixth millennium BC). There are quite a few artefacts from this period, but unfortunately a large number come from unknown locations. Probably the best-known Mesolithic site is found in the Kunda marshlands in northern Estonia. The site was discovered at the end of the nineteenth century and it has been re-excavated several times since (Indreko 1936; Hackens *et al.* 1996). The Kunda settlement gave its name to the Kunda culture, characterised by a wide usage of bone/antler weapons and implements. Sites belonging to the Kunda culture are known both in eastern Latvia (Loze 1988) and Lithuania.

The Neolithic period (fifth–third millennium BC) is represented by numerous, often well-investigated wetland sites. The beginning of the Neolithic in the eastern regions of the Baltic is defined by the start of pottery production, although the first farming societies only date back to the end of the fourth millennium BC. It is clear, though, that agriculturalists coexisted with foragers for many centuries, until 1800–1600 BC. Neolithic peat-bog sites are known over the whole of the eastern Baltic area, as well as in Belarus and Russia. The oldest known Neolithic site was discovered in Zedmar in the former East Prussia (Stadie 1921). Palynological work on this site carried out by H. Gross (1939) made a significant contribution to the general development of environmental studies in archaeology. Multidisciplinary investigations at Zedmar continued during the Soviet era (Doluchanov *et al.* 1975).

Neolithic wetland sites are also to be found in various other parts of the eastern Baltic regions. For instance, more than 40 sites were discovered in the Šventoji marshlands on the sea

1 By wetlands is meant those areas included within marshland, riverine and lacustrine environments.

coast of Lithuania (Rimantienė 1979, 1980, 1996a, 1996b). Coastal peat-bog sites were also discovered at Sarnate in Latvia (Vankina 1970). Areas with abundant Neolithic sites were investigated around Biržulis Lake in western Lithuania (Butrimas 1998), around Kretuonas Lake in eastern Lithuania (Girininkas 1980, 1984), in the Lubana Lake basin in eastern Latvia (Loze 1979, 1988), on the Onega Lake in eastern Estonia (Janits 1959), and in the upper part of the Daugava River in western Russia (Mikliajev 1969). Most of those sites belong to 'forest' Neolithic Narva, Comb and Pit ware cultures. The majority of Early to Middle Neolithic wetland sites represent seasonal (summer) fishing camps, built on naturally elevated areas subsequently covered in peat.

A new cultural aspect developed in the Late Neolithic (3200–2200 BC), with the appearance of agricultural societies of the Globular amphora, Rzucewo and Battle Axe cultures. These groups constructed dwellings on stilts in seasonally flooded swampy areas in order to control fishing resources. A large platform was erected above the water in the lagoon of Šventoji (Šventoji 6) in the first half of the third millennium BC (Rimantienė 1996b).

Sites on stilts (not necessarily settlements) were also constructed in the Early Bronze Age (2200–1750 BC), and a few are known from eastern Lithuania and Latvia. For example, a large platform with fish nets attached to it was built on a small river at Žemaitiškė 2 in east Lithuania (Girininkas 1980). Another Bronze Age dwelling on stilts is found at Kretuonas 1. In this case, houses were constructed on the lower part of a seasonally flooded terrace. More dwellings of this kind were also recorded in Abora and Lagaža in the Lubana Lake basin in eastern Latvia (Loze 1979).

The Early to Late Bronze Age periods from 1750 to 800 BC do not provide much evidence of wetland occupation, but many votive objects, hoards, isolated bronze artefacts and human sacrificial remains are found in various peat bogs.

'Proper' lake-dwellings

Until recently, the tradition of building lacustrine settlements in the conventional sense was believed to have begun around the fifth century BC. Lake-dwellings of this period were first discovered on the Masurian Lake region (former Eastern Prussia). More sites in the former Eastern Prussia were excavated by J. Heydeck on Lakes Arklity, Prab and Kok. He used the (at the time) innovative method of analysing cut-marks on wood, by reconstructing the character of the tools employed in cutting the wood, to establish the chronology of the settlements (Heydeck 1909). His work raised crucial points about the chronology of the Masurian lake-dwellings. So far, Polish archaeologists have discovered more than 50 lake-dwellings in that region and it is believed that they all belong to the west Baltic Barrow culture, i.e. to the Late Bronze Age/Early Iron Age (Okulicz, J. 1973; Okulicz, Ł. 1970, 1976). Recent investigations from a multidisciplinary perspective have shed new light on the chronology and the economic aspects of those lake-dwellers (Gackowski 2000).

Up until a decade or so ago, no other lacustrine sites were known in the eastern Baltic outside the Masurian Lake region. Only a few fragments of pottery, dating from the transitional period from the Bronze to Iron Age, were found in the Turlojiškė peat bog (Antanaitis 2001). The discovery of the Luokesas lake settlements thus not only expands the geographical area of this tradition, but it also shifts back the chronology to the eighth century BC. As a result, one may argue that the Bronze Age lake villages in north-eastern Europe developed much earlier, and were probably introduced from the East.

'Terrestrial' settlements

The Late Bronze Age–Early Iron Age transition in Lithuania is considered an uneventful period, with no great important economic or cultural changes (Grigalavičienė 1995). Two main cultural phenomena were characteristic of this time – the presence of the Brushed Pottery culture in east Lithuania and the west Baltic Barrow culture in the western part of the country. The Brushed Pottery culture is known mainly from investigations of the so-called ‘early hillforts’ – settlements situated on hills, though without visible fortifications. Today, more than 100 of such sites are recorded in Lithuania, and many more are known in the neighbouring countries of Latvia and Belarus. Early hillforts usually provide a large quantity of materials indicating long and intensive occupation. People lived in small wooden houses, with hearths made of stones. Ceramic production was very uniform – pots of several shapes with brushed surface dominated all the archaeological assemblages. Bronze was commonly worked in some settlements, whereas iron production is not recorded at all. The typical everyday objects of this culture were stone axes and bone/antler weapons. Very few graves are associated with this culture, by comparison with the relatively large number of settlements (Luchtanas 1992a).

The opposite situation is found in the western part of Lithuania, where graves are much more frequent than settlements in the first millennium BC. Graves of the Barrow culture are, in fact, fairly numerous near the Baltic coast. Barrows contain graves from different periods: the pre-Roman Iron Age graves, with cremations and iron artefacts dated from the La Tène period; cremations in urns, which is typical of the Sembian Peninsula Iron Age graves; and, finally, various inhumations accompanied by bronze artefacts common during that period. Several Urnfield culture graves have also been discovered in the central part of Lithuania, with Kernavė being the most important one (Luchtanas 1992b).

Generally, two main cultural units are observed in the eastern Baltic regions during the pre-Roman Iron Age: eastern Brushed Pottery cultures of early hillforts, and central/western cultures continuing Lusatian traditions. Lithuania appears to be on the border of those units, and this creates overlapping in the archaeological record. The Luokesas lake settlements will certainly provide a significant contribution for a better understanding of the period in question.

LAKE LUOKESAS SETTLEMENTS AND THE GEOGRAPHICAL CONTEXT

Location of the lake

Lake Luokesas is situated in a region forming the eastern part of Lithuania (Molėtai district) (Fig. 1), which is well known for its plentiful number of lakes all formed after the Last Glacial Maximum. The landscape morphology surrounding the lakes is quite hilly and the soil sandy and gravelly, with some boulders scattered around. Lake Luokesas is 2.4 km long, with a maximum width of 0.8 km and its undulated bottom reaches a maximum depth of 47.8 m. The lake has also two forest-covered islands (Baubonis 2000, 1–7). The surrounding landscape is undulating, with highlands covered in forest, and lowlands being mainly swamps. This swampy territory delineates the highest water-level reached by Lake Luokesas during the Atlantic period (8000–5000 BP), which existed before the first settlers established their settlements on the lake (Motuzaitė 2004a). On its eastern and southern sides, Lake Luokesas is connected with other lakes, which are reached through small channels. A very characteristic

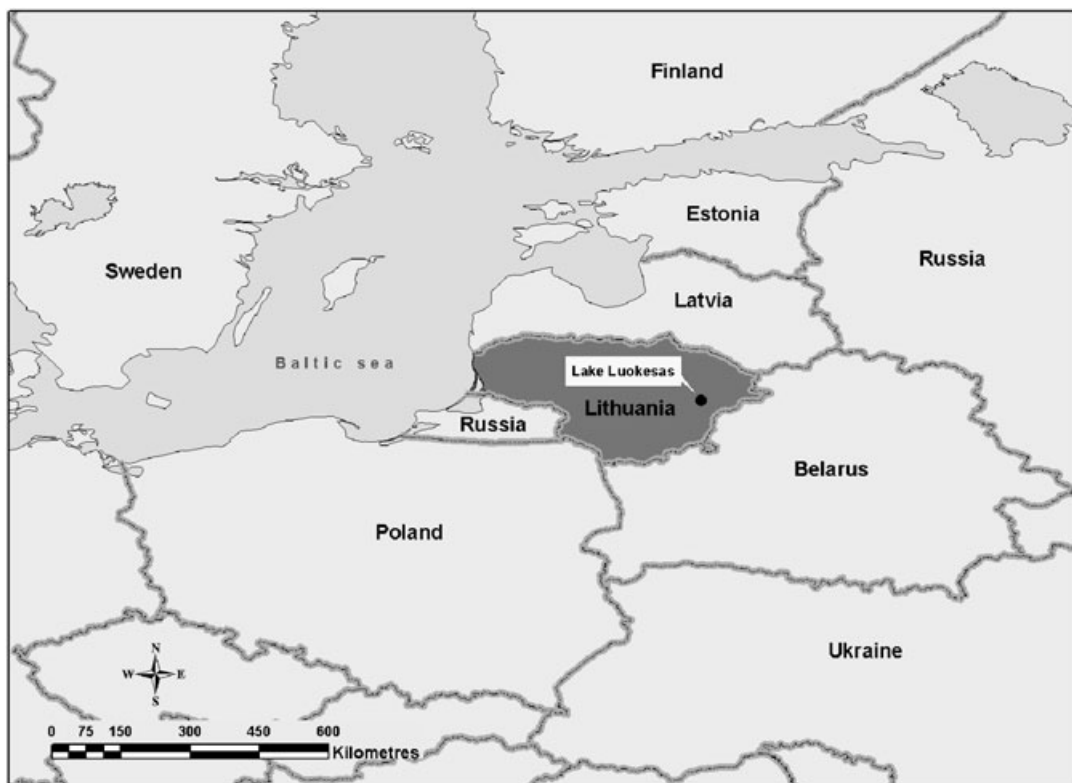


Figure 1
Map of north-eastern Europe.

feature of the lake is its set of distinct, widely extended morainic shoals. It is indeed on two of these shoals that the remains of the lacustrine settlements were discovered (Baubonis *et al.* 2002, 229–31).

Environmental context

The two pile settlements discovered on Lake Luokesas have been named as sites 1 and 2 and they are located opposite each other (Fig. 2). Site 1 is situated on a morainic shoal in the northern part of the lake. Site 2 is located in the southern part of Lake Luokesas, on a horn-shaped shoal, which extends from a peninsula-shaped shoreline towards north-east (Baubonis 2001, 1–7).

The water of the lake is fairly clear, with visibility extending up to 8 m. The depth at the shoals is between 110 cm and 190 cm, with steep drop-offs down to 10–15 m depth along their sides. A 12–20 cm layer of light lake sediments covers the bottom of the shoals and deeper down the lake bottom changes to a white smelly lake marl, with little freshwater shells. The cultural layers of the settlements start at a depth of 10–35 cm, but some piles, which were used to hold the buildings of the village, were driven down to 4.50 m into the soft lake marl overlying the morainic shoals (Baubonis 2002, 6).

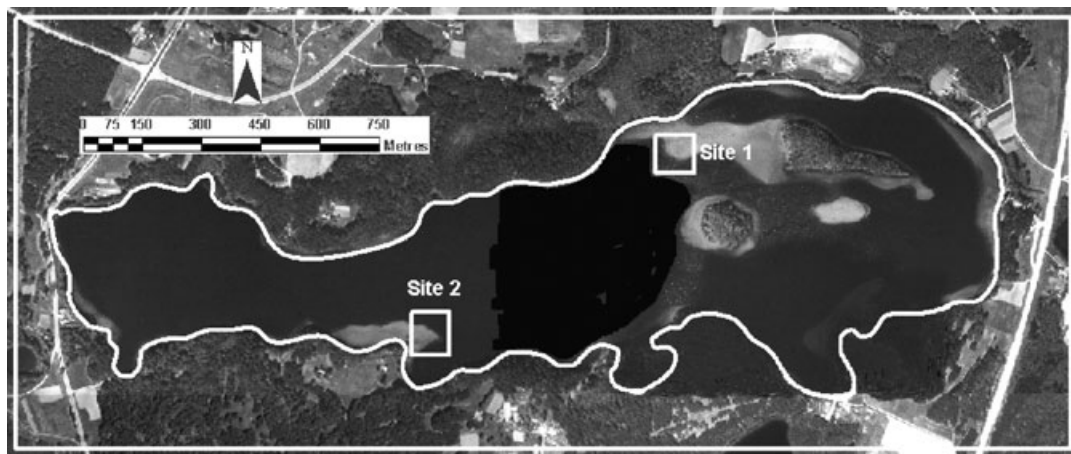


Figure 2

Lake Luokesas and the two lake-dwelling sites (base map obtained from the ortho-rectified aerial photograph from the Lithuanian geological survey database/archive 1990).

SURVEY AND DISCOVERY ON LITHUANIAN LAKES

Underwater investigations

Archaeological discovery of the first lake-dwelling in Lithuania came later than comparable finds in the territories of its immediate neighbours, Latvia and Poland, where investigations of such sites have been conducted for more than 30 years. This slowness was partly due to an academic scepticism in the prevailing archaeological tradition, and partly due to practical difficulties associated with underwater research (Kvedaravicius 1998).

A turning point occurred when, in their M.A. theses, Rokas Kraniauskas and Mantas Kvedaravicius (Vilnius University) suggested the possible presence of lacustrine dwellings in east Lithuania. Reconnaissance expeditions were begun by Zenonas Baubonis (Department of Cultural Heritage of the Republic of Lithuania) and, within the following three years, more than 20 lakes were surveyed, including Lake Luokesas, where ethnographic data pointed to a possible location of submerged wooden structures. The first two attempts to locate archaeological remains in this lake, including the underwater survey by a team from Torun University (Poland) in 1999, were unsuccessful. The perseverance of Kvedaravicius and his team was finally rewarded on 7 June, 2000, when, during one of the numerous attempts, they came across hundreds of vertical piles and horizontal wooden structures. They had just discovered a Late Bronze–Iron Age pile dwelling with a rich cultural layer consisting of hearths, organic remains, pottery and various other artefacts. The site lies at about 30m off the north-eastern shore of the lake at a present depth of 1.5–2m. The expedition continued in 2001, and further examination of the lake, carried out by Vilnius University students Giedre Motuzaite and Elena Pranckenaite, yielded more well-preserved piles and wooden structures in the southern part of the lake as well. A second site, with similar characteristics to the first, had been discovered! In 2003 the Lithuanian Cultural Heritage joined forces with a team from Oxford University and the Lake Luokesas project began.

The two sites were carefully surveyed to determine the perimeters of the settlements. Aerial photography facilitated the location of further structures of the villages, which were not visible from the ground. Both sites were mapped using various methods. In site 1, metal rods were placed next to each pile, making sure that they protruded above water, in order to create a visual impression of the site. In site 2, similarly, small buoys were attached to each pile to achieve the same result. Once the outline of the site was apparent, each pile's location and height were recorded using a total station and the data fed into a GIS system, for further elaboration.

Investigations around the lake

The astonishing discovery of the two settlements on Lake Luokesas induced the research team to expand the survey to the inland neighbouring areas. Various attempts to explore the surroundings of Lake Luokesas in search of contemporaneous inland settlements were made during the 2004 excavation season. Fifteen test pits of 1 × 1 m were excavated on lake peninsulas, hilltops, and islands on and close to the lake (Motuzaitė 2004b, 2). In one of the test pits located on a hill south of Lake Luokesas, a few ceramic sherds and a flint scraper were found. The hill, called by local people 'the hill of the witches', is one of the biggest hills in the area and its shape is reminiscent of that of a hillfort or a similar fortified settlement. Although no concrete evidence of prehistoric terrestrial settlements around the lake was found, we cannot reject the possibility of their existence until the area has been investigated more carefully.

EXCAVATION METHODS

The first underwater excavation of the Luokesas settlements started in the summer of 2002, and for that purpose the central part of site 1 was chosen. The reference grid (a metal 2 × 2 m square frame) was placed to include parts of an already visible wooden structure and a number of piles, with an orientation north–south. A water pump, powered by a petrol engine, was placed on a floating platform approximately 3 m from the excavation area, and a tube was lowered to the quadrangle. Water and sediments were vacuumed to the platform where they were subsequently sifted and sorted.

The excavation within the 2 × 2 m grid was carried out by removing a series of 10 cm-deep 1 × 1 m layers from top to bottom. The excavation was considered complete when the barren glacial deposits were reached. Each layer was drawn and photographed underwater and subsequently redrawn on 1 mm graph paper. All data were finally entered into an electronic database.

In the 2003 field season, three more 2 × 2 m areas were excavated, one in site 1 and two in site 2. In site 1, the 2 × 2 m grid was placed in a slightly off-centre position, in an area where hearthstones and various pottery fragments were previously found. The two 2 × 2 m grids in site 2 were placed outside the main wooden structures, and a new excavation technique called Plexiglas Caisson was introduced. A 2 × 2 Plexiglas caisson was sunk into the extremely soft lake bottom and excavated inside. Once the excavation was completed, the transparent four sides of the Plexiglas caisson allowed us to record the intact stratigraphy of the anthropogenic as well as the natural lacustrine deposits.

In 2004, the excavation season focused mainly upon site 2. Instead of the usual 2 × 2 m grid, a permanent 16 × 6 m quick-release scaffolding grid was constructed. The grid included part of a large wooden platform situated in the centre of the settlement. This relatively large

area was divided into a number of 2×2 m squares and excavated one by one using the above-mentioned techniques.

At the end of the field season, the underwater excavated area was covered with a synthetic blanket to protect the site from looting and erosion.

FINDINGS

Well-preserved Bronze Age–Early Iron Age artefacts are rather scarce in Lithuania. The uniqueness of Lake Luokesas settlements' findings lies not only in the fact that they belong to the first prehistoric pile dwelling ever discovered in this region, but also in their remarkable state of preservation. Artefact and building structure analyses of the Luokesas archaeological remains will allow us to shed some light on those wetland groups as well as make some comparative analyses with the more numerous, but less well-preserved, contemporaneous land settlements of Lithuania.

Site 1

The majority of wooden remains in site 1 consist of vertical piles (*c.*350) and scattered horizontal planks. The plan of the settlement consists of the central habitation area, together with a double fence around its northern and eastern sides (Fig. 3) (Baubonis *et al.* 2002).

Although only 4 sqm have been excavated so far, a number of artefacts were found lying on the bottom of the lake. Contrary to site 2, site 1 seems to have the characteristics of a typical lacustrine settlement. Amongst the large quantity of wooden material found on the site, a few fireplaces were found. Although the final distribution of them is yet to be established, they seem to be more concentrated in some areas than others.

In addition to a large number of pottery sherds (mostly scattered around on the bottom of the lake), an almost intact pot (Fig. 4), containing very well preserved hazelnuts, was found smashed on top of a burnt horizontal plank. The pot has been entirely reconstructed. Although we still do not know how much the surface of the pottery has been damaged by the water, the majority of it seems to belong to the local and contemporary Brushed Pottery type. Its composition is mainly clay and crushed granite (Baubonis 2003).

Three fragments of different stone axes (two of them found within the excavated area) have been recovered so far. With them was also found a unique unfinished wooden handle, belonging to one of the axes. Various other artefacts such as a wooden spoon (Fig. 5), an awl made of bone, unworked flints and a grinding stone were also found.

In addition to artefacts, the site has also yielded fragments of semi-burned animal bones and teeth belonging to pigs and cattle. So far, no bronze or other metal artefacts have been recovered from the settlement. One remarkable detail is that the majority of piles (all obtained from lopped trees) were driven more than 4 m in the lake marl. The surface of the piles was left as it was, without any burning treatment for better preservation (Baubonis 2004).

Site 2

Site 2 is substantially different from site 1, not only as far as contents are concerned, but also its plan (Baubonis *et al.* 2001). The pile distribution (about 300) shows a construction resembling a fairly large platform, linked to the shore with a long walkway (Fig. 6). The

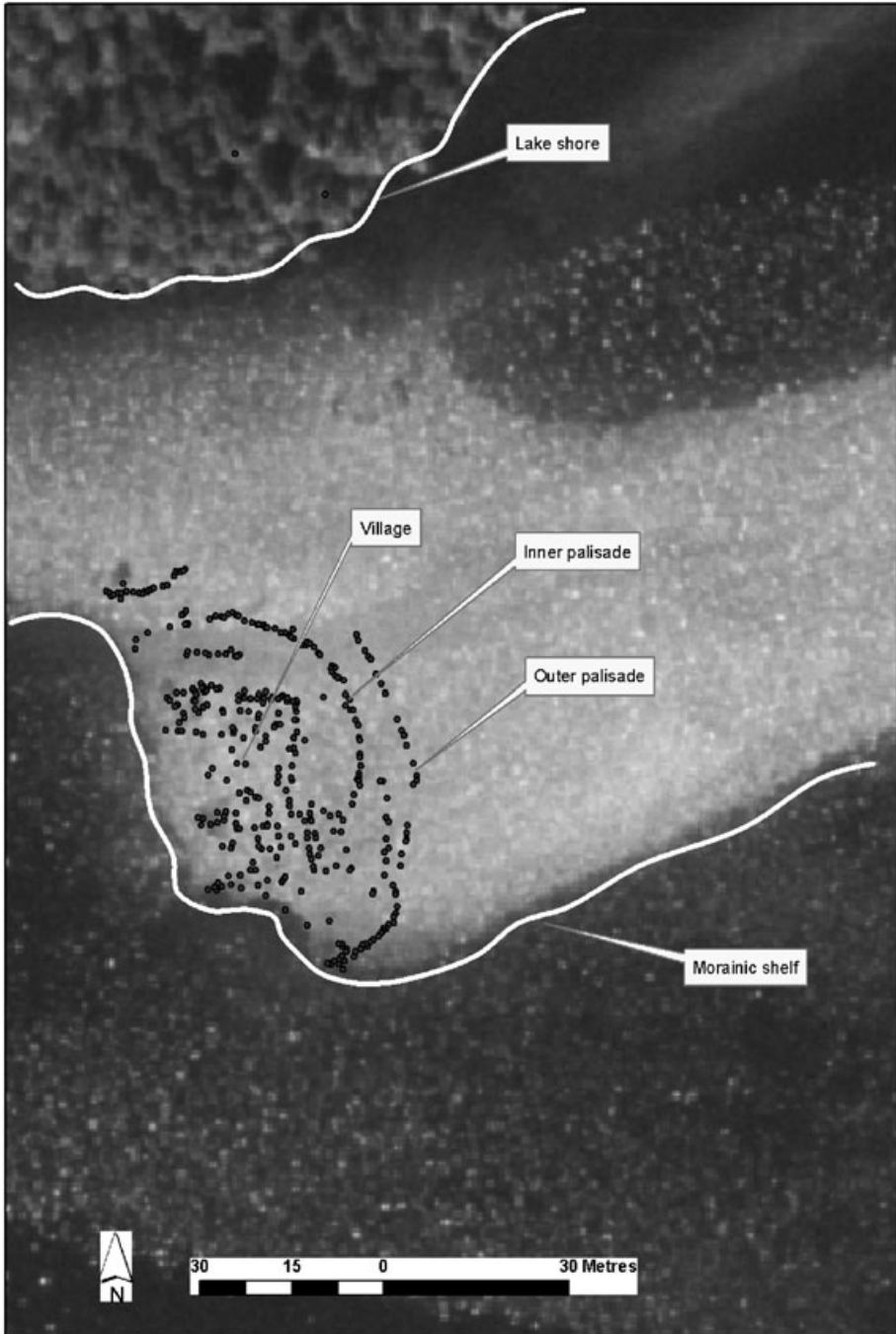


Figure 3

Site 1 on Lake Luokesas (base map obtained from the ortho-rectified aerial photograph from the Lithuanian geological survey database/archive 1990).

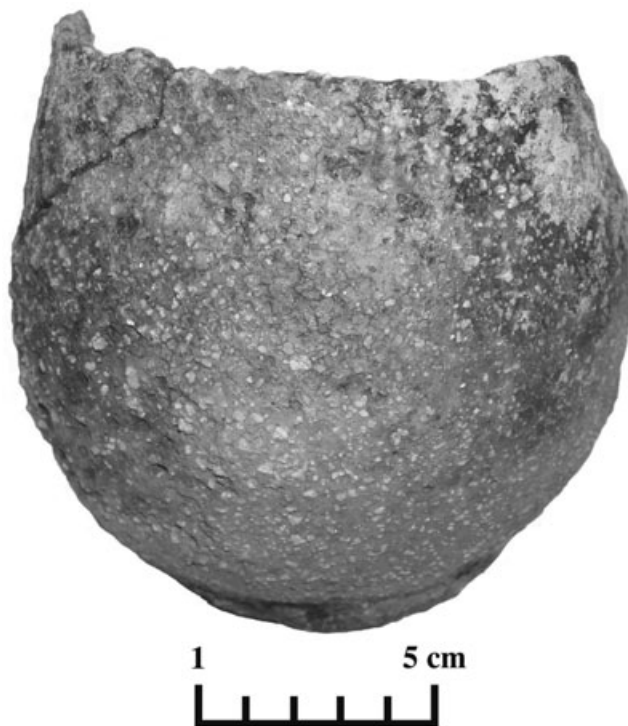


Figure 4
Almost entire pot found in site 1

72 sq m area excavated in 2004 exposed a considerably large part of the well-preserved platform (Fig. 7) with piles, cross-beams and worked planks still *in situ*, which reveal its elaborate method of construction. Because of the fairly large quantity of ashes lying around the area, site 2 also seems to have been set on fire before abandonment (Baubonis 2004).

The site also yielded a number of pottery fragments, which show similar characteristics to site 1, and indeed to some of the contemporaneous terrestrial settlements. An interesting discovery is that of a few 'exotic' pieces of pottery which seem to have been made by using a potter's wheel. Such a type of ceramic only appears in the region in the second half of the first millennium AD. There is therefore the possibility that the pottery comes from elsewhere in central Europe.

The two sites on Lake Luokesas are clearly different in construction and function. Site 1 is the classic pile dwelling of the type envisaged by F. Keller (Menotti 2001b), whereas site 2 looks more like a storage or trading post with a different construction. Further excavation and analyses of the site will reveal its exact function.

DATING AND SCIENTIFIC ANALYSES

Thirteen radiocarbon dates (C^{14}) have been obtained from both settlements so far: five from the Oxford Radiocarbon Accelerator Unit (see below); seven from the Laboratory of Radio-

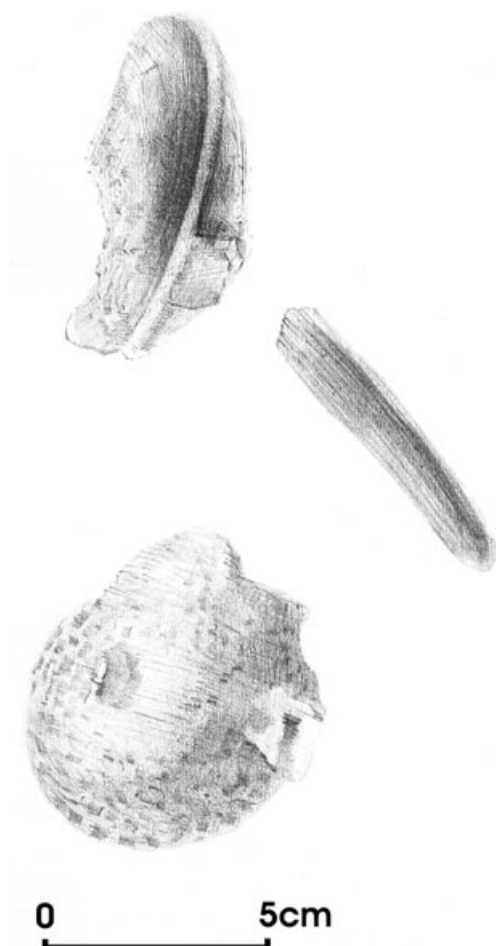


Figure 5
Wooden spoon found in site 1.

Isotopic Research at the Lithuanian Institute of Geology in Vilnius; and one from the Beta Analytic Radiocarbon Dating Laboratory in Florida, USA. All the dates except one show that both sites are contemporaneous, placing them within the end of the Late Bronze Age and the beginning of the Iron Age (eighth–fourth centuries BC).

A dendrochronological investigation of several of the timbers was undertaken by Daniel Miles and Michael Worthington of the RLAHA, but the number of rings per timber was insufficient to obtain reliable results. Nevertheless, a wiggle-matching dating method will subsequently be attempted to create an initial floating tree-ring sequence, in order to obtain more precise dates by fixing the timbers at specific positions on the calibration curve.

Stratigraphic analyses including thin-sections of underwater lacustrine deposits are being carried out by H. Lewis in collaboration with the McBurney Laboratory at Cambridge

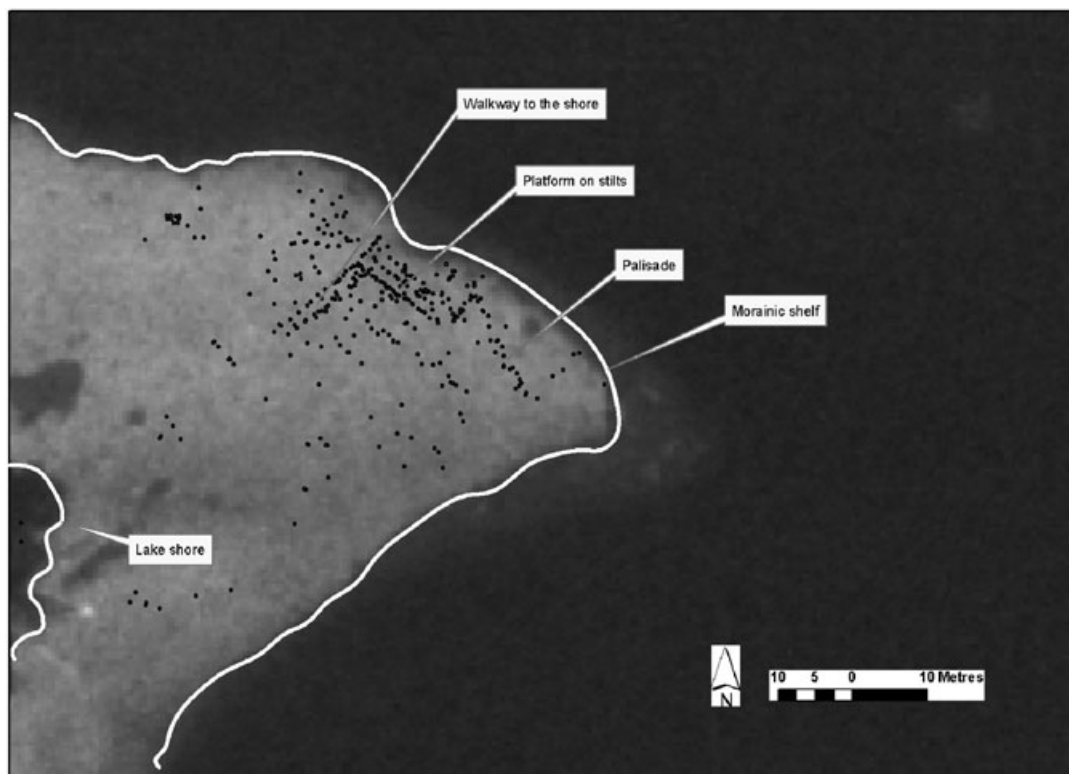


Figure 6

Site 2 on Lake Luokesas (base map obtained from the ortho-rectified aerial photograph from the Lithuanian geological survey database/archive 1990).

University (see below). Finally, pollen analyses are being completed by the Laboratory of the Geological Institute of Lithuania in Vilnius, in an attempt to reconstruct the palaeo-environment around Lake Luokesas.

RADIOCARBON DATING (C^{14})

As noted above, five samples of wood from the posts excavated in both sites at Lake Luokesas were submitted to the Oxford Radiocarbon Accelerator Unit (ORAU) at the University of Oxford. Three samples were taken from site 1 and two samples from site 2. The details of these samples are listed in Table 1. The aim of this admittedly small initial series was to explore the approximate temporal relationships between the various areas of both sites at Lake Luokesas. This is a preliminary study and we hope will mark the beginning of more dating analyses.



Figure 7
Underwater photograph of the platform found *in situ* in site 2.

TABLE 1
Samples selected for radiocarbon dating

Site 1:	Location in the site
Sample 1	Outer Fence L1 OF DS3
Sample 2	Inner Fence L1 IF DS2
Sample 3	Village L1 V DS3
Site 2:	
Sample 4	Platform L2 P DS8
Sample 5	Platform Fence L2 PF DS12

Method

Between 55 and 198 mg of wood was removed from the outer two to three tree-rings of each piece of wood to avoid ‘inbuilt age’² as much as possible. If the wood has been processed in any way, so as to remove exterior tree-rings, it is possible that the age obtained by radiocarbon dating would be too old.

2 The difference in age between the death of the sample and the archaeological event which is to be dated is defined as ‘inbuilt age’ (McFadgen 1982). In the case of wood, it is the combination of ‘growth age’ (the age of old wood in a tree) and ‘storage age’ (the time the tree was lying around before it was used) (McFadgen *et al.* 1994).

The wood samples were subjected to the usual treatment for wood. The samples were cleaned in an ultrasonic bath to remove soil and sediment detritus. They were then washed in 1 M HCl at 80°C for one hour and rinsed in distilled water. A solution of 0.2 M NaOH was then added to the wood samples. This was heated for one hour again at 80°C and then allowed to cool. The wood was again rinsed with water. Finally, the wood was given another acid wash followed by rinsing. The acid-base-acid insoluble fraction was then bleached. We used 5% w : vol sodium chlorite at pH3 and 80°C for one hour to bleach the wood samples. The resultant wood cellulose was then rinsed and dried.

Samples of between 5.0 and 7.2 mg of wood cellulose were combusted, and analysed using a Europa Scientific ANCA-MS system consisting of a 20-20 IR mass spectrometer interfaced to a Roboprep CHN sample converter unit operating in continuous flow mode, using an He carrier gas. This enables the measurement of $\delta^{13}\text{C}$ and carbon content, and C:N ratios and $\delta^{15}\text{N}$ if relevant. $\delta^{13}\text{C}$ values in this paper are reported with reference to VPDB. Graphite was prepared by reduction of CO_2 over an iron catalyst in an excess H_2 atmosphere at 560°C prior to AMS radiocarbon measurement (Bronk Ramsey and Hedges 1997; Bronk Ramsey *et al.* 2000). Radiocarbon dates given in Table 2 are reported in ^{14}C years BP using the Libby half-life after Stuiver and Polach (1977).

Calibration and interpretation

To enable the proper interpretation of these radiocarbon results it is necessary to convert them into sidereal years using a calibration curve constructed from precise radiocarbon measurements of dendro-dated wood (see Reimer *et al.* 2004). This is necessary due to the temporal fluctuation in the radiocarbon production rate. The radiocarbon results were calibrated using the OxCal 3.10 and the INTCAL04 calibration curve of Reimer *et al.* (2004). A section of this calibration curve is shown in Figure 8. Readers will note the flat section in the centre of the figure, which is known colloquially as the Iron Age plateau. Essentially this plateau makes precise dating on a calendrical timescale extremely difficult since the amount of radiocarbon in the atmosphere remained at a similar level between c.800 and 400 BC.

The age ranges obtained are given in Table 3 and shown in Figure 9. One can see how a date of 2450–2500 BP produces a wide calendrical range owing to the calibration plateau. Nevertheless, some very useful chronometric information has been forthcoming. The earliest date obtained came from the site 2 platform fence (OxA-14229). This result supports a calendar range of 815–790 BC. The precision is high because the result just pre-dates the plateau in the calibration curve. As mentioned earlier, we sampled only exterior wood to reduce potential inbuilt age effects and therefore we assume this to be a robust result. If we assume that all dates

TABLE 2
Radiocarbon dates of wood from the Lake Luokesas sites 1 and 2 (see Table 1 for details of provenance)

OxA number	Sample reference	$\delta^{13}\text{C}$	Radiocarbon age BP
OxA-14225	L1 OF DS3, wood	–24.4	2537 ± 26
OxA-14226	L1 IF DS2, wood	–27.9	2557 ± 27
OxA-14227	L1 V DS3, wood	–26.4	2345 ± 26
OxA-14228	L2 P DS8, wood	–28.3	2527 ± 27
OxA-14229	L2 PF DS12, wood	–26.3	2627 ± 26

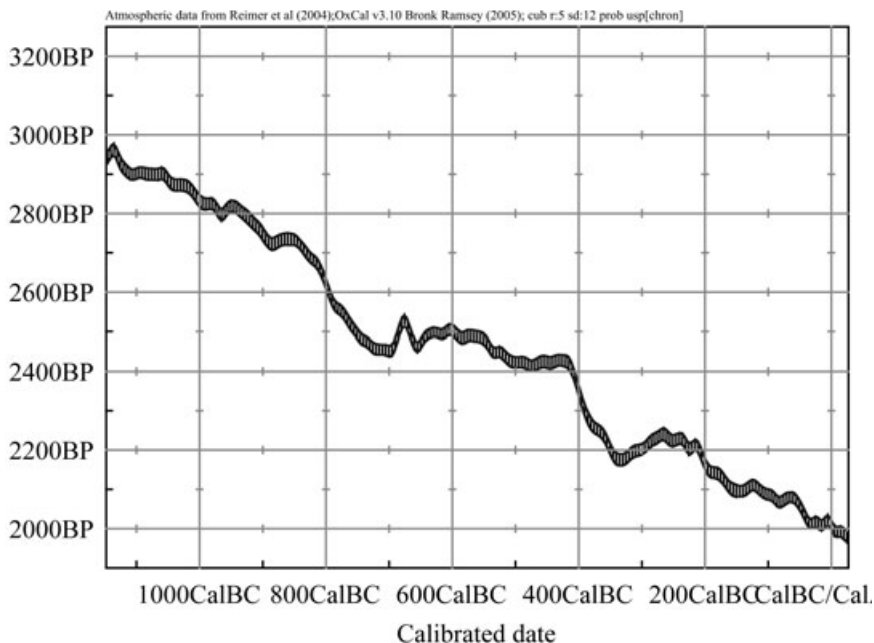


Figure 8

Section of the INTCAL04 calibration curve between 1800 and 3400 BP (Reimer *et al.* 2004). Note the plateau in the centre of the figure, which makes the calibration of radiocarbon years into calendar years imprecise. The fluctuations ('wiggles') in the calibration curve are caused by solar minima and maxima, which ameliorate cosmic rays impacting the Earth's upper atmosphere. The interaction of cosmic ray neutrons upon atoms of ^{14}N in the upper atmosphere results in the production of ^{14}C ; therefore the short-term changes in the concentration of ^{14}C reflect, in the main, variation in solar output and therefore constitute a palaeoclimate proxy.

TABLE 3
Calibrated age ranges at 68.2 and 95% confidence limits for the Lake Luokesas dates

OxA number	Cal BC range 68.2%		Cal BC range 95%	
	From	to	from	to
OxA-14225	-800	-590	-800	-540
OxA-14226	-800	-660	-810	-550
OxA-14227	-410	-385	-510	-370
OxA-14228	-790	-570	-790	-540
OxA-14229	-815	-790	-830	-775

are reliably dating the events in question then this date suggests very strongly that occupation at the sites on Lake Luokesas began by 800 BC. The other date from site 2 fell within the plateau and therefore produced a wide calendar range (790–570 BC at 68%). This range was mirrored at site 1 where dates for both inner and outer fence timbers produced identical results and consequently wide calendrical ranges. The final radiocarbon determination was from timber

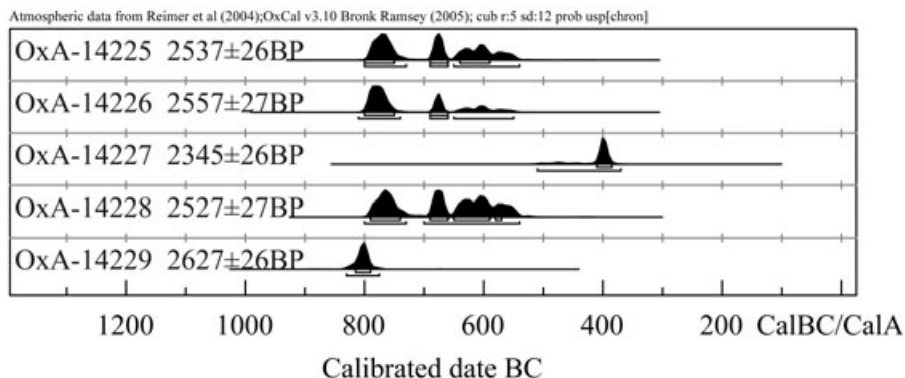


Figure 9

Calibrated age ranges for the Lake Luokesas radiocarbon dates. Figure generated using OxCal3.10 and the INTCAL04 calibration curve.

from the village area of site 1. This result suggests that occupation on the site lasted at least until the fourth century BC.

In addition to the five dates from the Oxford Radiocarbon Accelerator Unit, seven C^{14} dates from different samples were obtained from the Laboratory of Radio Isotopic Research at the Lithuanian Institute of Geology in Vilnius. Six dates show the same results (between eighth–fourth centuries BC). One date (coming from site 2), on the other hand, shows a much earlier occupation (3300 ± 60 BP, e.g. 1360–1240 BC Cal). If the date is confirmed with further analyses, we have two phases of occupation with an interval of more than 400 years. The only date (from site 1) coming from the Beta Analytic Radiocarbon Dating Laboratory in Florida, USA falls within the exact range of the majority (eighth–fourth centuries BC).

MICROMORPHOLOGY

Soil micromorphological studies of underwater sediments from prehistoric lake villages in central Europe have provided some interesting insights into the history of village construction and use, exploring issues of lake levels and location of dry land, the history of sedimentation, and use of space as represented by stratified micro-indicators (Wallace 2000a, 2000b, 2003). The Lake Luokesas settlements provide a useful opportunity to carry out similar studies on lake village sites in northern Europe, and, although these sites are later in date than those in the Alps, to compare the development, use of space, history and abandonment of these types of sites in another setting. There are several immediate issues which soil micromorphology can explore, especially in conjunction with sedimentary and palaeo-environmental studies, and with the ongoing programme of archaeological excavations. These include use of space, function and history of specific locations within the village site, as well as lake levels, proximity of dry land, local land use and the sedimentary record of the history of land use around the lake edge.

By taking core samples for study of intact remains at depth, we have the potential to extend the history of the site back beyond what is possible through excavation, and to create a more extensive spatial understanding, because cores can be taken in areas not seeing extensive (and expensive) excavation. In addition, cores provide a history of sedimentation in specific

locations, from which we can interpret what the site was like over time, and even what was happening on the land nearby.

Sampling

To see whether it was possible to obtain intact cores from the fine sediments in the lake bed, the 2004 field team took experimental samples by sinking short (<55 cm) drainage pipe tubes in three places on sites 1 and 2. Two cores were taken from site 1, one from within the known settlement area next to the lake bed drop-off (LI settle), and one from further to the north-east along the morainic shelf, in an area between major lines of posts (protective fences), near the edge of the settlement (LI BF). A single core was taken from site 2 (L2 S2), from an area to the east of the main settlement and excavation area.

These samples were sealed immediately, and brought to the McBurney Geoarchaeology Laboratory at Cambridge. They were successfully sliced in half through a delicate operation at the Geography Department Sediment Laboratory at Cambridge, by Steve Boreham and Julie Miller. The core samples were all intact (not slumped or disturbed), and contain interesting sedimentary sequences, which are described below and in Table 4.

Block sub-samples were taken from one half of each core for future soil micromorphology work, with the exception of one block (L1 Sett/7), which was retained by Steve Boreham for reference. The other core halves are stored in cool storage at the McBurney Laboratory for Geoarchaeology for further environmental sampling.

The cores

Sample LI BF consists of lake marl, with some variation, for an exposed 40 cm, underlying a series of fine layers of medium brown sandy silt, greyish-brown silty clay, a reddish coloured marly lens and a greyish-brown marl containing very fine charcoal (exposed in the upper 5 cm, from top of lake bed, i.e. lake bed-water interface). All of the layers in the sequence contain fine molluscs. The upper lenses are interesting, especially the slightly oxidised (reddish) lens at the top of the exposed sequence, the presence of relatively iron- and organic-rich layers ('brownish' colours), and the presence of charcoal. With the possible exception of these upper layers, there is little indication of cultural activity within the core deposits macroscopically, although some charcoal seen in the lower marls could provide information about the local landscape. However, there is potential for microscopic cultural inclusions, such as ash (see below), and the sequence will be interesting regarding the history of sedimentation. Four sub-samples were taken for soil micromorphology (L1 BF/1–4).

Sample L1 Settle is the most important core sample regarding the history of the lake shore and the location of the settlement. A depth of 20 cm of exposed lake marl underlies a sequence of organic deposits, including a probable peat profile. The base of this sequence is marked by a thin layer full of large fragments of charcoal and possibly uncharred wood, perhaps marking a collapse or destruction layer associated with a settlement platform. Above this is a highly organic and charcoal-rich peaty layer (presumably a transitional horizon), underlying a developed peat sequence. In this sequence, a possible change over time from peat and carr formation to reed bed or another type of 'watery' organic deposit may be represented (Steve Boreham, pers. comm.), presumably relating to the more recent submersion of the location under the lake. This entire sequence, including the basal charcoal layer, suggests that structures were

THE FIRST LAKE-DWELLERS OF LITHUANIA

TABLE 4
Core samples (sites 1 and 2)

L1 BF		
Depth (cm) from lake bed/water interface	Description	Block samples (see Figure 1)
0–1	Grey-brown marl, very fine charcoal, molluscs	L1 BF/4
1.1–1.5	Slightly reddish coloured marly lens	L1 BF/4
1.6–2.5	Greyish-brown silty clay, fine to medium-sized shell sand, molluscs	L1 BF/4
2.6–3.6	Medium brown very fine sandy silt, molluscs	L1 BF/4
3.7–12	Very light brown 'marl', shell sand and very rare fine charcoal, molluscs	L1 BF/3, L1 BF/4
13–21	'Clean' light yellowish-brown marl with some rooting, molluscs	L1 BF/2, possibly base L1 BF/3
22–26	Blotchy, light brown marl with roots, molluscs	L1 BF/2
27–45+	Relatively clean yellow marl, as above	L1 BF/1
L1 Settle		
Depth (cm) from lake bed/water interface	Description	Block samples (see Figure 1)
0–1.5	Coarse sand and rounded gravels	L1 Sett/6
1.6–9	Peat with woody fragments	L1 Sett/5, L1 Sett/6
9.1–10	Greyish-yellow sandy clay (in-washed?)	L1 Sett/5
10.1–19	Very dark brown peat with reddish-brown patches (<2 cm in size)	L1 Sett/4, L1 Sett/5
19.1–20	Reddish-brown lens	Possibly in base of L1 Sett/4
21–24	Very dark brown to black possible peat with charcoal	L1 Sett/3
25–27	Very dark grey gritty peaty layer	L1 Sett/3
28–32	Layer of burnt wood and possible peat	L1 Sett/2
32–52+	Yellowish-brown lake marl, molluscs (<0.3 cm)	L1 Sett/1, L1 Sett/2, L1 Sett/7
L2 S2		
Depth (cm) from lake bed/water interface	Description	Block samples (see Figure 1)
0–4	Grey silty clay with fine organic inclusions	L2 S2/5
5–11	Very light brown marl, some woody fragments	L2 S2/4, L2 S2/5
12–16	Yellowish-brown marl	L2 S2/3
17–21	Greyish-yellow marl with woody fragments and charcoal; possible ash	L2 S2/3
22–46+	Light yellowish-brown marl, occasional to rare woody (?root) fragments and very fine charcoal	L2 S2/1, L2 S2/2

either erected in the lake bed (in the water), or perhaps that piles were driven through at some stage in the overlying swampy land (not in permanent water – this theory is still to be confirmed by proper dating of the sediments). At one point within the peat sequence there is a lens of fine gravels and sands, which looks like in-washed material, possibly from further inland. The peat underlies coarse sand and rounded gravels. Six sub-samples were taken for soil micromorphology (L1 Sett/1–6), and one block of marl retained by Steve Boreham (L1 Sett/7).

The location of wooden (presumably construction) remains before or on a possible alder carr or peat deposit is reminiscent of Meare lake village in Britain. At Meare a 'watery' organic

deposit, representing rushes and reeds, was replaced by sphagnum and alder peat, with the earliest wooden buildings built onto this peat. The investigators suggested that the very substantial timber foundations seen there were needed to support house floors and prevent subsidence in the peat sediments. Further 'drying up' of the lake edge was seen, with the houses next having clay floors directly onto the earth (Bulleid 1948).

Sample L2 S2 is mainly composed of various lake marl layers, but with one interesting layer containing charcoal fragments and possible ash within this sequence. At its top there is a layer of grey silty clay with fine organic inclusions, which may also prove interesting in regard to lake settlement and/or lake-shore history. Five sub-samples were taken for soil micromorphology (L2 S2/1–5).

Further action and potential

The sub-sampled blocks will be impregnated with crystic resin through acetone replacement, cured until hard, sliced and ground to produce thin-sections following the methods outlined by Guilloché (1985) and Murphy (1986). The resulting thin-sections will be analysed following the approaches described in Bullock *et al.* (1985) and Stoops (2003). Given the early stages of this project, at present it is proposed that only three thin-sections are produced: one from the layer with possible 'ash' in core L2 S2, and two from the charcoal layer and peat sequence in core L1 Settle. These will target the deposits with the most obvious archaeological interest, and will enable the McBurney Laboratory to determine the best means for producing thin-sections from these lake-bed sediments. The remaining samples will be acetone-replaced and impregnated, cured and stored for thin-section production at the next stage of the project. The block of marl retained by Steve Boreham for reference will not be impregnated with resin, and will be available for other types of studies.

The remaining half-cores are in cold storage at the McBurney Laboratory. These should be sub-sampled from all contexts for a suite of comparative analyses. Basic sedimentary analyses (especially texture) will be useful for establishing depositional processes and origins of sedimentary material. Mollusc shells are seen throughout the sequence, and these remains should reflect specific local environments and/or the locations from which they have been in-washed (e.g. freshwater vs. swamp vs. dryland species). Archaeobotanical study of charcoal remains in all layers, but especially in the charcoal layer in L1 Settle, would obviously be interesting, and the history of the peat sequence would also be elucidated through this approach. It should be possible to sub-sample for pollen analyses as well, for comparison to regional pollen diagrams and any pollen work being carried out in the deeper deposits of Lake Luokesas. Before any of this sub-sampling begins, however, it would be useful to have an assessment for each of these (and any other) approaches from the intact half-cores.

CONCLUSIONS

The importance of Luokesas settlements is not only stressed by their remarkably well-preserved and significant contents, but their potential to solve environmental as well as cultural issues concerning patterns of human occupation of prehistoric wetland areas in northern and central Europe. Their chronology (c.800–400 BC) places them at the Late Bronze Age–Iron Age transitional period, exactly when an evident decrease in wetland sites was taking place in various parts of Europe. Initial micromorphological analyses on the sites' lake deposits have already

pointed out instability in the lake hydrological balance, due to a possible climatic variation. This prospect can only be fully confirmed with more palynologic analyses and a proper reconstruction of the palaeo-environment around the lake. Spatial analyses of the single habitations, the settlements and their catchment areas will certainly help us clarify important demographic and socio-economic aspects of those lacustrine groups. At this stage of the project, we can only state that the real potential of both sites will be confirmed by further investigation.

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