

Edited by:

**IVAN CHEBEN, MARTIN FURHOLT, KNUT RASSMANN, ALENA BISTAKOVA,
MARIA WUNDERLICH, NILS MÜLLER-SCHEESSEL**

ARCHAEOLOGY IN THE ŽITAVA VALLEY II

The Neolithic landscape of south-western Slovakia



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Preface by the series editors

With this book series, the Collaborative Research Centre *Scales of Transformation: Human-Environmental Interaction in Prehistoric and Archaic Societies* (CRC 1266) at Kiel University enables the bundled presentation of current research outcomes of the multiple aspects of socio-environmental transformations in ancient societies. As editors of this publication platform, we are pleased to be able to publish monographs with detailed basic data and comprehensive interpretations from different case studies and landscapes as well as the extensive output from numerous scientific meetings and international workshops.

The book series is dedicated to the fundamental research questions of CRC 1266, dealing with transformations on different temporal, spatial and social scales, here defined as processes leading to a substantial and enduring reorganization of socio-environmental interaction patterns. What are the substantial transformations that describe human development from 15,000 years ago to the beginning of the Common Era? How did interactions between the natural environment and human populations change over time? What role did humans play as cognitive actors trying to deal with changing social and environmental conditions? Which factors triggered the transformations that led to substantial societal and economic inequality?

The understanding of human practices within often intertwined social and environmental contexts is one of the most fundamental aspects of archaeological research. Moreover, in current debates, the dynamics and feedback involved in human-environmental relationships have become a major issue, particularly when looking at the detectable and sometimes devastating consequences of human interference with nature. Archaeology, with its long-term perspective on human societies and landscapes, is in the unique position to trace and link comparable phenomena in the past, to study human involvement with the natural environment, to investigate the impact of humans on nature, and to outline the consequences of environmental change on human societies. Modern interdisciplinary research enables us to reach beyond simplistic monocausal lines of explanation and overcome evolutionary perspectives. Looking at the period from 15,000 to 1 BCE, CRC 1266 takes a diachronic view in order to investigate transformations involved in the development of Late Pleistocene hunter-gatherers, horticulturalists, early agriculturalists, early metallurgists as well as early state societies, thus covering a wide array of societal formations and environmental conditions.

In this second volume on research in the Žitava Valley, whose sites are hold tremendous significance for European prehistory, the authors present detailed documentation and analyses from fieldwork in the region. The publication of the two volumes on the Žitava Valley represents something special for the CRC 1266. This

second volume presents the results of many years of fieldwork and excavations in the Žitava Valley, which represent one of the four major archaeological fieldwork projects of the CRC 1266.

The world of western Slovakia and, in particular, the site of Vráble, was opened up to us by Knut Rassmann (Romano-Germanic Commission (RGK), Frankfurt) and Josef Bátora (Slovak Academy of Sciences, Nitra), who pointed out the high potential of this research landscape very early on; both had begun fieldwork at the Early Bronze Age settlement of Vráble-Fidvár in the 1990s. Accordingly, the ‘International Course on ArchaeoGeophysics’ (INCA) summer school 2009 (EU Erasmus Intensive Programme, via the German Academic Exchange Service (DAAD)) was conducted there by, among others, researchers from Kiel, Bratislava (Roman Pašteka), Izmit (Şerif Barış) and Nitra (Josef Bátora). During the course, as part of the geophysical surveys carried out, Wolfgang Rabbel and Christoph Rinne documented parts of the *Linearbandkeramik* (Linear Pottery Culture, hereafter LBK) settlement geomagnetically for the first time. During the geomagnetic survey the first find of a Neolithic ceramic sherd was discovered at the site of Vráble-Velké Lehemby (Fig. 1).

As this survey revealed a new, larger, diachronic research perspective alongside the Early Bronze Age settlement of Vráble-Velké Lehemby, a research agenda was developed in collaboration with the Slovak Academy of Sciences in Nitra. On the German side, the RGK is responsible for the Early Bronze Age and the Roman Imperial Period, while the Institute of Prehistoric and Protohistoric Archaeology (UFG) at Kiel University is responsible for the Neolithic period. While the field research on the Bronze Age was financially supported by a DFG project led by Knut Rassmann (RGK Frankfurt) and Felix Bittmann (Wilhelmshaven) (‘The rise and decline of the central settlement of Fidvár near Vráble (Southwestern Slovakia) – Studies on the economy, social structure and political organization of a social unit within its wider surroundings’, 2011–2023), for the Kiel Institute the research was made possible through project C2 ‘The dynamics of settlement concentration processes and land-use in early farming communities in the north-western Carpathian Basin’ within the CRC 1266. The project leaders for this project were Martin Furholt (2016–2025) and Maria Wunderlich (2020–2025). The collaboration with the Slovak Academy of Sciences in Nitra was managed by Ivan Cheben. We would like to thank Ivan Cheben, Martin Furholt and Maria Wunderlich as the excavation directors on site, as well as all the participating scientists and staff for their excellent work.

The success of this research is evidenced by, among other things, the continuation of the work on site, ensured at Kiel University by the DFG projects ‘Excavation of a unique LBK mass burial in Vráble, SW-Slovakia and exploration of its social context’ (PIs Katharina Fuchs, Martin Furholt, 2023–2024) and ‘Interdisciplinary investigation of unusual body manipulations and depositional practices at the LBK settlement of Vráble Velke-Léhemby (5200–4950 BCE), south-west Slovakia’ (PIs



Figure 1. First find of a Neolithic ceramic sherd discovered at the site of Vráble-Velké Lehemby, recovered during geomagnetic survey. Photo: Wolfgang Rabbel.

Katharina Fuchs, Martin Furholt and Nils Müller-Scheeßel, in cooperation with Ivan Cheben, Zuzana Hukelová and Alena Bistáková, since 2025).

Further evidence of the successful work in the region is the presentation of the project results from the CRC 1266, subproject C2, in the two volumes on the Žitava Valley (of which this book is the second volume). Here, the important finds and features, as well as the scientific results, are presented, revealing the global significance of the Early Neolithic site of Vráble-Velké Lehemby. This lays the foundation for a joint, diachronic comparison, which will be possible once the results from the Early Bronze Age site of Vráble-Fidvár are published by the RGK, hopefully in the near future.

Wiebke Kirleis and Johannes Müller

Contents

Preface by the series editors	5
Preface by the directors of the involved institutes <i>Martin Furholt, Kerstin P. Hofmann, Matej Ruttkay</i>	11
Section 1: Introduction	
1.1 Introduction to the geographic setting and the archaeological research project in the Žitava Valley, south-western Slovakia <i>Martin Furholt, Ivan Cheben, Knut Rassmann, Nils Müller-Scheeßel</i>	15
Section 2: Spatial scales	
2.1 The geographic environment in the settlement area of the Linear Pottery culture and its limits to its adjacent regions <i>Fynn Wilkes</i>	23
2.2 Geophysical investigations at Úľany nad Žitavou and Vlkaš in the Žitava Valley, south-western Slovakia <i>Natalie Pickartz, Tina Wunderlich, Erica Corradini, Ercan Erkul, Diana Panning, Dennis Wilken, Martin Furholt, Wolfgang Rabbel</i>	33
2.3 Prospection results of the LBK and Želiezovce settlement sites in the Žitava Valley, south-western Slovakia <i>Bastian Breitenfeld</i>	49
Section 3: Social scales	
3.1 Built structures of the Early Neolithic in the Žitava Valley, south-western Slovakia <i>Robert Staniuk, Nils Müller-Scheeßel, Martin Furholt, Alena Bistáková, Ivan Cheben</i>	71
3.2 The pottery and ornamental styles of the Early Neolithic in the Žitava Valley, south-western Slovakia <i>Ivan Cheben, Alena Bistáková</i>	111

3.3 The animal remains from the LBK and Želiezovce Group settlement sites of Úľany nad Žitavou and Vlkaš, Žitava Valley, south-western Slovakia	161
<i>Rebekka Eckelmann, Nils Eberle</i>	
3.4 Availability and choice of plant resources at the LBK and Želiezovce settlement sites Úľany nad Žitavou and Vlkaš in the Žitava Valley, south-western Slovakia: Archaeobotanical and anthracological analyses	177
<i>Dragana Filipović, Tim M. Schroedter, Tanja Reiser, Wiebke Kirleis</i>	
3.5 Integrated plant and faunal stable isotopic analysis from the archaeozoological and archaeobotanical assemblages of the LBK and Želiezovce settlement sites Úľany nad Žitavou and Vlkaš in the Žitava Valley, south-western Slovakia	205
<i>Rosalind E. Gillis, Rebekka Eckelmann, Dragana Filipović</i>	
Section 4: Temporal scales	
4.1 Radiocarbon dates from the Early Neolithic settlement sites of Úľany nad Žitavou and Vlkaš, in the Žitava Valley, south-western Slovakia	221
<i>Nils Müller-Scheeßel, Robert Staniuk, John Meadows, Martin Furholt</i>	
4.2 The absolute dating of the Late LBK	233
<i>Tine Karck, Nils Müller-Scheeßel</i>	
Section 5: Integrating scales	
5.1 Simulating land use scenarios for the LBK and Želiezovce settlement site of Vráble	259
<i>Julian Laabs</i>	
5.2 Spatial modelling of LBK and Lengyel settlement territories: a new approach to understanding population dynamics, social structures, and exchange networks	279
<i>Sebastian Schultrich, Knut Rassmann, Kata Furholt, Martin Furholt</i>	
5.3 Prehistoric communities in the Upper Žitava Valley, south-western Slovakia: Integrating scales	305
<i>Maria Wunderlich, Ivan Cheben, Alena Bistáková, Martin Furholt, Nils Müller-Scheeßel, Robert Staniuk</i>	

Preface by the directors of the involved institutes

Martin Furholt, Kerstin P. Hofmann, Matej Ruttkay

This book is an outcome of more than 10 years of successful collegial collaboration between three research institutions, namely the Archeologický ústav (AÚ; Archaeological Institute) of the Slovenská akadémia vied (SAV; Slovakian Academy of Sciences); the Institut für Ur- und Frühgeschichte (Institute of Pre- and Protohistory) at the Christian-Albrechts-Universität zu Kiel (CAU); and the Römisch-Germanische Kommission (RGK; Romano-Germanic Commission) of the Deutsches Archäologisches Institut (DAI; German Archaeological Institute), and an interim collaboration with the University of Oslo, during the time project leader Martin Furholt worked there.

Our research on Neolithic settlement in the Žitava Valley commenced in 2012, after an invitation to join in the investigation of the Neolithic settlement at Vráble, which had been discovered by the team around Knut Rassmann (RGK) and Jozef Bátora (AÚ SAV), who worked at the Bronze Age site of Fidvár, near the present-day town of Vráble. It is due to their diachronic vision on the landscape-archaeological approach to the site of Vráble 'Fidvár' and the Žitava Valley, and to their generosity in supporting a new research initiative focusing on the Neolithic period, that Ivan Cheben and Martin Furholt were able to establish this project and, since 2016, obtain long-term funding from the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation), project number 290391021, Collaborative Research Centre 1266, 'Scales of Transformation', at the CAU. Subproject C2, 'The Dynamics of Settlement Concentration Processes and Land-use in Early Farming Communities of the Northwestern Carpathian Basin', continued 2020–2024 under the leadership of Maria Wunderlich, Martin Furholt and Hans-Rudolph Bork. In this regard, we especially thank the speakers of the CRC 1266, Johannes Müller and Wiebke Kirleis, for their support.

The research at the Neolithic settlement of Vráble 'Velké Lehemby' and 'Farské' was directly based on the magnetic plan generously provided to us by Knut Rassmann. Over time, the research team has grown, supplied by members of our three institutes. From AÚ SAV, Alena Bistáková and Zuzana Hukeľová, and from CAU Kiel, Maria Wunderlich and Katharina Fuchs, as well as Kata Furholt and Till Kühl, are now regularly taking part in the research. The project database was designed and programmed by Nils Müller-Scheeßel, who was able to build on his experience in

designing and programming a similar database for the Vráble 'Fidvár' project. Müller-Scheeßel, who for many years worked at the RGK, was part of the Vráble 'Fidvár' team and moved to CAU Kiel in 2016 to become an integral part and creative driving force of the Neolithic project, well exemplifies the productive relationship between our institutions. During field campaigns, there was a very fruitful collaboration and regular interaction between the excavation team and the survey team, as well as individual exchanges on research strategies and applied methods. As directors of our respective institutes, we also appreciate the support of former institute directors Johannes Müller (CRC 1266), Svend Hansen (RGK) and Eszter Bánffy (RGK).

This is already volume II of the Žitava Valley series, and like volume I, this book contains co-authored contributions from members of all three institutions. As the research is still ongoing, we look forward to further collaboration, more exciting research results and Volume III of the series.

Kiel, Frankfurt am Main, and Nitra, December 2023

Section 1: Introduction

1.1 Introduction to the geographic setting and the archaeological research project in the Žitava Valley, south-western Slovakia

*Martin Furholt, Ivan Cheben, Knut Rassmann,
Nils Müller-Scheeßel*

Introduction

This volume presents the results from our regional studies in the Upper Žitava Valley, south-western Slovakia. These were conducted in the context of our investigations at the Early Neolithic settlement site of Vráble ‘Veľké Lehemby’ and ‘Farské’, which were presented in volume I of this series (Furholt *et al.*, 2020a), and the Early and Middle Bronze Age settlement site of Vráble ‘Fidvár’, which will be presented in a forthcoming monograph.

It is remarkable to find two of the most outstanding settlement sites in the wider region in close proximity to each other, especially as there is no obvious explanation for the choice of this exact place. The Žitava is anything but an impressive river; the valley of the nearby river Nitra would have been the much more obvious choice for settlement. The Kováčovský potok, a creek that flows down into the Žitava from the east, through an east–west-oriented valley, is one of a series of similar creeks (see Fig. 1.1.1). The soil along this creek is fertile, but so is the soil over the entire Žitava Valley. However, this specific spot, located just to the south of the modern town of Vráble, attracted settlement concentrations during several periods in prehistory. First, there is the Early Neolithic *Linearbandkeramik* (LBK; Linear Pottery) and Želiezovce group site in the fields known as Veľké Lehemby and Farské, where several hundred people lived together in three spatially separated neighbourhoods within the same village for about 300 years, from 5250 to 4950 BCE. This is about 100 years after the initial colonisation of the Žitava Valley. After the settlement was abandoned, a few houses of the Lengyel period were erected 500 m to the south. During the Middle Copper Age (Baden period; 3600–2900 BCE), settlement first occurs at ‘Fidvár’, just to the east of the old Neolithic site, whose remains by that time would not have been visible anymore. This settlement could have been the predecessor of a more durable

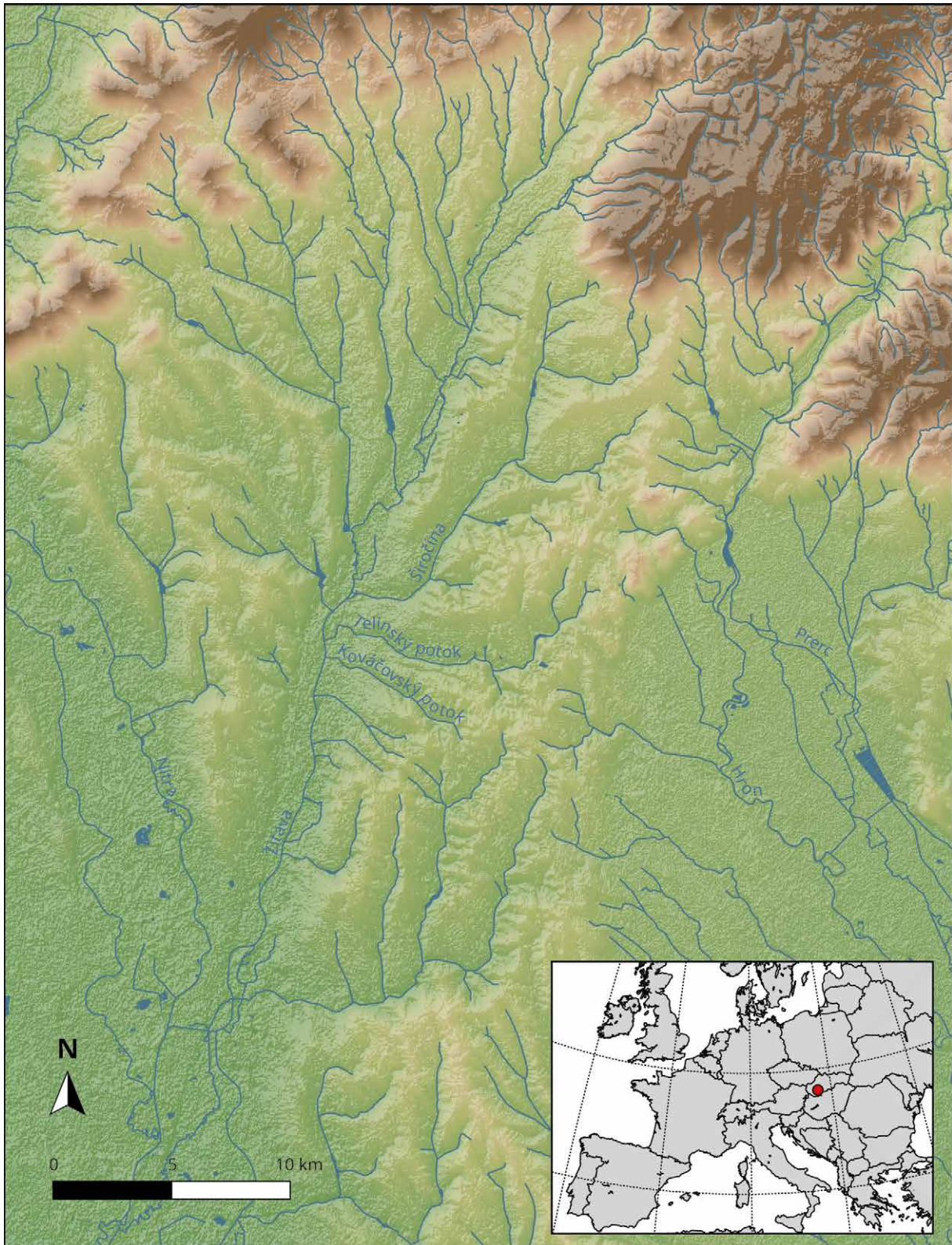


Figure 1.1. Location of the Žitava Valley, in south-western Slovakia, and the main rivers and creeks.

and massive agglomeration which took off in the Early Bronze Age (2300–1800 BCE) and reached its peak in the Middle Bronze Age (1800–1200 BCE). Another 1000 years later, the place was used to erect several (two or three) Roman military camps, most probably during the Marcomannic wars, between 166 and 180 CE.

This repeated focus on this specific area, especially in the form of the Neolithic and the Bronze Age settlements, sparked the idea to broaden the focus of research chronologically. The research on Bronze Age settlement at Vráble had been going on since 2007, in a cooperation between the RGK, represented by Knut Rassmann, and the AÚ SAV, represented by Josef Bátora. After the discovery of the Neolithic and Roman settlement remains to the east of the Bronze Age site, in 2008–2010, Martin Furholt, of Kiel University, and Ivan Cheben, of the AÚ SAV, started to investigate the Neolithic site of Vráble ‘Veľké Lehemby’ and ‘Farské’, in 2012 and 2013, respectively. The work on the Neolithic site, published in *Archaeology in the Žitava Valley I* (Furholt *et al.*, 2020a), was accompanied from the outset by an interest in the regional perspective on Neolithic settlement. In the spring of 2014, a regional survey was conducted in order to check the direct surroundings of Vráble for more settlement traces. This was done in cooperation with the Bronze Age research team, who at the same time surveyed the Žitava Valley for Bronze Age sites. In the course of this 2014 survey, a Neolithic site with Želiezovce group pottery was identified close to a previously unknown Bronze Age fortified site north of the village of Hul. In 2017 and 2018, two spring campaigns and one summer campaign were dedicated to a systematic survey of Neolithic settlement in the Upper Žitava Valley and its tributaries.

Geography

The Žitavská pahorkatina uplands (Fig. 1.1.1) form a landscape subunit in the central part of the Danube Uplands and together with the Žitava floodplain represent a clearly defined geographical area. This is a type of lowland landscape with cultural steppe to forest-steppe, in which highly productive arable lands occur. In the western and northern parts, the Žitava Uplands are delimited by the Trábeč mountains, which are also the watershed of both the Nitra and the Žitava. On the north-eastern side they are delimited by the Pohronský Inovec mountains, in which the Žitava originates. Along the eastern and part of the south-eastern edge of the upland stretches the Žitava floodplain, which is separated from the basin of the river Hron by the Hronská pahorkatina uplands – its western slopes slope down to the stream Širočina and the Žitava. A substantial part of the settlements of the LBK to Lengyel culture are situated on the left (eastern) side of the Žitava, including its left-bank tributaries, which are located along the western edge of the Hronská pahorkatina uplands. The Žitava floodplain, with its flat relief and altitude in the range of 130–220 m, is 37 km long and 1 to 3 km wide. In the southwest, the Žitavská pahorkatina upland borders the Nitra floodplain, and in the south, its border is formed by the hills of the Nitrianska tabuľa, which gradually passes into the Danube plain (Kočícký and Ivanič, 2011). This is the area in which most of the activities of the project that are focused on settlement patterns of the oldest Neolithic communities are carried out (Furholt *et al.*, 2020a).

The Žitava, whose length of flow is almost 100 km and whose basin area occupies 1244 km², flows in SSW direction from the north-western slopes of Pohronský Inovec. Today it is a river of the IVth order, and it is a left tributary of the River Nitra, into which it flows south of the village of Martovce. It is an upland-lowland type of river with a wide river floodplain (www.svp.sk). In the upper part of its course, the Žitava flows through the Žitava floodplain, where it takes on numerous right-hand tributaries of branched streams of the Vth to VIIth orders flowing through the Žitava Uplands, which is divided into small ridges by valleys. In the northern part of the

upland, the longest tributaries include Hostiansky potok, Slažiansky potok, Čerešňový potok, Drevenica and Bocegaj. In the southern part, which is significantly narrower, the Lúžtek stream is the most prominent of the right-hand tributaries. The situation is different on the left bank, where there is a significantly less branched network of streams that flow into the river from the Hronská pahorkatina. The longest tributary of the northern part of the Žitava is the Širočina stream, which together with its tributaries strongly resembles the territory through which the Žitava flows. In the southern part of the upland, three tributaries flow near Vráble – Telinský potok, Kováčovský potok and Melecký potok. Between the villages of Žitavce and Veľká Maňa, parts of the original, meandering riverbed of the Žitava (known as Stará Žitava; stará = old river) are preserved. Near the village of Hul, on the border of the Žitava and Nitra floodplains, the Žitava stream Liska takes over, which is the last in this part of its flow.

The Žitava was connected to the Nitra by a new riverbed in the cadastre of the village of Dolný Ohaj. The Stará flows through the Danube plain in a southerly direction, and below Martovce it flows into Stará Nitra. At the same time, it is connected by a canal to its old, original riverbed, which flows at Patince, where it flowed into the Danube in the past.

Research aims

Our overall research interest is directed towards the question of the socio-economic and political conditions and consequences of early population concentration. We are especially interested in the question whether or not the social innovation of concentrated village life is associated with social cohesion of the village population and to what extent there are socially autonomous subunits, such as households, neighbourhoods, lineages, and how such subunits relate to each other (see Furholt *et al.*, 2020b). Do social group boundaries become stable or do they remain fluid, with people coming and going, as it is for example found at nearby Vedrovice (Zvelebil *et al.*, 2013)? These questions are connected to the question of political organisation, as is expressed in, among others, local and regional centralisation. Differences in the overall settlement layout between Neolithic Vráble and Bronze Age Vráble seem to indicate clear differences in centralisation. Bronze Age Vráble shows a centralised outlay, with an elevated tell settlement, later successively marked by three concentric ditches, and surrounding flat settlements, with more regularly spaced house rows. Storage pits are concentrated in one area, indicating central control of material resources. In contrast, Neolithic Vráble is organised in three carbon-copy-like neighbourhoods, placed beside each other, something that would correspond well to some form of segmental organisation. Storage pits are spread out over the settlement and are thus more likely associated with individual houses. As discussed in Chapter 6.3 of Volume I (Furholt *et al.*, 2020a), we infer rising internal tension between the neighbourhoods over time, culminating in the construction of a ditch system around one neighbourhood, which blocks contact with the other two settlement parts. Burials associated with that ditch system indicate the existence of different categories of people, at least when it comes to the manner of their deposition. These indications of internal conflict and social inequality coincide with the steady, maybe rapid decline in population numbers (house numbers) in Neolithic Vráble. This can be interpreted in several ways. We have proposed an internal structural tension between household autonomy and village solidarity, in which concentration of wealth in certain individuals and resulting social inequality was incompatible with the idea of concentrated co-habitation in a situation where people have ample possibilities to evade such a system via social fission (Furholt *et al.*, 2020a; 2020b).

Our main research questions for our regional surveys sprang from our work on the Vráble sites. We were mostly interested in placing Vráble into its regional

context, thus assessing the first arrival of Neolithic settlers in the region, as well as the dynamics of settlement over time. First, we wanted to know to what extent the agglomeration of settlement at Vrábľe represented an overall regional trend of demographic growth or, instead, a process of regional centralization, *i.e.* we wanted to know whether Vrábľe grew because people relocated from neighbouring settlements, or whether the population density increased overall, either via people moving in from the outside or via high birth rates. Second, we wanted to study the properties of the regional social networks, by assessing the similarities and differences in material culture, especially pottery decoration styles and lithic raw materials, between sites. Third, we were interested in comparing subsistence strategies, in order to assess to what degree the spatially concentrated and integrated plant cultivation and animal husbandry regime which took advantage of manure on areas close to the site, as documented for Neolithic Vrábľe (Gillis *et al.*, 2020), was exceptional or, instead, the norm in this region. The assessment of this early Neolithic regional system would then provide the basis for our fourth research interest, a diachronic comparison of regional settlement systems between the Early Neolithic and the Early Bronze Age, especially in terms of the degree of centralization.

Methodological approach

When it comes to the LBK period, under the particular conditions of the Žitava Valley, houses – or, more precisely, the pairs of lateral long pits accompanying houses – can be easily detected through geophysical survey. Although the pits found through survey of course indicate only a minimum number of houses, our work at Vrábľe does strongly suggest that they are a good estimate of real house numbers. This means that we are able to come close to an estimate of the number of houses in the entire region. We thus have a chance to better understand how many settlements are contemporary with the Vrábľe LBK site, their size and their occupation density (using the proxy number of houses). An assessment of the chronological sequence should allow us to reconstruct the regional settlement dynamics, as we preliminarily presented in Chapter 6.1 of Volume I (Furholt *et al.*, 2020a). The analyses of the archaeological materials, including animal bones and plant remains, in conjunction with stable isotope analyses, provide the basis for a reconstruction of the subsistence economies.

We started out from the sites registered in the archives of the Archeologický ústav (AU; Archaeological Institute) of the Slovenská akadémia vied (SAV; Slovakian Academy of Sciences), in Nitra, and in the literature. Here, we especially relied on Peter Tóth's work on the prehistoric settlements in south-western Slovakia (Tóth, 2010) and on the work of Monika Gabulová (2015), and we also tested sites on which the local peasants or hobbyist archaeological fieldworkers had mentioned finding Neolithic material. The first step was to locate a potential site and to verify the presence of prehistoric and, if possible, Neolithic materials on the freshly ploughed surface. The verified sites were then subjected to systematic surveys, which involved, ideally, systematic field walking and registration of grid coordinates of prehistoric materials by GPS; collection of diagnostic pieces; drone-based aerial photography and 3D-modelling; and geophysical prospection. The latter three activities were organised in collaboration with the Geophysical Department of Kiel University and subproject G2 of the *Deutsche Forschungsgemeinschaft* (DFG; German Research Foundation), project number 290391021, Collaborative Research Centre (CRC) 1266, which added a broad array of more sophisticated methodological approaches to our own 2D-magnetic prospection (see Chapter 2.2). The more systematic prospection activities were subject to permission by the landowner to walk on the field or to use a geomagnetic device, to limits on the accessibility of specific fields due to sowing schedules, and to time constraints. The archaeological finds from the surveys were

assessed and analysed by Bastian Breitenfeld, in the course of his MA thesis. In the summer of 2018, we conducted small-scale excavations at two of the prospected sites, Vlkaš and Úľany nad Žitavou. Features and stratigraphy from these excavations are presented elsewhere in this volume, by Robert Staniuk *et al.* The typology of pottery from these sites and the entire working region are described and discussed by Ivan Cheben and Alena Bistáková. Animal bones were analysed by Rebekka Eckelmann and Nils Eberle, plant remains were determined by Dragana Filipović *et al.*, and stable isotope analyses on plants and animal bones were conducted by Rosalind Gillis *et al.* and presented elsewhere in this volume. The ^{14}C dates obtained during our excavations are discussed by Nils Müller-Schneeßel *et al.* Tine Karck and Nils Müller-Schneeßel discuss the ^{14}C chronology of the LBK in our study region and its wider geographical context. A methodological essay to model and identify settlement territories is presented by Sebastian Schultrich, Knut Rassmann, Kata Furholt and Martin Furholt. A concluding synthesis and social anthropological analysis are provided by Maria Wunderlich *et al.*

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Section 2: Spatial scales

2.1 The geographic environment in the settlement area of the Linear Pottery culture and its limits to its adjacent regions

Fynn Wilkes

Abstract

Settlements of the Linear Pottery culture (LBK, after the German *Linearbandkeramik*) are distributed over wide areas of central Europe. Over the decades, several regional studies on the LBK have outlined the environmental factors of temperature, precipitation and soil. The first part of this paper presents analyses of data of 443 LBK settlements all over Europe and shows the wide range of environments occupied, with a special focus on the presence of loess. The second part looks more generally at the area of LBK occupation and compares its environment to that of the neighbouring regions, to show which environmental factors limited the spread of LBK settlements into the adjacent areas of northern, southern and eastern Europe.

Keywords: LBK, Central Europe, settlement area, environmental preferences

Introduction

The LBK is one of the archaeological cultures in Europe with the largest distribution. From the Hungarian Plain to the Paris Basin and from the Harz Mountains to Lake Balaton (Lüning, 2000; Bogucki, 2001), it crosses many different geographic environments. Especially with regard to the agricultural economy of the LBK (Schier, 2015), environmental factors can be seen as a central variable in the selection of the settlement location, as these factors limit economic usage (Jankuhn, 1977; Herrmann, 2016). The main environmental factors usually considered in LBK research are precipitation (Sielmann, 1971; Linke, 1976; Sabel, 1983; Kreuz, 1990; Nagy *et al.*, 2014); temperature (Sielmann, 1972; 1976; Sabel, 1983; Kreuz, 1990; Hedges *et al.*, 2013); elevation (Biermann, 2001); and, most importantly, soil (Sabel, 1983; Kreuz, 1990; Bogucki and Grygiel, 1993; Milisauskas, 2001; Saile and Lorz, 2003; Bakels, 2009; Dębiec and Saile, 2015). While most site monographs contain a

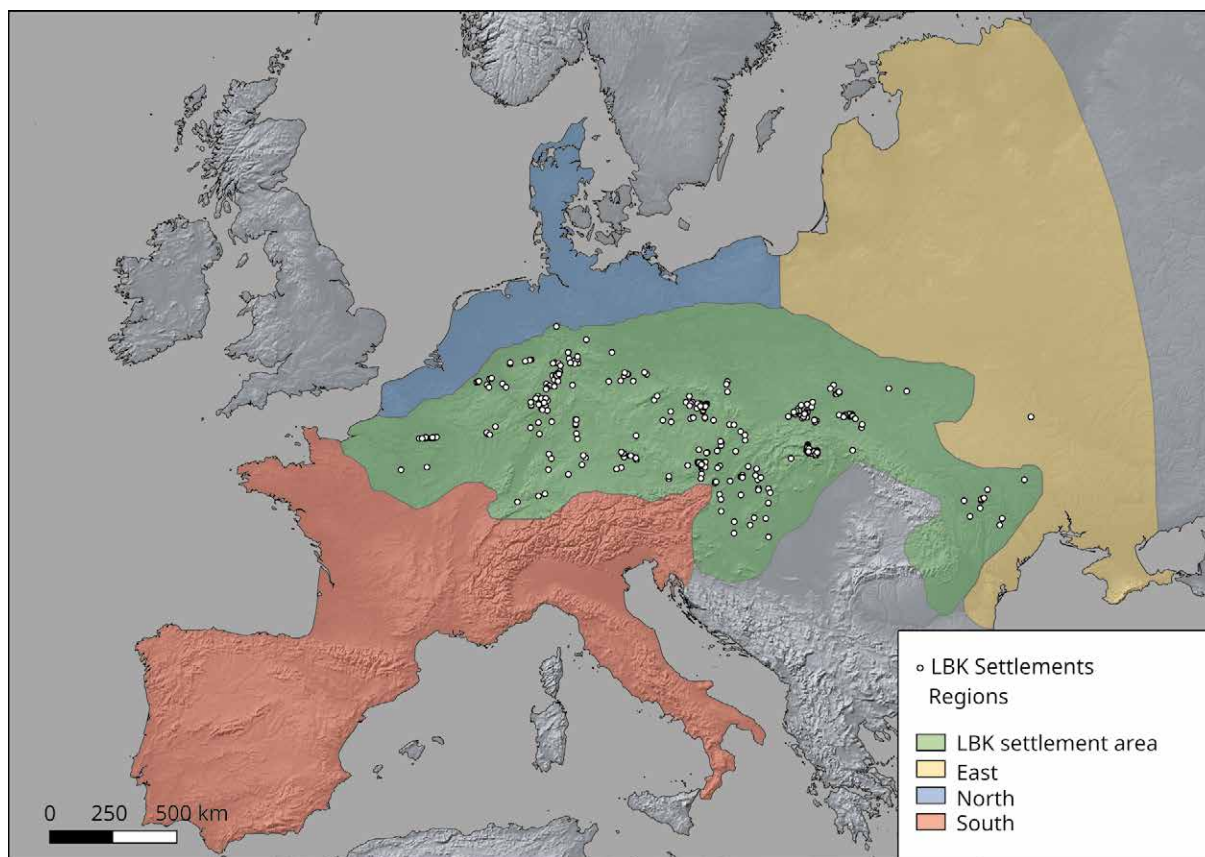


Figure 2.1.1. Geographical units and sites used in the analysis and referred to in the text. LBK distribution area (green) after Bogucki, 2001.

chapter on environmental conditions, research on abiotic environmental factors (e.g. temperature, precipitation) in the LBK settlement areas has become rare over the past decades, possibly because most of the facts were clarified as early as the 1970s and 1980s. It is time, however, for an update, since most of the studies on this topic are regional in scope and lack the supra-regional perspective.

This paper¹ intends to show the limiting factors for selected abiotic environmental factors (e.g. temperature, precipitation) as well as the possible limiting factors for a further distribution of the LBK into the neighbouring regions of northern, eastern and southern Europe (Fig. 2.1.1). The first part of this analysis describes the mean annual temperature, annual precipitation, elevation, and aspects of soil in the settlement area of the LBK. The purpose of this is to update and collate past research. The second part looks at slightly different measures to define the difference between the LBK settlement area and neighbouring regions (northern, eastern and southern Europe), checking whether one or several of these proxies formed critical thresholds between the regions and therefore can be defined as a main influence on settlement activity.

Environmental proxies

In most parts of its distribution, the LBK marks the beginning of agriculture. The main crops harvested by LBK settlers were emmer (*T. dicoccum*) and einkorn (*T. monococcum*). The environmental profile for wheat should, in general, delimit the broader area in which LBK settlements are present. For wheat production, longer periods with temperatures

1 This paper derives from my bachelor thesis, titled Standortfaktoren linearbandkeramischer Siedlungen in Europa (tr. Locational factors in LBK settlements in Europe), which was submitted as part of my studies at the Institute for Prehistory and Protohistory of Kiel University in 2017.

above 15 °C are recommended (Aslan *et al.*, 2016; FAO, 2021). Wheat grows in areas with an annual precipitation of at least 300 mm; better still are values between 450 and 600 mm (Zaharieva and Monneveux, 2014; FAO, 2021). Since growth stops at temperatures around 0 °C (Aslan *et al.*, 2016), the number of days with an average temperature of 0 °C or below ('cold days') somewhat equals the period in which agriculture is not possible. This period presumably must have been bridged by other food sources or by stored foods. It has to be assumed that as more 'cold days' occur in a region, the suitability for prehistoric agriculture decreases. The last, and probably most important, environmental factor in wheat cultivation is soil condition (Kudrat *et al.*, 2006). In general, soils developed on loess sediments tend to have the highest soil value, which measures agricultural potential (Rust, 2006; Neumair, Haas and Schlesinger, 2018). Settlements of the LBK are usually associated with loess soils, with 45% to over 90% of settlements situated on loess depending on the region (Milisauskas, 2001; Biermann, 2001).

With regard to wheat cultivation, four proxies have been selected for comparison with regions adjacent to the LBK settlement area: growing degree days (GDD); moisture index (MI); number of 'cold days'; and the presence of loess sediments.

The GDD is a measure to estimate the energy available for plant growth. Certain plants require a certain amount of GDDs to reach their maximum development (Bollero *et al.*, 1996). The index is calculated using the accumulation of average daily temperatures and a minimum threshold temperature (minimum growing temperature) (Metzger *et al.*, 2013; Anandhi, 2016). The GDD therefore functions as a descriptive value for temperature development throughout the year that offers a more differentiated perspective than, for example, mean annual temperature. In this study, the relative regional GDD values are compared for a relative interpretation. This means that higher GDD values are understood as offering more potential energy for plant growth and therefore better agricultural conditions.

The MI is a measure of relative water access within a region. It ranges from -1 (aridity) to 1 (humidity) and describes whether the water supply exceeds or falls below the water demand (Willmott and Feddema, 1992). For the present analysis, the MI is used in preference to the annual precipitation since it also takes water loss in environments (e.g. evapotranspiration) into consideration and addresses only the plant-available water. The MI in this article is used to allow relative interpretations of the environment, with more humid conditions interpreted as being more suitable for agriculture.

As mentioned above, the number of 'cold days' can be seen as a measure of days where crop growth and cultivation are not possible at all. The data regarding 'cold days' was taken from a selection of 71 European Weather stations (weather.com). A raster was then generated for the working region.

To determine the proximity to areas with loess sediments, the mapping of these loess areas by Haase and colleagues (2007) was used. It should be mentioned that, although agriculturally valuable soils form on loess, a number of other environmental factors play a role in soil formation. Furthermore, soils on volcanic sediments or on floodplains (FAO, 2015) can also produce high yields. However, since loess sediments were discussed as an important site factor of LBK settlements, the following analysis focuses on them.

Methodology

The data set of 443 settlements covers the entire chronological span of the LBK, and the settlements are treated like synchronic sites. The data were collected through intensive literature research. Sites were added to the record if they meet any of the following criteria:

- Sites that have been addressed as a settlement in the literature
- Sites that have excavated LBK settlement contexts

- Sites that have been geophysically surveyed and show LBK settlement structures (e.g. house-ditch systems)
- Sites with very high numbers of LBK pottery sherds

Since a few sites could only be located according to general information (plot name, city quarter), a buffer of 5 km was drawn around the sites. This was done to check whether the sites can be associated with loess soils in general.

Raster datasets for the mean annual temperature and annual precipitation for the period between 1971 and 2000 were accessed from the Global Climate Monitor Project (Harris *et al.*, 2014; Camarillo-Naranjo *et al.*, 2019). A digital elevation model (DEM) was accessed from the EEA Copernicus Programme (EU-DEM v1.1, European Environment Agency, 2016). The dataset of the locations of loess areas was provided by G. Haase (Haase *et al.*, 2007). The data were processed in QGIS and information on temperature, precipitation, elevation and soil was assigned to each settlement with the aid of 'add raster/vector values to point' queries.

For the second part of the analysis, a 10 km point raster was generated, covering continental Europe up to the line Gulf of Finland-Crimea, excluding Scandinavia and the British Isles. The regions were assigned based on their position in relation to the LBK settlement area. The Balkans were excluded because early farming societies developed in that area before the emergence of the LBK in central Europe.

In a next step, four regions were distinguished (Fig. 2.1.1). Based on a distribution map of the maximum extent of the LBK, points from the raster have been assigned to a northern, eastern and southern and LBK region.

Data for GDD and MI values were drawn from the ENVIREM Project datasets (Title and Bemmels, 2018a; 2018b). They are based on climate data from the period 1960–1990. A raster of 'cold days' was compiled by collecting the data of 71 weather stations (1975–2000) and running an inverse distance weighting in QGIS. Values on GDD, MI, cold days and presence of loess (Yes/No) were then assigned to the points of the four regions (QGIS, 'add raster/vector values to point' query).

The data were further analysed in R, calculating the mean and standard deviation for each proxy. The level of significance between the individual regions and the LBK settlement area was determined using a two-sample t-test (Table 2.1.4, R 3.6.1, R Core Team 2021). If the t-test resulted in a p-value less than 0.05, the observation is considered significant. For data visualisation, the data were plotted in R, using the standard R plotting functions (R Core Team 2021).

Results

The environment of the LBK settlers

Settlements of the LBK were built in areas with a mean annual temperature between 5 and 13 °C, with a mean of 9.9 °C (Table 2.1.1; Fig. 2.1.2). Most settlements (61%) are situated in areas with a mean annual temperature between 9 and 11 °C. Approximately 13% are in warmer regions (11–13 °C) and 15% in cooler regions (5–9 °C).

Looking at annual precipitation (Table 2.1.1; Fig. 2.1.2), we see that LBK settlements can be found in areas between 300 and 1200 mm. On average, the annual precipitation of the settlement area is 711 mm. Around 90% of the settlements are situated in regions with 400 to 900 mm annual precipitation. Especially in the rain shadow of the Carpathian Mountains, some sites (only 1% of the settlements) have less than 400 mm of mean annual precipitation. The remaining 9% are in areas with between 900 and 1200 mm of mean annual precipitation.

Settlements are located between 0 to 800 m a.s.l., with an average altitude of 252 m (Table 2.1.1; Fig. 2.1.2). Around 88% of the settlements are located between 0 to 400 m

	Temperature	Precipitation	Elevation	Loess
Range	5–13 °C	300–1200 mm	0–800 m a.s.l.	Present: 82% Absent: 18%
Mean	9.9 °C	711 mm	252 m a.s.l.	

Table 2.1.1. Range and mean values of selected geographic-environmental factors of the LBK settlement area, based on 443 LBK settlements.

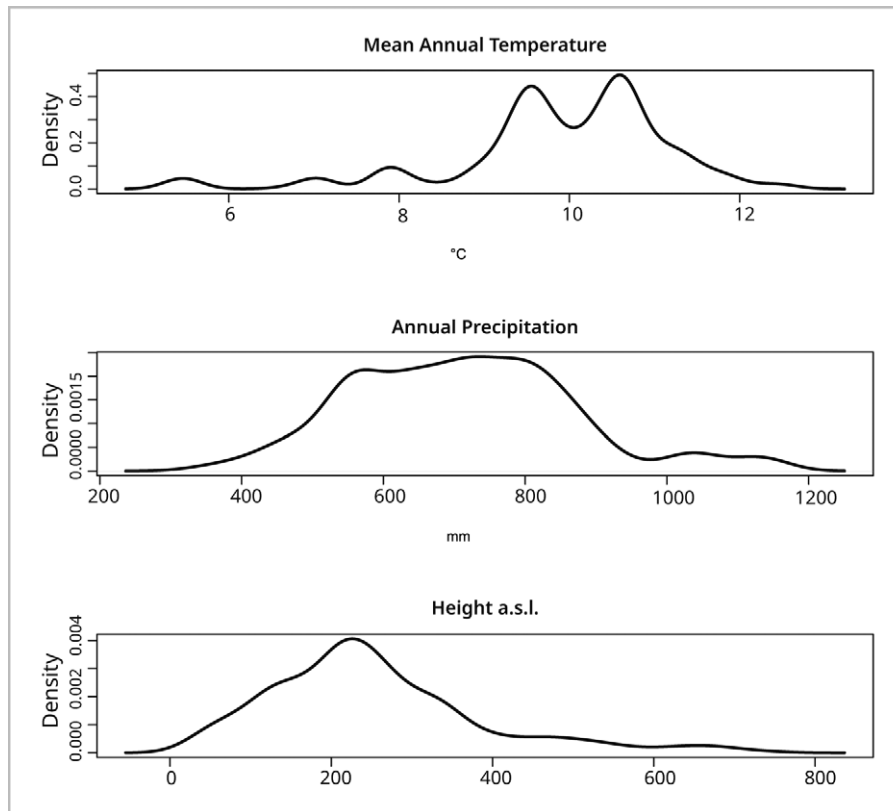


Figure 2.1.2. Mean annual temperature, annual precipitation and elevation above sea level of LBK settlements ($n = 443$).

a.s.l. and 12% at elevations at up to 700 m a.s.l. Only two settlements are situated at elevations between 700 to 800 m a.s.l. Overall, 82% of the sites are situated on or close to loess, while for the remaining 18% loess sediments are not available within a 5 km range (Table 2.1.1).

The environmental limits of LBK settlers

The MI (Fig. 2.1.3) within the LBK settlement area indicates the presence of a variety of different environmental conditions. It ranges from relatively arid regions (−0.4) to relatively humid conditions (0.4), with an average value (aMI) of −0.112. Compared with the adjacent regions (Table 2.1.2), it significantly differs from northern Europe (aMI: 0.05) and differs with weak significance from eastern Europe (aMI: −0.117). There is no significant difference in the MI between the LBK area and southern Europe (aMI: −0.114), but the values in southern Europe have the widest span (from −0.7 to 0.9). However, a notable difference only exists with northern Europe, with its more humid conditions.

Looking at the GDDs (Fig. 2.1.3), we see that the LBK settlement area significantly differs from every other region (Table 2.1.2). The average GDD in the LBK area is 2649, with a relatively high range, from 1000 to 4000. Northern Europe shows slightly higher average GDDs, of 2831, with a narrower span, between 2000 and 4000, meaning that there are more uniform conditions than exist in the LBK area. The south of Europe has much higher GDDs (4099) compared with the LBK area but also ranges

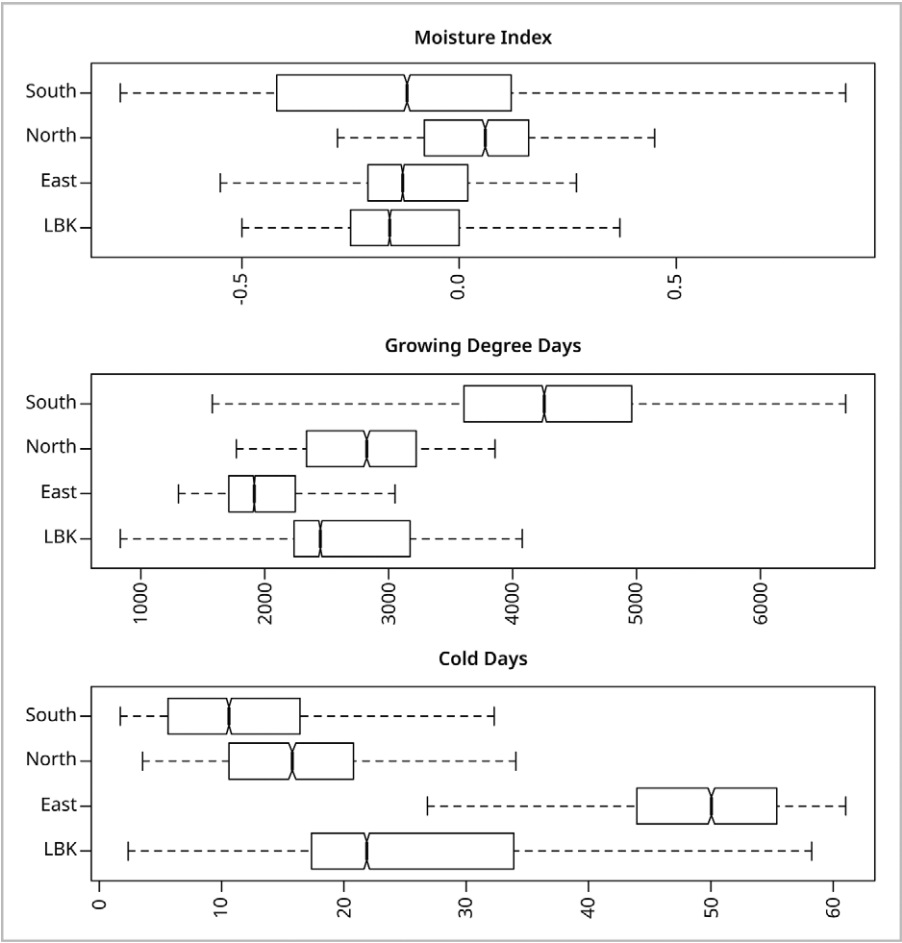


Figure 2.1.3. Means and ranges of the moisture index, and number of ‘growing degree days’ and ‘cold days’ in the analysed regions in Europe (see Fig. 2.1.1).

Table 2.1.2. P-values (two-sample t-test) of environmental factors, between the analysed regions and the LBK settlement area.

Region	Moisture index	Growing degree days	Cold days
Northern Europe	0.00	0.00	0.00
Southern Europe	0.42	0.00	0.00
Eastern Europe	0.04	0.00	0.00

Table 2.1.3. Presence of loess sediments within the observed regions. Values are based on a GIS query of a 10 km point raster by region.

Region	n raster points	Present	Absent
LBK settlement area	13,362	28%	72%
Northern Europe	3,080	7%	93%
Southern Europe	15,120	5%	95%
Eastern Europe	11,947	22%	78%

very widely, from 1800 to 6600. The lowest amount of GDDs among all regions are in eastern Europe, with a mean value of 2040, ranging from 1300 to 3300.

The average number of ‘cold days’ (Fig. 2.1.3) in the LBK area is 25.5, with a relatively wide range, from 2 to 58. Northern (16.7) and southern Europe (11.6) have a much lower number of ‘cold days’, with both regions ranging from 0 to around 33 ‘cold days’. The biggest difference can be observed in eastern Europe, with an average of 49 ‘cold days’, ranging from 20 to more than 60 ‘cold days’. The differences between the regions and the LBK settlement area are significant (Table 2.1.2).

Region	Moisture index	Growing degree days	Cold days	Loess
Northern Europe	+	+	++	--
Southern Europe	–	++	++	--
Eastern Europe	0	–	--	+

Table 2.1.4. Comparison of selected environmental factors between the LBK settlement area and neighbouring regions: ++ better; + slightly better; 0 similar; – slightly worse; — worse. Cold days: days below an average temperature of 0 °C; loess: presence/absence of loess soil.

In the LBK settlement area, 28% of the raster points are located on loess sediments (Table 2.1.3). Towards the east, the situation is similar, with loess present at 22% of the points. Northern (7%) and southern Europe (5%) are different, with under 10% of the points situated on loess sediments.

Discussion

The results of the first analysis are a general description of the geographic environment in which the LBK settlements are situated (Table 2.1.1). Looking at the wide range of the individual environmental factors (Table 2.1.1), it appears that the settlements occupied a variety of different environments. The long-recognised connection between loess sediments and settlements of the LBK (Sabel, 1983; Milisauskas, 2001; Saile and Lorz, 2003) is corroborated, since 82% of the settlements are located on loess.

Looking at the limits of the LBK settlement area, we can see that it appears that there are different limiting causes of the further settlement development towards the adjacent regions (Table 2.1.4). It is important to mention that the range in the data of the LBK settlement area is wide because of its position in central Europe, with a huge variety of different environments and climatic regions, such as the Carpathian Basin, the foothills of the Alps, and the Paris Basin. In general, the LBK area can be described as a good symbiosis of the different environmental factors with regard to agriculture. Most importantly, there is a lot of loess present in the area. Moreover, the GDD and number of ‘cold days’ are moderate compared with the adjacent regions. The LBK settlement area is characterised by stable environmental conditions that do not limit agricultural use at any point.

Starting with northern Europe, we see that the overall climatic situation is slightly better than in the LBK area, with a relative short period of ‘cold days’ and an overall humid climate. Also, there is higher potential energy for plant growth (GDD) available. Looking at the presence of loess sediments in the area, we see that it appears that the strong absence of those sediments may have functioned as a limiting factor for the expansion of LBK settlements to the north.

The situation is similar for southern Europe, where even less loess sediment is present. In general, the climatic situation is good, with a high GDD and a small number of ‘cold days’. Although the average MI value is similar to that of the LBK area, it must be taken into consideration that southern Europe includes very different environments (e.g. the Alps and Andalusia). Overall, the region can be described as relatively more arid, possibly with the danger of droughts. It is possible that in addition to the absence of loess, the relative aridity was also a limiting factor for LBK settlement spread into southern Europe.

To the east, the limiting factors are most likely of climatic origin. This has already been suggested by Dębiec and Saile (2015) but is proven by the results presented here. Loess is vastly available in eastern Europe, and the proportion of loess increases further towards the east, so that loess is not a limiting factor. Looking at the MI, we see that the situation is almost identical compared with the LBK area. The main

differences are the GDD and the number of ‘cold days’. Even more than the relatively low amount of potential energy for plant growth (GDD), it is the period with no possibility for plant growth (cold days) that was the obvious limiting factor for a further spread of LBK settlement towards the east.

Conclusion

With the help of a set of environmental data, it was possible to outline the environmental setting in which LBK settlements were built. Looking at a slightly different set of proxies, it was possible to show that the LBK occupied an area with a wide range of environments. With regard to agriculture, it appears that the settlement locations offered relatively stable and good conditions.

In general, there are also favourable environmental conditions in neighbouring regions, but not for all factors considered. Even if the effect of the adverse environmental conditions on agricultural production cannot be precisely quantified, we can assume that they had an impact on the choice of settlement location. The limiting factor between the settlement area of the LBK and northern area seems to be the absence of loess. For southern Europe, growing aridity towards the south and the absence of loess were most likely limiting the expansion. In eastern Europe, the harsh climatic conditions, with a long period of ‘cold days’ and relatively low growing energy limited the spread of the LBK into the Eurasian Steppe.

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2.2 Geophysical investigations at Úľany nad Žitavou and Vlkas in the Žitava Valley, south-western Slovakia

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Abstract

Depth-sensitive geophysical soundings and measurements of magnetic susceptibility can complement magnetic maps, which do not provide unambiguous information on the depth of archaeological features or on their magnetic material properties. However, this information is necessary for fully evaluating magnetic maps quantitatively. Here, we discuss in how far ground-penetrating radar (GPR), electric resistivity tomography (ERT), electromagnetic induction (EMI) and magnetic susceptibility (MS) measurements can support this quantitative interpretation. The surveys were conducted at the *Linearbandkeramik* (LBK; Linear Pottery culture) sites of Úľany nad Žitavou ‘Dolné diely’ and Vlkas ‘Do hľského chotára’, in the Žitava Valley (Nitriansky kraj, Slovakia). The magnetic surveys mapped the layout of the LBK houses by the anomalies of the lateral long pits accompanying the houses. The aim of the ERT, EMI and MS measurements is to investigate the geometry and magnetic properties of the remains of houses. The GPR survey investigated a layered, hill-like structure whose relation to the LBK site is thus far unclear. The measurements of the MS document cross-sections of postholes and lateral long pits. The interpretation of the other measurements turned out to be more challenging due to the local soil and agricultural conditions: a plough layer of up to 60 cm thickness, electric conductivity values with a variability from 5 mS/m to 50 mS/m, and targets with an expected thickness of a few decimetres lead to measurements at the edge of detectability of those targets. ERT profiles show indications for the structures imaged by magnetics but have too little resolution with respect to these conditions. The EMI measurements indicate the location of features by slightly decreased conductivity values impeded by measurement noise. By numerical modelling of EMI measurements, we show that for future measurements, either the plough layer must be removed or a device with larger coil separations must be used.

Keywords: Geophysical analysis of pit fills, magnetics of unburnt archaeological findings, soil magnetism, modelling

Introduction

Magnetic surveying of archaeological sites usually aims to generate a complete map indicating the shape and size of archaeological features. However, solely based on magnetic field data, it is neither possible to unambiguously determine depth and depth extension nor magnetic material properties of the subsurface structures. This is caused by the inherent ambiguity of magnetic sources with respect to magnetic data measured at Earth's surface. Theoretically, there is an infinite number of magnetic subsurface models that can explain one given set of measurements equally well (*e.g.* Li and Oldenburg, 1996).

To determine the depth extent or magnetic properties of the subsurface structures causing the magnetic anomalies, additional constraining information is needed. These can be derived from supplementary depth-sensitive geophysical measurements or drillings.

In a previous study, we showed how EMI and GPR can be combined in order to construct a three-dimensional image of a lateral long pit at Vrábce 'Veľké Lehemby' (Nitriansky kraj, Slovakia) (Pickartz *et al.*, 2020b). In another study, we showed that the combination of susceptibility measurements and magnetic surface data give insight into site formation processes and the remanent and induced portions of the recorded magnetic signal (Pickartz *et al.*, 2020a).

In this chapter, we present measurements conducted at the LBK sites of Úľany nad Žitavou 'Dolné diely' and Vlčias 'Do hľuského chotára', in the Žitava Valley, Slovakia (Fig. 2.2.1). The results of the large-scale magnetic prospection at these sites are discussed in detail elsewhere (see Chapter 2.3 in this volume). The magnetic maps show the anomalies of lateral long pits that are also the main targets in this chapter. Here, we present the results of GPR measurements at Úľany nad Žitavou 'Dolné diely' and ERT as well as electromagnetic EMI at Vlčias 'Do hľuského chotára'. In principle, these types of measurements are depth-sensitive, but they show different depth penetration and structural resolution depending on the local soil type and conditions. Therefore, the aim of these measurements was to test in how far GPR, EMI and ERT are able to resolve the depth of LBK structures in the Žitava Valley. In addition, the MS was measured during the course of excavations along profiles through a lateral long pit at Vlčias 'Do hľuského chotára' and through postholes at Úľany nad Žitavou 'Dolné diely'. The aim of the susceptibility measurements was to investigate the magnetic properties of the remains of houses for further quantitative interpretation of the magnetic anomalies.

The measurements presented below were subject to a number of circumstances that affect accuracy and resolution. In particular, some of the measurements had to be performed on newly ploughed fields showing a very rough surface; archaeological targets were partly covered by a topsoil layer, the thickness of which was the same order or even larger than the size of the archaeological

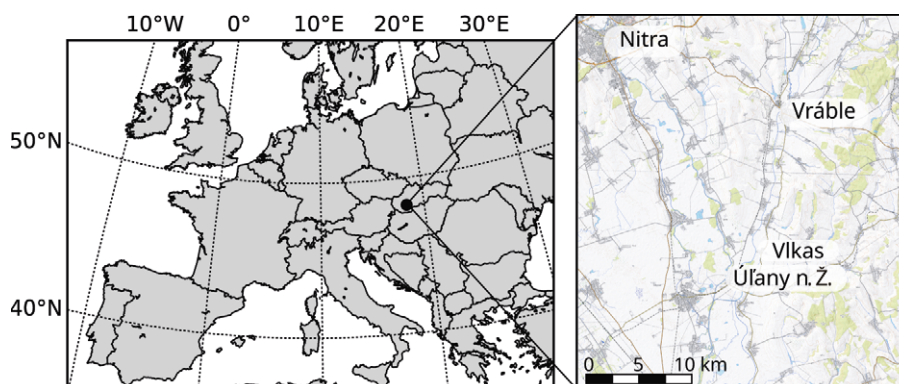


Figure 2.2.1. Left: Location of the Žitava Valley, Slovakia, within Europe. Right: Location of Vrábce 'Veľké Lehemby', Vlčias 'Do hľuského chotára' and Úľany nad Žitavou 'Dolné diely' in the Žitava Valley.

objects; and the surrounding material and archaeological features may show only small contrasts in the electric conductivity. As a consequence of these circumstances, not all magnetic anomalies were identifiable even through the electric and electromagnetic measurements.

With this background, the aim of this chapter is to investigate what concrete benefits can be expected from EMI, GPR and ERT measurements as a complement to magnetic mapping with regard to the field conditions found in the Žitava Valley. For this purpose, we (a) show successful and unsuccessful examples of complementary measurements; (b) perform numerical model computations considering actual and alternative soil conditions; and (c) discuss the reasons for success and failure and show ways how the measurement setup could be improved in these cases in the future.

Methods

Ground-penetrating radar

GPR devices emit electromagnetic pulses of a few nanoseconds' duration via a transmitter antenna into the ground. The pulses propagate through the subsurface depending on electromagnetic soil properties. The electrical conductivity influences energy absorption and therefore also sounding depth, whereas the dielectric permittivity and its contrasts affect the propagation velocity of the signal and the strength of the reflection from subsurface interfaces, respectively (*e.g.* Davis and Annan, 1989). The emitted pulses are reflected at the interfaces between subsurface layers and objects that differ from each other in terms of electromagnetic soil properties. The receiver antenna of the GPR device measures the reflected signals at the surface.

We conducted the GPR survey of the present study with a 200 MHz antenna by GSSI Inc. Processing steps applied to our data are: (a) setting of coordinates and creating a constant trace distance of 2 cm; (b) t_0 correction using the first break of the direct wave; (c) bandpass filtering between 50 and 400 MHz; (d) wavenumber highpass (cut-off wavenumber 0.1/m) to mute horizontal events; (e) depth migration with a constant velocity of 9 cm/ns (determined via hyperbola fitting); and (f) creating depth slices by summing the absolute amplitudes in depth windows of 0.1 m. Then layers were picked in the radargrams that could be traced over the entire area. These layers can be displayed either as radargrams (vertical sections) or as depth slices (horizontal sections).

Electromagnetic induction

EMI devices consist of a transmitter and one or more receiver coils. The transmitter coil emits a 'primary' oscillating magnetic field. Electric eddy currents are induced in the soil that depend on the electrical conductivity distribution of the subsurface. They generate a 'secondary' magnetic field recorded at the receiver coils together with the primary field. The measured output is values of the 'apparent electrical conductivity' of the soil. These measurements represent average values of the soil volume encircled by the diameter of a 'footprint', Earth's surface and the sounding depth. Footprint and sounding depth depend on signal frequency and transmitter-receiver distance.

If the applied EMI instrument enables measurements with different sounding depths, inversion computations can be conducted that convert the corresponding average apparent electrical conductivity values into depth functions of 'true' in-situ electrical conductivity. These 1D depth functions can then be spatially compiled

into an approximate 2D or 3D distribution of electrical conductivity, from which depths of soil layers and interfaces can be derived. The EMI procedure is technically very efficient, but the results need depth calibration by drilling or spot excavation because of an inherent physical uncertainty relation between electric conductivity and layer thickness.

We used a CMD Mini-Explorer by GF Instruments. The device consists of one transmitter and three receiver coils, the planes of which can be oriented horizontally (horizontal coplanar mode, or HCP) or vertically (vertical coplanar mode, or VCP). The distances between the transmitter and the receivers are 0.32 m, 0.71 m and 1.18 m, leading to effective sounding depths of 0.25 m, 0.5 m and 0.9 m in VCP mode and 0.5 m, 1.0 m and 1.8 m in HCP mode. Further details on the method and the device can be found in, *e.g.* Bonsall *et al.* (2013).

The measurements were performed with 10 Hz sampling frequency using the HCP configuration and are called continuous measurements. Additionally, stationary measurements with a measurement time of 10 seconds at a point distance of 1 m were performed. This allows us to examine the noise which may be introduced by the movement of walking for the continuous measurements.

The inversion computations were performed with the software IX1D by Interpex, using the 'smooth model' mode (Constable *et al.*, 1987). In this mode the sounded depth range is subdivided into a set of layers with predefined thicknesses, which are kept fixed during the computation, while the conductivity values are altered using smoothness constraints. We defined 10 layers between 0.05 m and 3 m depth with logarithmically equidistant thicknesses. The resulting one-dimensional models were stitched together to form the profiles of electric conductivity values. For the modelling study, we used the forward 1D code of von Hebel (2016) and the device parameters of the CMD Mini-Explorer and CMD Explorer given by the manufacturer.

Electric resistivity tomography

The principle of an ERT is as follows: electric current is sent into the ground by two current electrodes, and the resulting difference in the electric potential is measured between a second pair of electrodes, the potential electrodes. From this, the apparent resistivity can be calculated as the ratio of potential difference and applied current multiplied by a geometrical factor. The geometrical factor contains the distances of the electrodes as well as their arrangement. A larger distance between the electrodes results in a higher depth of investigation. To perform an ERT, a larger number of electrodes is placed equidistantly along a profile. Then, the measurement device uses a set of four electrodes for each measurement and moves through all possible electrode combinations, resulting in a 'pseudosection' of apparent resistivities. The measured apparent resistivities resemble a mean value for the subsurface volume that was penetrated by the applied current. What are known as inversion calculations determine a subsurface model of resistivity values that is in agreement with the measurements and resembles the specific resistivity distribution. Nevertheless, this process is also ambiguous, and several subsurface models can be found to explain the measured values equally well.

We used the RESECS device by Geoserve, with 0.5 m electrode spacing and three configurations: Dipole-dipole, Schlumberger and Wenner-alpha. The inversion calculations were performed with the software BERT (Günther *et al.*, 2006).

Magnetic susceptibility

MS is a specific property of materials that describes how strongly it gets magnetised in the presence of an external magnetic field, which in archaeological studies is Earth's magnetic field. Anomalies detected by magnetic prospection originate from variations

in the magnetisation of the subsurface, *e.g.* by induced magnetisation resulting from MS variations. The susceptibility can be seen as a proxy for the iron oxide content and anthropogenic activities, such as fire, deposition of organic material in pits and construction of buildings, which can enhance the iron oxide content. Therefore, the MS can be used to document archaeological structures. Furthermore, high-resolution measurements with point distances of a few centimetres enable the documentation of gradual variations. For the discussion of the measurement technique of induction coil devices, such as the ones we applied, we refer to Evans and Heller (2003).

We measured the susceptibility inside the excavations on the archaeological profiles. The distance of measurement points is 10 cm horizontally and 5 cm vertically. The device SM-30 by ZH instruments and the MS2K sensor with the MS3 logger by Bartington were used. For display, the values have been interpolated to a 2.5 cm to 2.5 cm grid.

Results

Ground-penetrating radar at Úľany nad Žitavou ‘Dolné diely’

A GPR survey north of a modern building using a 200 MHz antenna revealed an approximately southwest-northeast running elevation consisting of several layers that build up a hill-like structure (Fig. 2.2.2). This elongated hill corresponds to today's surface elevation, and there is still a topographic high at this location. In this area, the penetration depth of GPR reaches up to 2 m below the surface and clearly shows the layer interfaces. For future campaigns, it would be helpful to conduct coring in order to detect the former Neolithic land surface. A larger-scale GPR survey could then be used to trace this surface over a larger area, providing useful information about house locations.

Magnetic susceptibility at Úľany nad Žitavou ‘Dolné diely’

The MS of cross-sections through postholes was measured during the excavation in 2018. Figure 2.2.3 shows the comparison of photographs and MS values for three postholes. The postholes are visible in the form of increased susceptibility values. However, the contrast between the surrounding material and the fill of the postholes is low. The measured values range from 10×10^{-5} SI (outside the postholes) to 50×10^{-5} SI (inside the postholes).

To our knowledge, postholes of LBK settlements in the Upper Žitava Valley have not been documented before with any geophysical method. In terms of magnetic gradiometer measurements, forward calculations show that the maximum amplitude of the magnetic anomalies of a subsurface structure such as these postholes is about 0.06 nT and therefore below the resolution of the sensor. This explains why the postholes are not visible in the magnetic map.

EMI at Vlkas ‘Do hulského chotára’

Figure 2.2.4 shows the measured values and the conductivity model derived from the inversion of EMI data. The measured apparent conductivity values show small variations, of a few mS/m, along the profile for all coil separations in the two measurement modes. Most variations are detected with the receiver coil with

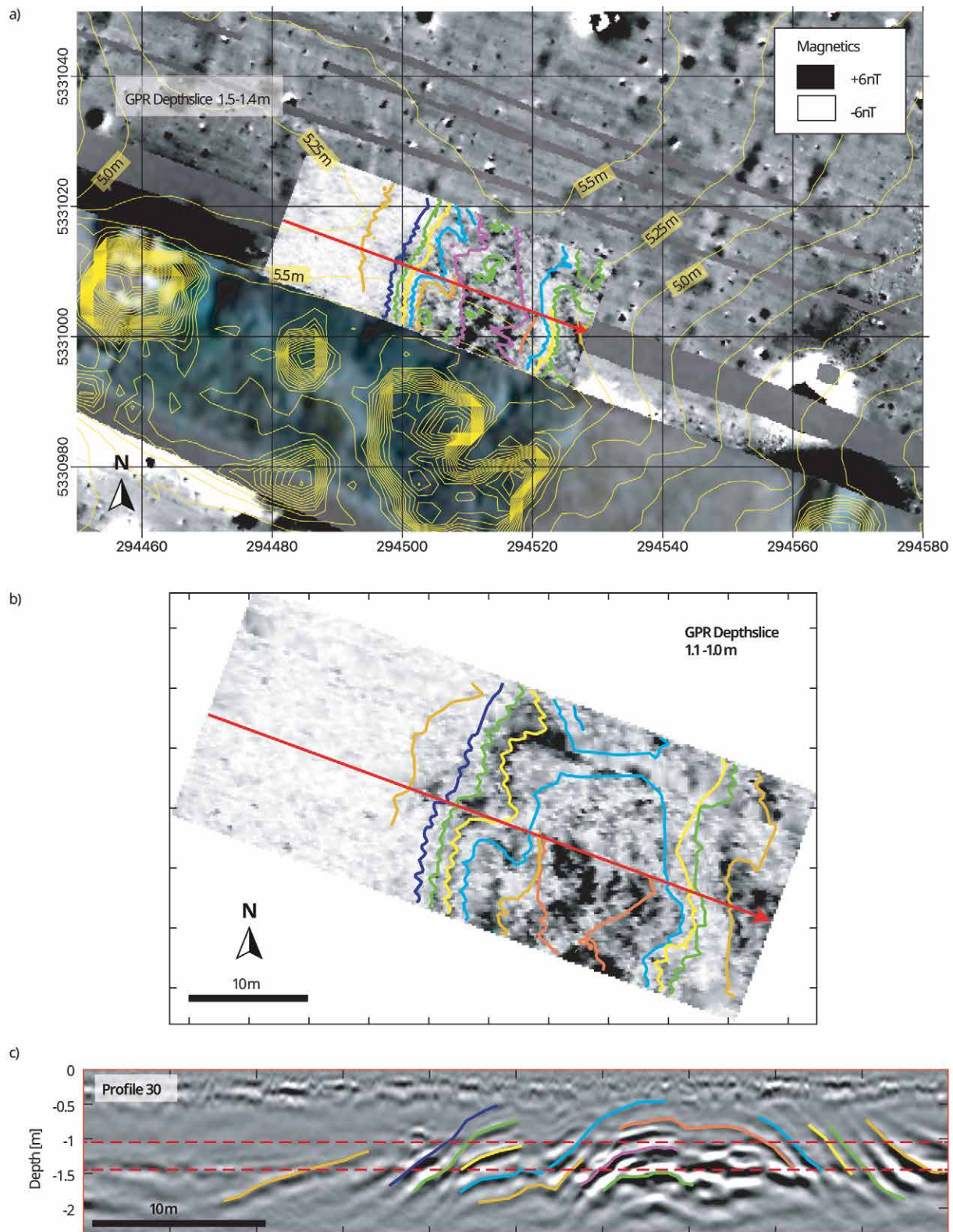


Figure 2.2.2. a) Úľany nad Žitavou 'Dolné diely'. Magnetic map with topographic contours and interpreted GPR depth slice between 1.4 and 1.5 m depth. The red arrow shows the location of the profile in c) (WGS84/UTM34N). b) Depth slice between 1.1 and 1 m depth. c) Radargram in the middle of the area, showing interpretation of layers.

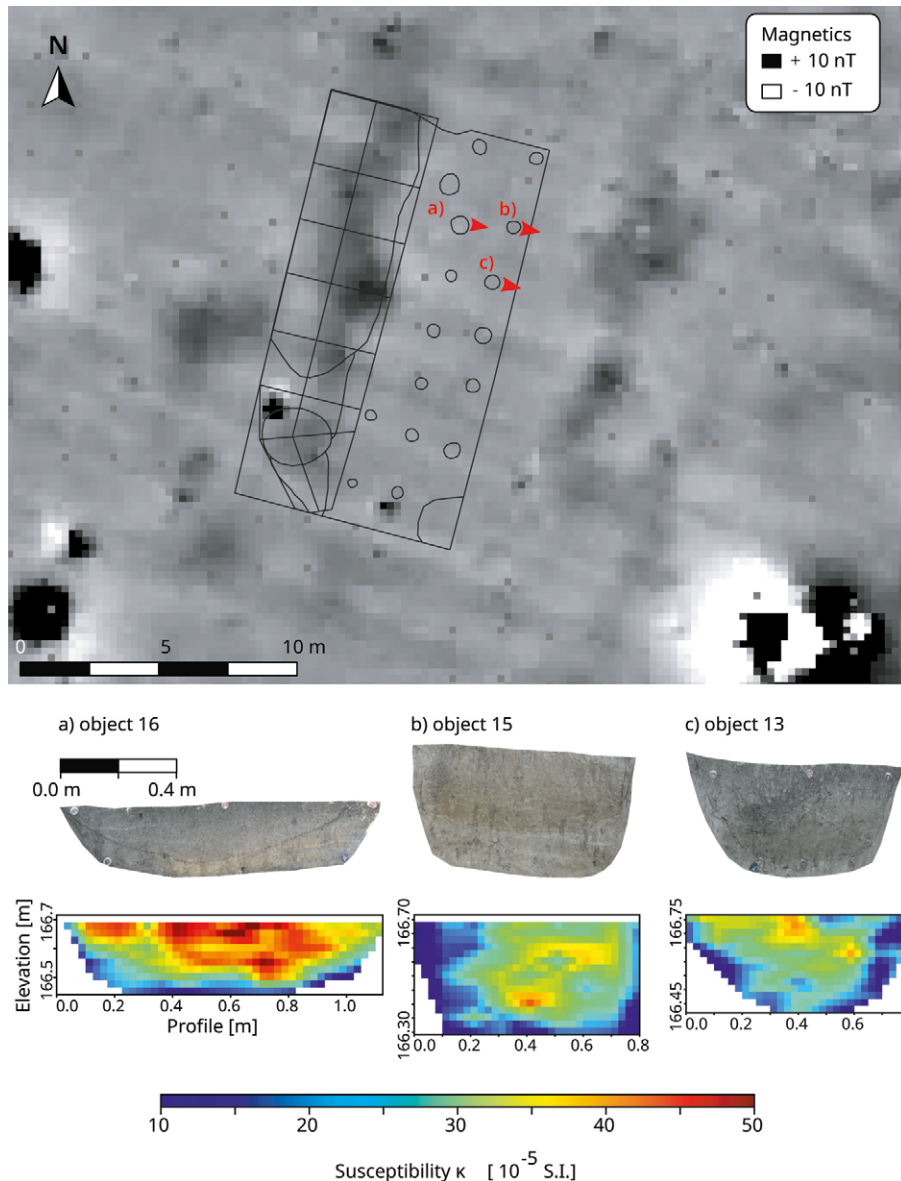


Figure 2.2.3. Úľany nad Žitavou 'Dolné diely'. Magnetic map and comparison of excavated postholes (top) and respective magnetic susceptibility measurements (bottom). From left to right: Objects 16, 15, 13.

the smallest distance to the transmitter. These values are assigned to an effective sounding depth of 0.5 m. In most parts, the inversions assign the subsurface a conductivity of between 20 and 25 mS/m underneath a higher conductive top layer, of around 50 mS/m. In the western part of the profile, a structure with decreased conductivity values, of about 10–18 mS/m, is visible in the conductivity model derived from the point measurements. This correlates spatially with the anomalies of a LBK building in the magnetic map. However, in a similar depth range and in the same range of conductivity values, the inversion model of the continuous measurements shows a layer of decreased conductivity rather than distinctly separated structures. This comparison suggests that by the motion of walking, the noise level is increased and therefore the existing subsurface structures blend into the artefacts.

To investigate if the lateral long pits seen in the magnetic map can be imaged by the used EMI device (CMD Mini-Explorer) or if another instrument (e.g. CMD Explorer) with larger penetration depth may be better for future measurements, we conducted synthetic modelling. Figure 2.2.5 shows the measured electric conductivity

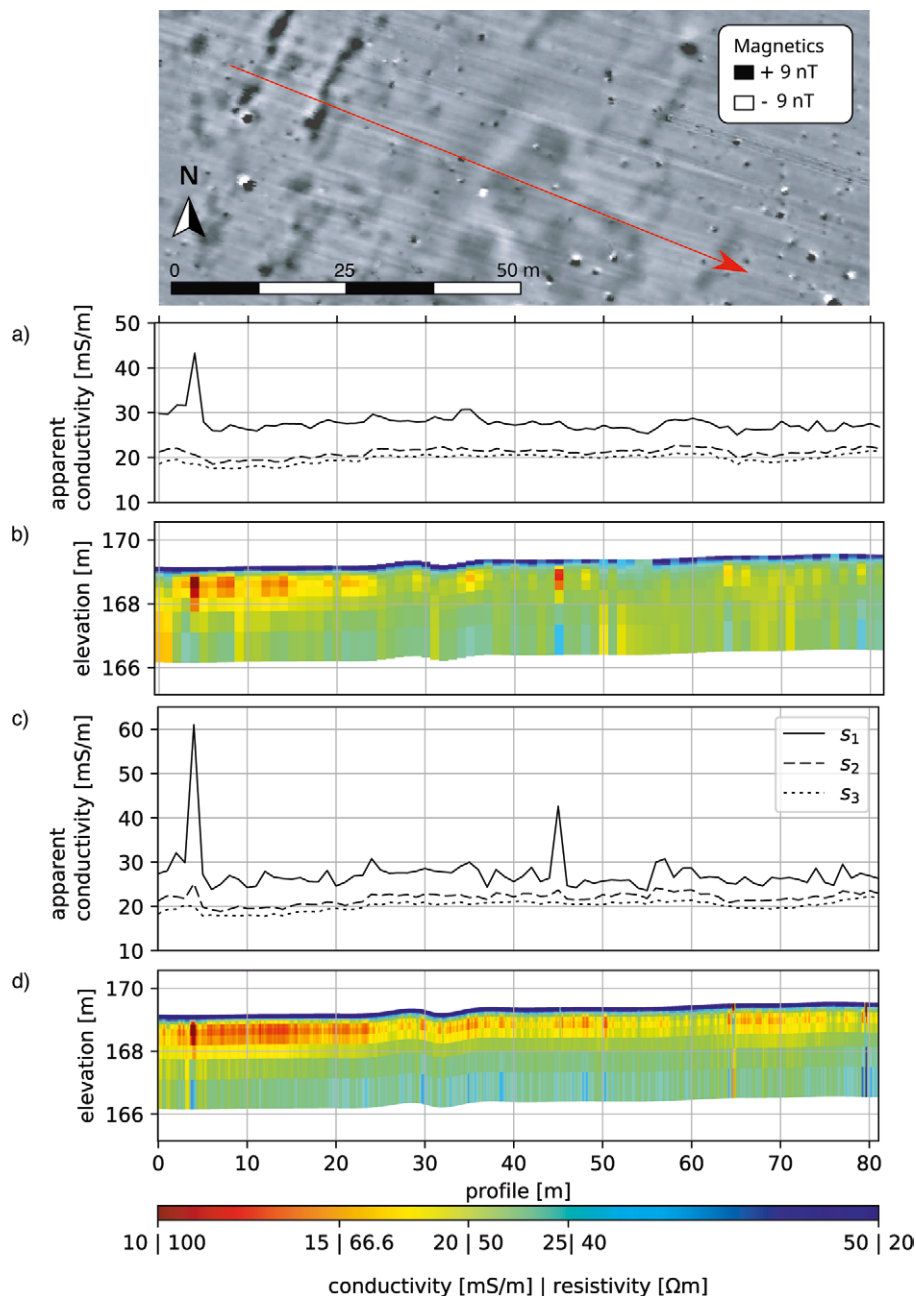


Figure 2.2.4. Vlkas 'Do hulského chotára'. Top: magnetic map; below: Comparison of measured apparent conductivity values of a) point and c) continuous measurements, as well as the respective resulting subsurface models from the inversion calculations, with IX1D based on the b) point and the d) continuous measurements.

values for both instruments in both coil configurations. The alternative device, the CMD Explorer, has three coil spacings, of 1.48 m, 2.82 m and 4.49 m, which leads to effective penetration depths of 1.1 m, 2.1 m and 3.3 m in VCP mode and 2.2 m, 4.2 m and 6.7 m in HCP mode. For Models 1–3, a plough layer of 0.6 m thickness is present at the surface. Model 1 is the undisturbed soil without archaeological features, whereas Models 2 and 3 comprise a ditch of 0.25 m and 1 m thickness, respectively. The loess layer has a stratified conductivity distribution, with increasing conductivity towards depth. The measured values for both instruments and coil orientations are very similar for all three models, although showing slightly lower values for the model with the thick ditch. Models 4–6 show the same settings, but the plough layer has been removed. In these cases, the measured values span a larger range of conductivities (approx. 5–33 mS/m) compared with the models with plough layer (approx. 19–32 mS/m). This shift towards lower measured conductivity values

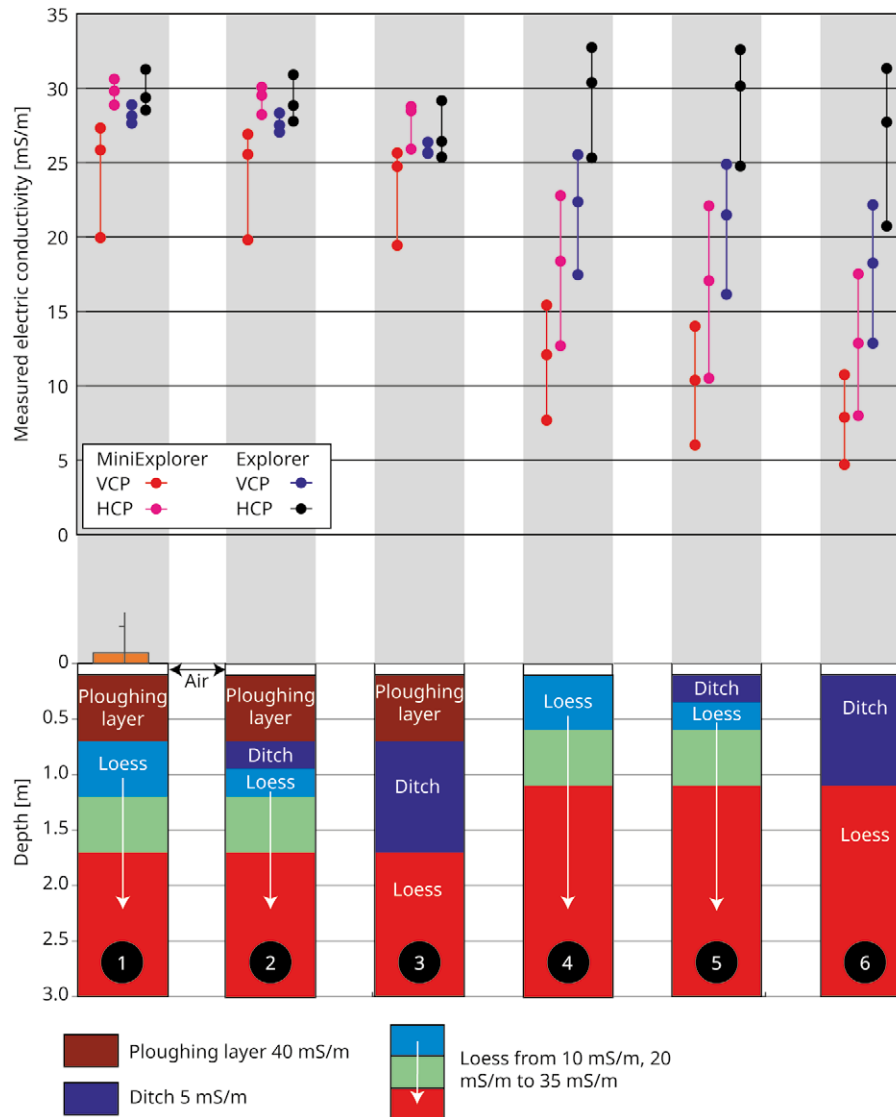


Figure 2.2.5. Calculated apparent conductivities with two different coil orientations and two different instruments over six different subsurface models. All models assume a measurement height of 0.1 m above the surface. Models 1–3 have a 0.6 m thick plough layer of 40 mS/m on top, whereas Models 4–6 do not have this layer. Models 1 and 4 represent the undisturbed soil without archaeological features, whereas Models 2 and 5 have a ditch of 25 cm thickness and Models 3 and 6 a ditch of 100 cm thickness. The three markers on each measurement line represent the three different coil spacings.

indicates the higher influence of the less-conductive ditch and loess layers compared with the plough layer.

If we compare the measurement values between models with and without ditch (which is the object of interest), we see that for the setting with plough layer and a thin ditch of 25 cm (Models 1 and 2) there is a difference between measured values below 1 mS/m for both devices and coil orientations (Fig. 2.2.6). These differences increase if the ditch is getting thicker (Models 1–3) and for the CMD Explorer the differences are above the assumed measurement accuracy level of 2 mS/m. For the settings with removed plough layer and a thin ditch (Models 4 and 5) the differences are slightly higher compared with Models 1 and 2, but still below the assumed level of measurement accuracy. For a 1 m thick ditch and removed plough layer (Models 4–6), greater differences are observed, which are almost all clearly above the level of measurement accuracy. The conclusions drawn from this modelling study are:

1. If there is a plough layer present, the instrument with larger penetration depths (CMD Explorer) will be able to detect a ditch of 1 m thickness below the plough layer.
2. If the plough layer is removed (in the beginning of an excavation), both instruments are able to detect a ditch of 1 m depth. Nevertheless, if the ditch is only 0.25 m deep, it will probably not be detected by either instrument.

Figure 2.2.6. Differences in measured conductivities between the undisturbed soil models (1 and 4) and the models in which a ditch is present. The shaded area marks the differences below measurement accuracy, which is given by the manufacturer to be ± 4 percent at 50 mS/m ($= 2$ mS/m).

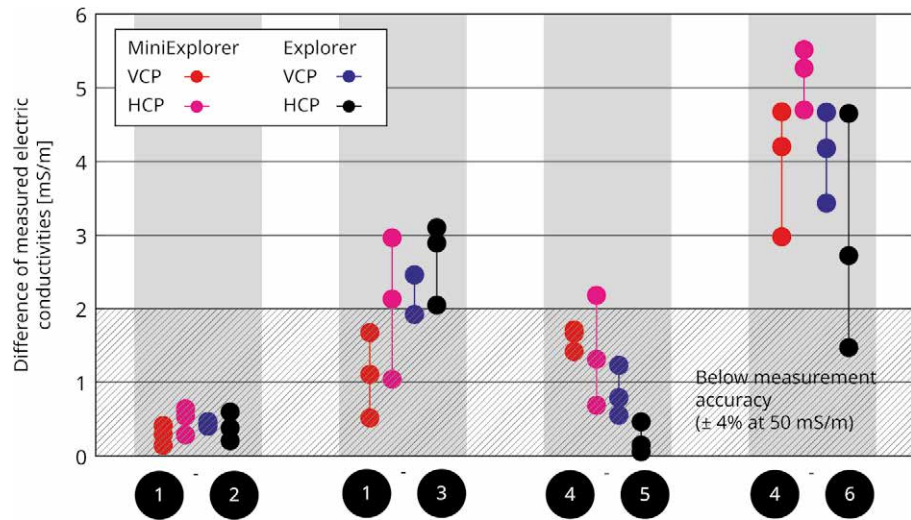


Figure 2.2.7. Vlkaš 'Do hulského chotára'. Electric resistivity tomography Profile E14, crossing two lateral long pits (between 0 and 20 m) and a larger structure (between approx. 30 and 55 m).

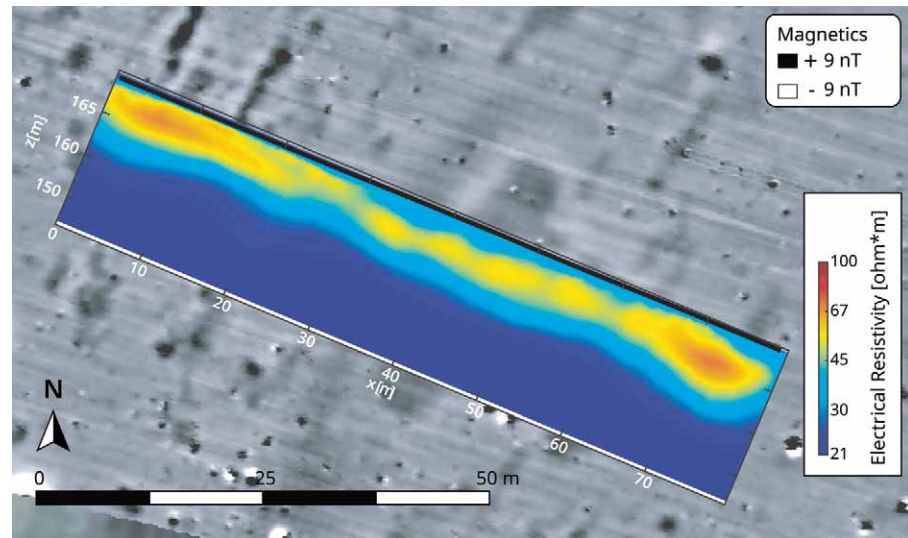
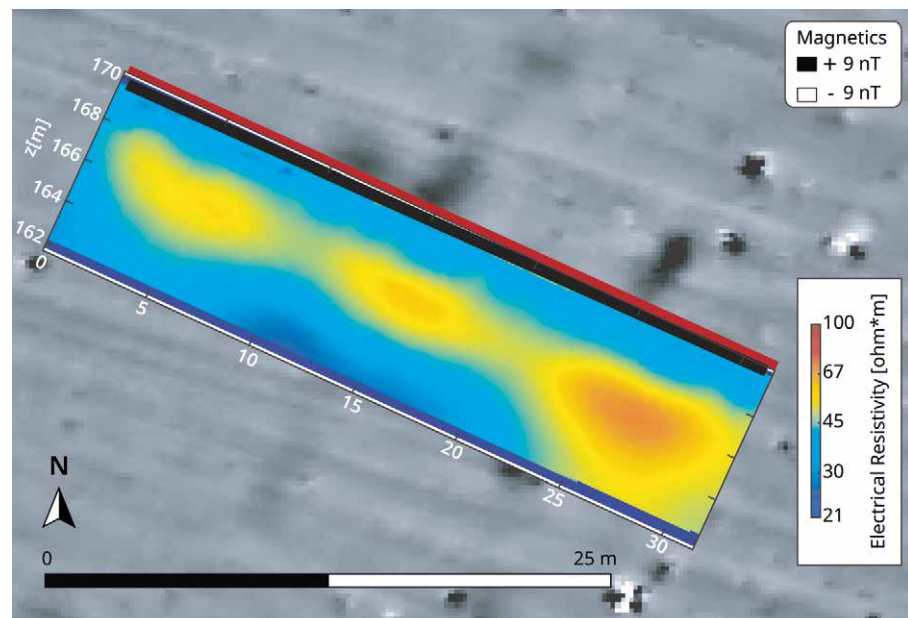


Figure 2.2.8. Vlkaš. Electric resistivity tomography Profile E15, crossing two lateral long pits (at approx. 15 m and 25 m).



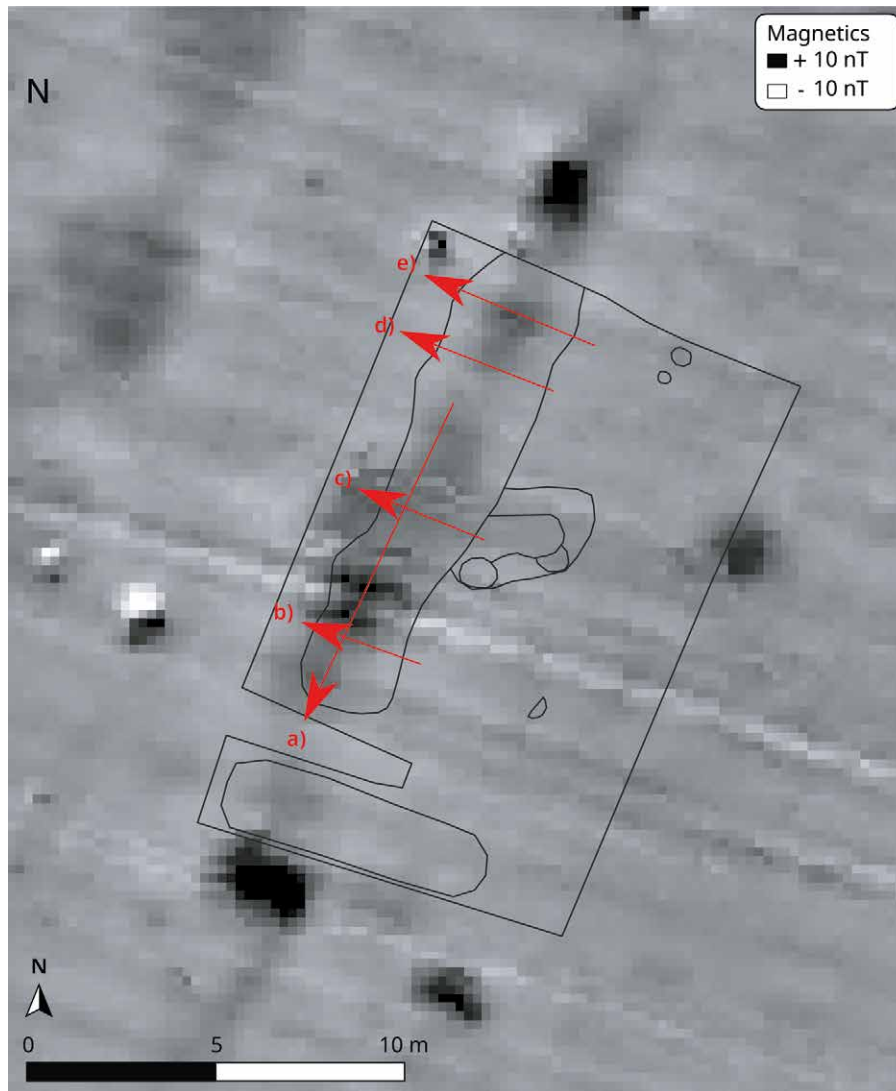


Figure 2.2.9. Vlkas 'Do hľského chotára'. Magnetic map of the excavated Trench 12, showing the outlines of the features and the location of the magnetic susceptibility profiles.

Electric resistivity tomography at Vlkas 'Do hľského chotára'

Both ERT profiles cross the lateral long pits of a house seen in the magnetic map, but the pits are not visible in either of these profiles (Fig. 2.2.7 and 2.2.8). Nevertheless, in Figure 2.2.7, there is a more-resistive layer underneath the house location. A thinning of this layer in the middle part of the profile and a slight depression of the upper layer may be connected with the larger magnetic structure. The general structure of the ERT image in Figure 2.2.7 is comparable to the EMI subsurface model presented above, but the layer of high resistivity starts and extends deeper.

Magnetic susceptibility at Vlkas 'Do hľského chotára'

The MS was measured in excavation Trench 12 in 2018 (see Chapter 3.1 in this volume). Here, we present exemplary measurements along profiles through one excavated lateral long pit. Figure 2.2.9 shows the magnetic map with the outline of the excavated area and the features, as well as the location of the presented MS profiles.

Figure 2.2.10. Vlkaš 'Do hulského chotára'. Comparison of excavated profile (top) and respective magnetic susceptibility measurements (bottom) for profile a) in Figure 2.2.9.

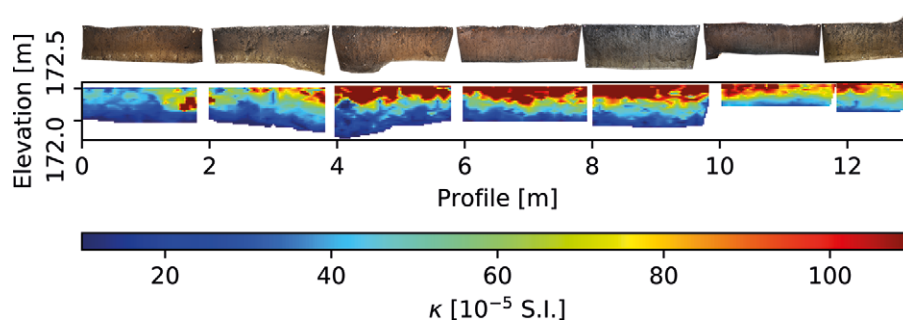


Figure 2.2.11. Vlkaš 'Do hulského chotára'. Comparison of excavated profile (top) and respective magnetic susceptibility measurements (bottom) for profile b) in Figure 2.2.9. Notice the pieces of daub in the pit fill (photograph) between 1.5 and 2.0 m and the correlation with particularly high susceptibility values.

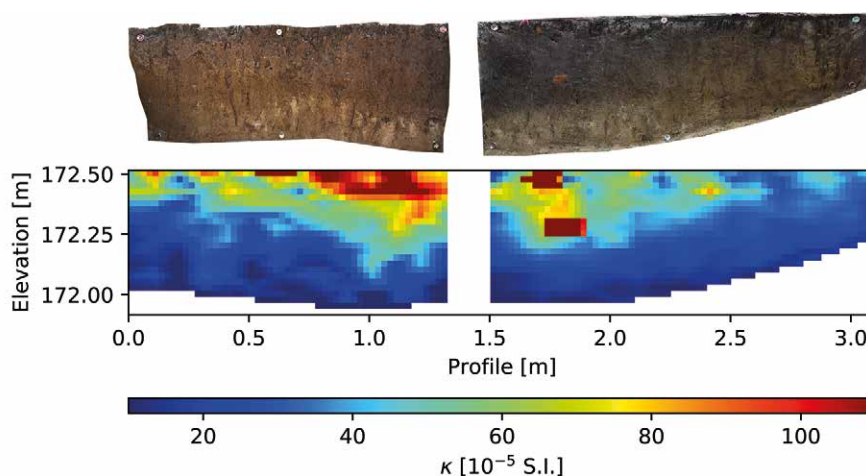
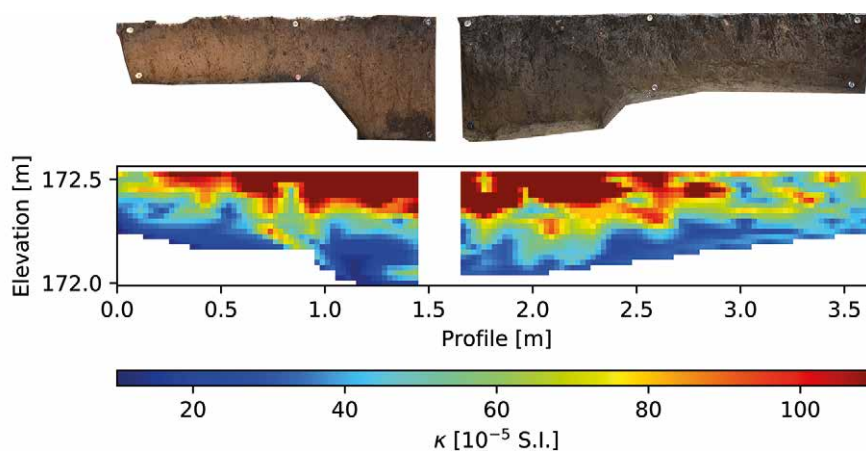


Figure 2.2.12. Vlkaš 'Do hulského chotára'. Comparison of excavated profile (top) and respective magnetic susceptibility measurements (bottom) for profile c) in Figure 2.2.9.



Figures 2.2.11–14 show the small cross-sections through the pit as comparison between photography and MS values at four different locations (see Fig. 2.2.9). Figure 2.2.10 shows the cross-section along the long axis of this pit.

The fill of the pit can be identified by increased MS values. The cross-sections show that the pit fill is heterogeneous in terms of the MS values, as was also observed before (Pickartz *et al.*, 2020a). The eastern part of the profile in Figure 2.2.11 shows two spots with measured susceptibility values above 100×10^{-5} SI. The comparison with the photograph shows that these correlate with pieces of daub.

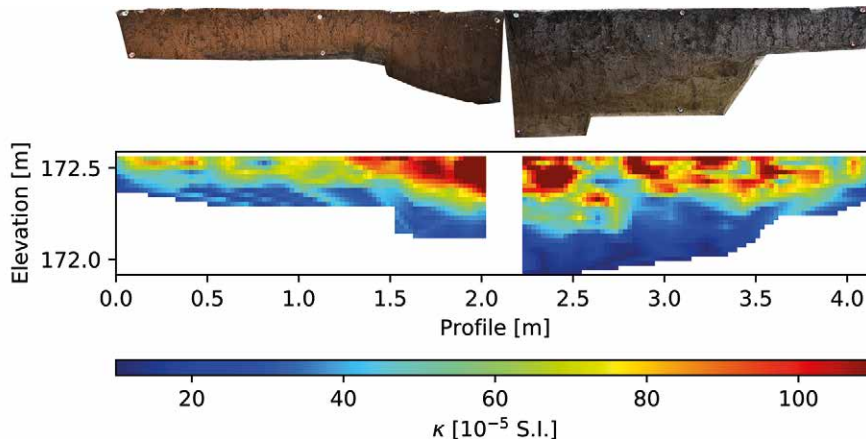


Figure 2.2.13. Vlkas 'Do hľského chotára'. Comparison of excavated profile (top) and respective magnetic susceptibility measurements (bottom) for profile d) in Figure 2.2.9.

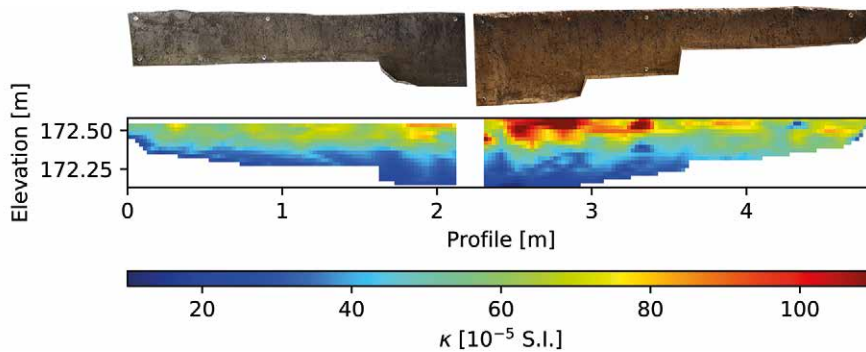


Figure 2.2.14. Vlkas 'Do hľského chotára'. Comparison of excavated profile (top) and respective magnetic susceptibility measurements (bottom) for profile e) in Figure 2.2.9.

The microtopography of the bottom of the pit is irregular in terms of MS variations. This indicates that the lateral long pits are composed of an apposition of smaller pits. These may have been dug and filled at independent points in time (Pickartz *et al.*, 2020b).

Discussion

The aim of this study was to complement the magnetic maps with depth information and susceptibility measurements. However, we found that the embedded archaeological structures seen in the magnetic map cannot be detected in every geological setting. The detectability is dependent on the physical properties of the subsurface and the features and the geometry, as well as the characteristics of the measurement devices. This discussion is divided into sections focusing on the applied methods.

Ground-penetrating radar

The GPR survey at Úľany nad Žitavou 'Dolné diely' shows different reflections that form a layered, hill-like structure in the subsurface. The modern topography also has a small hilltop at this location. The interpretation in the archaeological context is still unclear. Possibly one of those layers is the Neolithic surface. To test this, coring is planned in a future field campaign.

Earlier studies have shown that the lateral long pits can also be documented with GPR, after removal of the plough layer (Pickartz *et al.*, 2020b). At another Neolithic site on loess, Kainz (2016) also observed difficulties with the detection of pits below

the topsoil. However, they were also able to measure the archaeological features with GPR after topsoil removal.

GPR was also applied at the other sites in the Žitava Valley, but unfortunately could only be accomplished on top of the plough layer. The results show no hint of the lateral long pits and are thus not shown here. The undetectability of the lateral long pits within the Žitava Valley by GPR seems to be a result of several aspects. These are (1) a heterogeneous plough layer with microtopography that leads to bad and variable coupling between the antenna and the ground; (2) high electric conductivity of the surface layer (about 40 mS/m), which may even be increased by the unknown factor of the imaginary part of dielectric permittivity and thus high attenuation; and (3) low permittivity contrasts between pit fill and surrounding material.

Electromagnetic induction

The EMI inversion results show areas of decreased conductivity at the locations of the magnetic anomaly of the Neolithic house. However, the variability of the conductivity along the measured profiles is low (values range from 10 mS/m to 50 mS/m). Therefore, the noise occurring due to continuous measurements seems to mask the expected structures.

The modelling studies showed that a device with larger coil spacings can yield measurements with a higher variability between feature and surrounding soil, especially if a plough layer is present, exceeding the level of measurement accuracy as published by the manufacturer. However, the modelling studies were performed with a 1D subsurface model. This means that the subsurface model consists of horizontal layers and therefore the lateral extension of the pits is not considered. The larger distance between transmitter and receiver coil not only yields a deeper penetration depth, but also a larger subsurface volume through which the electromagnetic field travels. Similar to those measured with ERT, the values measured with EMI represent an ‘average’ value of the penetrated volume. Consequently, structures with a small lateral extension may also not be detectable with a device with larger coil spacings.

Electric resistivity tomography

The inversion results of the ERT profiles show some variability that partly correlates with the magnetic anomalies and the EMI model. However, they seem to be too large and deep for the structures that are expected. This is a resolution problem of the ERT inversion and could be improved by incorporating additional constraints on *e.g.* layer interfaces or in-situ resistivities (Wunderlich *et al.*, 2018). This would reduce the ambiguity of the inversion calculations and may result in a model that more closely resembles the expected dimensions of the pits’ cross-sections.

Magnetic susceptibility

The measurements of the MS show the fill of the pit and postholes by increased susceptibility values compared with the background level. For the pits, the variability is low, ranging from 10×10^{-5} SI to 50×10^{-5} SI (outside to inside). However, MS measurement is the only geophysical method that was able to document the postholes at all in the Žitava Valley. Despite of the clear result of the MS measurement, this could only be conducted in this manner during excavations, *i.e.* it cannot be used to plan those excavations.

The cross-sections of the lateral long pits are also visible in the MS measurements. The variability in depth of the increased susceptibility layer has been observed before (Pickartz *et al.*, 2020a; 2020b). Moreover, the MS values can form the basis for a better

understanding of the magnetic anomalies in terms of modelling studies to determine the ratio of induced and remanent magnetisation (Pickartz *et al.*, 2020a).

However, the complete cross-sections are stitched together from single measurements of profile sections that have been conducted with different devices. It is known that different devices yield different MS values for the same samples (Deng and Smith, 2016). This means that there can be a systematic offset between the sections that were measured with different devices. However, the MS distribution within the sections is consistent, and qualitative interpretations are reliable.

Conclusions

Magnetic surveys yield well-interpretable maps of the LBK settlement sites in the Žitava Valley (see Chapter 2.3; Furholt *et al.*, 2014). Targeting the building remains of the sites, *i.e.* the lateral long pits and postholes, measurements of the MS depict these, as we have shown in this chapter and previously (Pickartz *et al.*, 2020a). However, the methods that measure the electric resistivity, *i.e.* EMI and ERT, yield results that are challenging to interpret in the presented study sites. The modelling study for EMI indicates that the contrast in conductivity between the pit fill and the surrounding material may just be too low and the object too deeply buried under the masking topsoil to give a clear response. An improvement for future measurements would be to either use an EMI device with larger coil spacings, as was tested here in the modelling study, or to remove the plough layer. A previous study has already shown that after removal of the topsoil, the inversion results of the EMI measurements correlate well with the excavation results (Pickartz *et al.*, 2020b). At Úľany nad Žitavou ‘Dolné diely’, GPR measurements were successful in delineating subsurface layers, of which may be the Neolithic surface. To improve the understanding of the GPR and ERT measurements, we propose to add in-situ measurements from boreholes or direct push and also dating of material taken from boreholes to identify the Neolithic surface, which is the likely horizon for further settlement finds.

Acknowledgements

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2.3 Prospection results of the LBK and Želiezovce settlement sites in the Žitava Valley, south-western Slovakia

Bastian Breitenfeld

Abstract

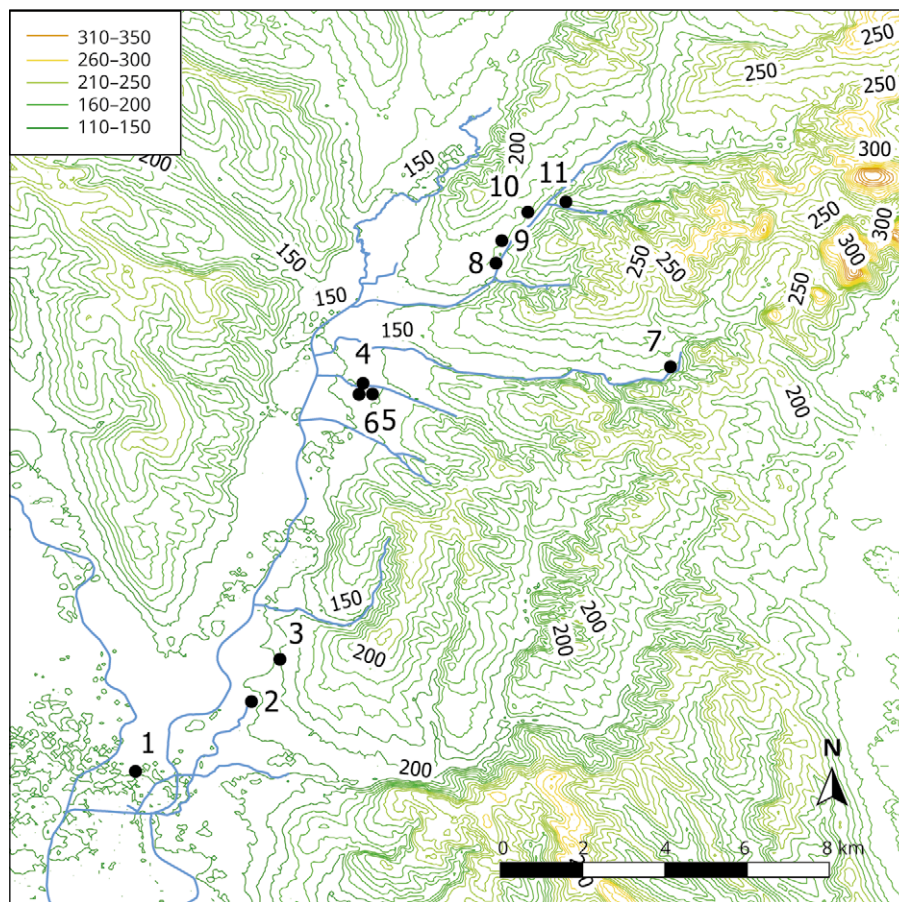
We conducted intensive fieldwalking surveys on six settlement sites of the Early Neolithic in the Upper Žitava Valley. Four of these locations were further investigated with magnetic prospection. The datasets were used to infer the chronology of the settlement sites. A correlation between surface finds and subsurface contexts was investigated by a combination of non-invasive methods. We discovered multiple settlements from the younger *Linearbandkeramik* (LBK; Linear Pottery) culture and Želiezovce group (ŽG), displaying largely contemporary habitation sites of varying degree and size. The results suggest a basic correlation between finds and contexts.

Keywords: Field survey, find distribution, magnetic prospection, ceramic chronology

Introduction

The region under investigation, located in south-western Slovakia, is part of the fluctuation in resources and cultural phenomena throughout the Carpathian Basin and the Danube River drainage since the start of the Holocene. In the 6th millennium, settlers of what is known as the LBK culture used the fertile loess soils along the Žitava River for their settlements, while a local variant of the LBK, the ŽG, evolved. Since 2012, multiple field seasons within the project ‘The Dynamics of Settlement Concentration Processes and Land-Use in Early Farming Communities of the Northwestern Carpathian Basin’, funded by the Deutsche Forschungsgemeinschaft (DFG; German Research Foundation) have attested to the significance of the site of Vráble ‘Veľké Lehemby’, with its three contemporary neighbourhoods (Furholt *et al.*, 2020). The agglomeration of three settlement cores, one enclosed by a ditch system, led us to ask how the local LBK settlements were structured, and the investigation of other sites from the same time period promised insights into settlement structure and dating and, overall, a better understanding of settlement dynamics in the Early Neolithic in the Žitava Valley.

Figure 2.3.1. Map showing the location of the Žitava Valley and sites mentioned in the text:
 1 Úľany nad Žitavou 'Dolné diely';
 2 Vlkaš 'Do hľuského chotára';
 3 Veľká Maňa 'Za hlbokou cestou';
 4–6 Vráble 'Veľké Lehemby';
 7 Číjfare 'Nad trstím'; 8 Tajná 'Nad lúkami'; 9 Tajná 'Klisovnice';
 10 Nevidzany 'Dolné urbáre';
 11 Nevidzany 'Za kostolom'.



In 2017 and 2018, two field campaigns focusing on locations in the wider vicinity of Vráble were organised. Promising locations were chosen on the basis of find registers and published catalogues (Ruttkayová and Ruttkay, 1991; Kopčeková, 2010; Gabulová, 2015). We present here the results of intensive field survey on six and magnetic prospection on seven localities in the Upper Žitava Valley (Fig. 2.3.1). Being an important research focus in the investigation of the LBK, information from non-invasive prospection promised the possibility to estimate spatial organisation. Recognising both the internal structure of the settlements and their sizes is of significance, as these allow conclusions to be drawn about the regional organisation. Research questions mainly concerned the spatial structuring, as well as the relative dating of the sites under investigation, informing about LBK settlements in the vicinity of Vráble 'Veľké Lehemby'. Furthermore, other geophysical investigations were conducted at selected sites (see Chapter 2.2). New evidence and datasets from the prospection provided an opportunity to combine these with results from excavations. The obtained information from two sites with settlement contexts was used to organise two excavations in 2018 (see Chapter 3.1).

Methodology

This survey was designed to locate settlement sites from the younger LBK (YLBK) and the ŽG in the vicinity of Vráble 'Veľké Lehemby'. A classical approach would be to take a look at suitable locations in the environment, especially given the relative uniformity in the settlement locations known from the LBK, in close proximity to small rivers and a specific soil (see Chapter 2.1). However, large-scale, intensive

surveys were not possible due to modern structures, and limiting factors, such as time and labour. Find registers and previous work in the region provided the foundation for possible locations of domestic sites, mostly known from isolated surface artefacts.

In a first phase, locations were tracked down and checked for possible limiting factors, such as modern structures or vegetation cover. If fieldwork was manageable, a small team searched the surface unsystematically. Considerable amounts of diagnostics led to site assessments and the execution of systematic prospection.

The intensive surveys were conducted in transects with differing amounts of trained personnel. Specific experts were on hand. The participants formed straight lines approximately 2 m apart from one another, keeping a low search radius to ensure a high detection probability (Banning, 2002; Banning *et al.*, 2006; 2017). Supervisors kept track of transects, compliance with gaps, and alignment. Diagnostic artefacts were gathered for later analysis, and the coordinates of all prehistoric artefacts were measured via GPS. The pottery, as the main diagnostic artefact group, was documented by a recording system developed for the Vráble materials (see Cheben *et al.*, 2020). Based on the decoration, the material was typologically analysed, allowing an estimation of the relative chronology of the sites. The typological model goes back to J. Pavúk (1994; 2009), who identified decoration of chronological significance.

After successful surveys, most of the sites were measured with magnetic prospection. This is known to produce useful visualisations of subsurface LBK contexts (Furholt *et al.*, 2014; Müller-Scheeßel *et al.*, 2020). The backfill of lateral long pits that accompany the longhouses leads to divergent magnetisation from the surrounding soil (Pickartz *et al.*, 2020). The contexts are often dug into loess, which has a lower magnetisation than, for example, the usual backfill (Neubauer, 2001). Variations in Earth's magnetic field vector were measured by magnetic gradiometry. The measurements were conducted with fluxgate sensors from Foerster or Sensys mounted on carts and supported by DGPS for spatial positioning. Usually, the area of measurement was determined by the borders of the specific parcels, area of vegetation, weather and time expenditure.

Results

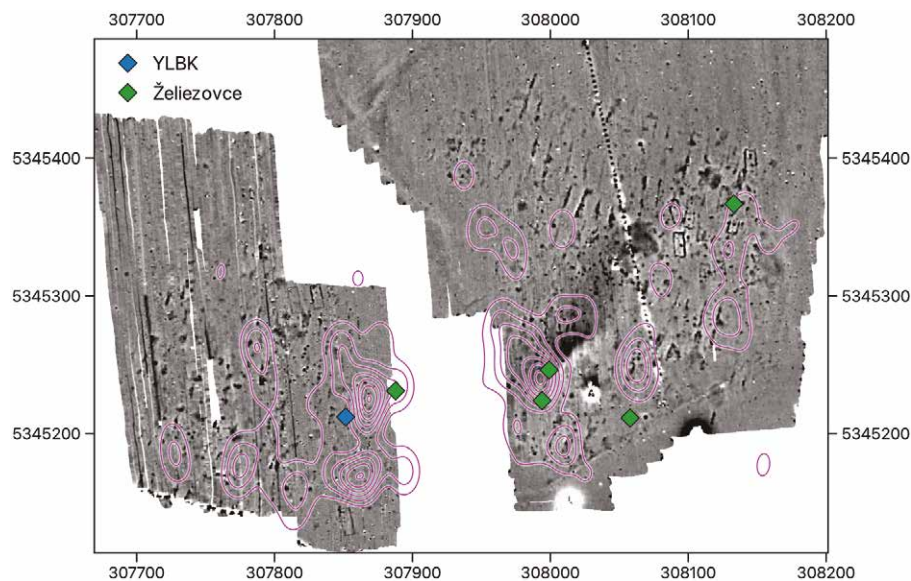
Čifáre 'Nad trstím'

Čifáre is located east of Vráble, next to the stream Telinský potok, where reports suggested the existence of a site from the LBK. In the surrounding area, finds from the LBK, Maďarovce and Baden cultures have been reported (Bátora, 1981: 31; Ruttkayová and Ruttkay, 1991: 14; Gabulová, 2015: 151).

The survey covered an area of 13.6 ha and located find distributions across two small elevations and a gully. Despite reduced visibility due to snow cover, multiple find clusters were documented. Two main clusters were located alongside the depression that formed a gap in the find distribution (Fig. 2.3.2). Erosion may have formed a find-covering colluvium within the depression.

Overall, the survey located over 370 artefacts, 38 of which were kept for further analysis. Compared with other sites, a high number of lithics were collected, comprising three flint blades, one obsidian fragment as well as two adze fragments. Most pottery decoration, such as motifs formed by straight and angled incised lines and finger imprints, are typical for the LBK and the ŽG but are not significant chronologically. Only four sherds are thought to be significant chronologically. Pottery with the characteristic 'Notenkopf' (music note) decoration was recognised, as well as pottery with notches through lines. This sparse diagnostic material is characteristic

Figure 2.3.2. Čifáre 'Nad trstím'. Combined results of magnetic prospection and find distribution. Kernel density estimate contour of pottery distribution with diagnostic sherds marked separately.



of the YLBK and ŽG pottery styles. While notches indicate the later, local decorative variety, the 'music note' decoration suggests an early phase of the ŽG or a late phase of the YLBK. Considering the small sample, this chronological tendency needs to be verified. Some material of a different type was ascribed to the Baden culture, with its characteristic ornamental strips.

Magnetic prospection was conducted on each side of the depression. The map shows many positive anomalies, which for the most part are relatively small and of varying form. Smaller anomalies are interpreted as settlement pits, but their character or function needs to be confirmed by excavations. Overall, the area of LBK and ŽG settlement is estimated at about 9 ha, including the depression. The western area covers 3.6 ha. Here, anomalies are dispersed but mainly visible in the southern half, where possible lateral long pits are slightly visible. For problems concerning the connection between anomaly interpretation and subsurface contexts, see Winkelmann *et al.* (2020). In the eastern area, the characteristic lateral long pits from longhouses are identified, most of them clustering in an area of 4 ha. In sum, based on the elongated anomalies, at least 30 longhouses are indicated. All show an orientation of roughly NNE–SSW, and a closer examination of the orientation by colleagues determined a mean value of 16.1° from north (Müller-Scheeßel *et al.*, 2020: table 1). Dimensions vary, and some tend to be of rectangular or almost square shape, which is uncharacteristic for the LBK. These structures are interpreted as houses from a different time period.

East of the depression, an open space without identifiable structures is visible. Areas without built structures within settlements are known from other contemporary sites, such as Štúrovo (Nitriansky kraj, Slovakia) and Vráble 'Veľké Lehemby' (Pavúk, 1994; Furholt *et al.*, 2014).

The combination of artefact distributions and magnetic survey displays differences in the location of artefact concentrations and reconstructed habitation structures. The formation processes of the surface record are not clear, but erosional processes linked with ploughing are likely factors for displacements, as suggested by higher find densities towards and in the depression. The investigations verified a settlement from the YLBK and the ŽG. Anomalies suggest longhouse structures with slightly different orientations, built in rows. Habitation during later phases is suggested by differing house layouts and diagnostic pottery.

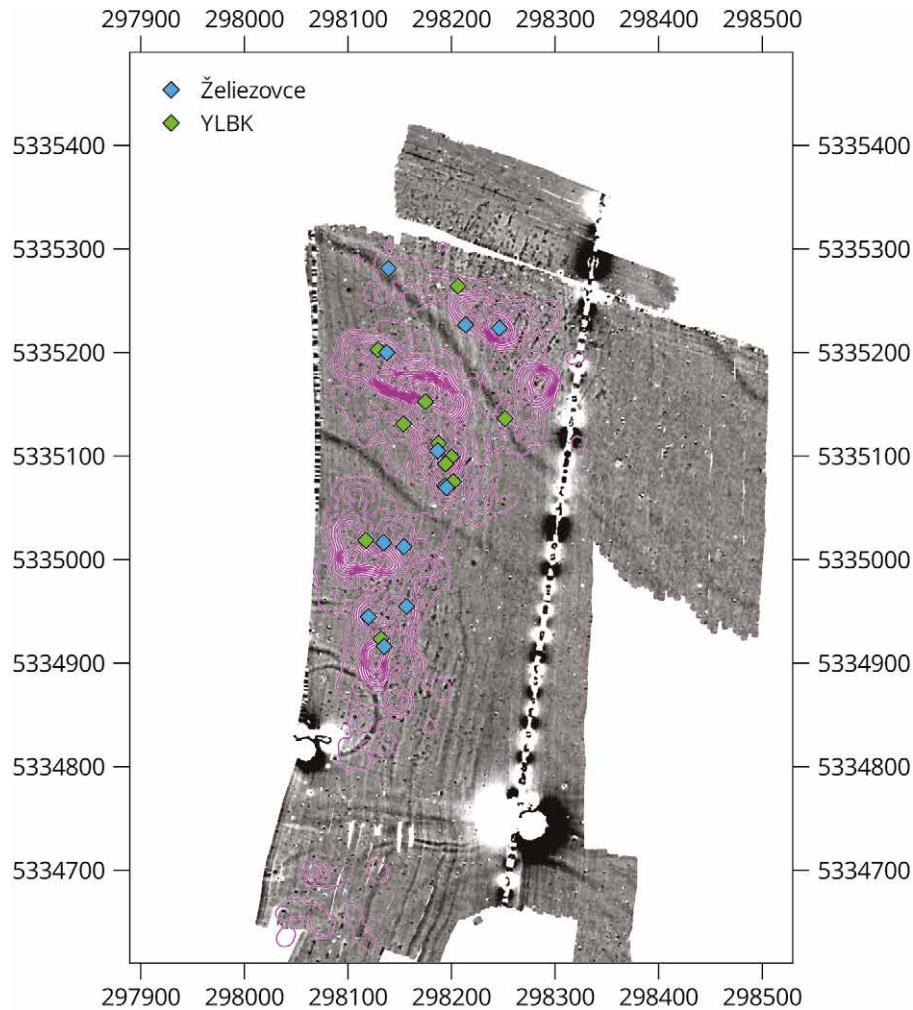


Figure 2.3.3. Velká Maňa 'Za hlbokou cestou'. Kernel density estimate contour of the pottery distribution with diagnostic sherds marked separately.

Velká Maňa 'Za hlbokou cestou'

Construction work on the nearby street cut through different contexts from the YLBK, ŽG, Lengyel and Baden culture (Kuzma, 1996: 114). A site with pottery from the LBK was mentioned by A. Točík and located to the south, which probably is the same settlement complex (Točík, 1981: 299; 307; fig. 170.12).

The intensive field survey recognised find clusters covering multiple small elevations and depressions. The investigated area is 15.9 ha, and 1833 individual find locations were documented. They clustered in three areas, with small gaps between them, which cover a total area of approximately 7 ha. In general, the diagnostic sherds are intermixed. The central cluster is dominated by pottery attributed to the YLBK, while the area with the highest artefact density is characterised by diagnostics representing the YLBK and early ŽG (Fig. 2.3.3). Some material attributed to roughly the same phase tends to cluster, but the distribution does not show significant concentrations of phase-specific pottery. From the 230 sherds with decoration, only 12 per cent were diagnostic. The diagnostic elements comprised 'music note' impressions in different motifs, interrupting or ending incised lines (Pl. 2.3.1, 4; Pl. 2.3.2, 14, 19). Similar finds are known from excavated contexts and are attributed to the middle phase of the YLBK (Pavúk, 1969: fig. 4.16). Other decorations (e.g. triangular impressions (Pl. 2.3.1, 11) combined with three lines (Pl. 2.3.2, 8)) are more indicative of the transition to the ŽG (Pavúk, 1994: 145). Some ŽG fragments were decorated with typical notches (Pl. 2.3.2, 11). Long notches, wavy bands, as

well as an elaborate decoration with notches (Pl. 2.3.1, 5; Pl. 2.3.2, 3) are assigned to the developed phase of the ŽG (Cheben *et al.*, 2020). Fluted decoration and notched ornamental strips were recognised as Baden culture material. Comparable finds are known from Velké Vozokany (Cheben *et al.*, 2013: 90, fig. 5). Other ceramic fragments date to the Middle Ages, with their design resembling Slavic decorations. Besides pottery, a fragmented grindstone and two flint fragments were found.

Most of the ceramic material was located on small elevations, indicating subsurface archaeological contexts. Major displacement of the material is unlikely, and erosion towards the slope gradient in the west is possible but not visible in the distribution.

A magnetic survey resulted in the reconstruction of 29 longhouses (Fig. 2.3.3), with a mean orientation of 24.5° from the north-south axis, spanning a proposed settlement area of 5.7 ha (Müller-Scheeßel *et al.*, 2020).

Nevidzany ‘Dolné urbáre’

The site is located on the west bank of the stream Širočina, an inflow of the Žitava. This west bank has a relatively steep eastern slope gradient and is heavily used agriculturally. Artefacts from the Neolithic, Eneolithic, Iron Age, Roman Era and Middle Ages were reported from the investigated area (Ruttkayová and Ruttkay, 1991). Archaeological features extending farther north of the surveyed area, as recognised after fresh ploughing of LBK contexts. An area of approximately 5 ha was investigated by intensive survey, locating 3250 individual finds. The survey was not able to investigate the entire find distribution, as there was no visible decrease in find density in southerly direction. The highest find density was noted close to the centre of the survey. Downslope, a higher number of sherds of coarse pottery were recognised. Relatively dated pottery did not show significant concentrations. For the most part, diagnostic pottery from the YLBK and ŽG was intermixed (Fig. 2.3.4). The distribution of diagnostic sherds displays a slight concentration of typologically younger material in the north-western part. Altogether, 872 finds were gathered for later analysis, mostly pottery. Documented lithics included debris, blades and blade fragments of flint and obsidian, as well as three adze fragments.

The analysis of decoration included 403 ceramic sherds. Different compositions of ‘music note’ impressions, partly connected, are ascribed to the YLBK and the transition to the ŽG (*e.g.* Pl. 2.3.3, 4, 14; Pl. 2.3.4, 18). About 7 percent of the diagnostic fragments were incised with notches typical of the local variant. Fragments with more elaborate motifs, such as four notches arranged vertically interrupting angled bands (Pl. 2.3.4, 19), or a long notch covering two bands (Pl. 2.3.3, 11), are a later development. Some pottery was decorated on both sides, which is especially known from bowls and is linked to the ŽG (Pavúk, 2009). One sherd (Pl. 2.3.4, 17) with comb-like impressions in an array above the base joined by multiple vertical lines is ascribed to the Bajc-Retz type (*Furchenstich*) ceramic tradition, with direct comparisons known from other sites (Cheben, 2000; Piatničková, 2010).

While the analysis focused on the finds from the LBK, 40 fragments from other periods were gathered. Typical finds from the Baden and Lengyel cultures were identified, which have direct comparisons from earlier investigations of the locality (Ruttkayová and Ruttkay, 1991: fig. 22; fig. 27.1). The site also contained pottery from the Middle Ages.

The magnetic prospection covered an area of 5 ha. Again, minor anomalies are scattered throughout the greyscale map. The area with lateral long pits extends only about 2.5 ha, and the find concentrations correspond to these subsurface contexts. Gaps in the surface distribution are comparable to the results of the magnetic prospection, except for the south-eastern part, where anomalies are sparse. Therefore, displacement due to erosion is possible, but post-depositional processes are considered to be a minor factor.

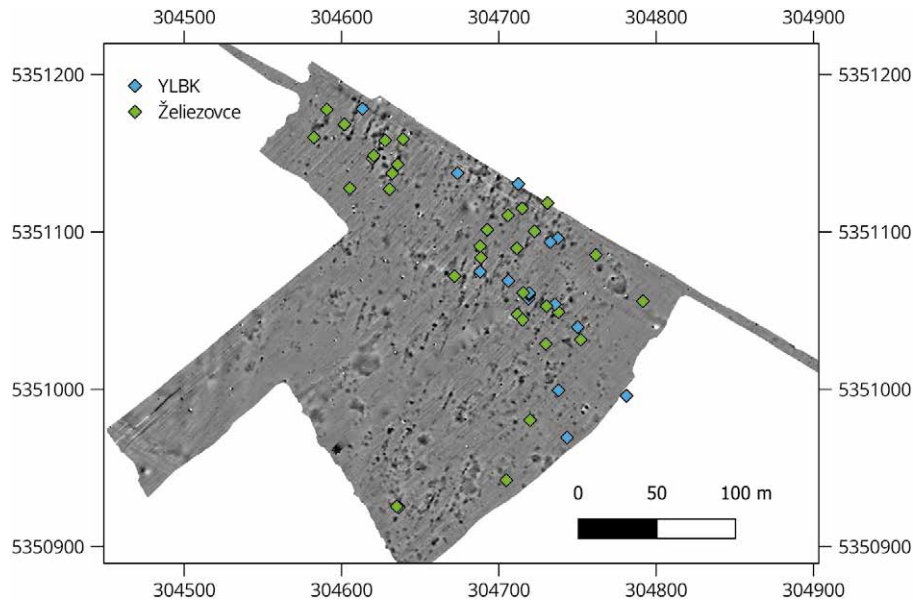


Figure 2.3.4. Nevidzany 'Dolné urbáre'. Combined results of magnetic prospection and diagnostic find distribution.

The pits suggest an orientation of former longhouses in roughly NE–SW direction. Without knowing the complete ground plan of the settlement, the structuring of visible anomalies suggests alignments in multiple rows. Some anomalies in the north-western part seem to be clustered, which is also true for diagnostics ascribed to the ŽG. Based on the results from Vrábľe, this may be linked to farmstead-specific decoration (Cheben *et al.*, 2020).

Nevidzany 'Za kostolom'

This site is known to have yielded finds from the LBK, ŽG, Lengyel and Baden cultures, however, the exact location differs (Ruttayová and Ruttay, 1991: 30, fig. 22; fig. 24; fig. 25; fig. 27; Gabulová, 2015). During an unsystematic survey, only finds from the Lengyel culture were identified, and no further investigation was organised.

Tajná 'Klisovnice'

A field survey conducted by J. Batora located prehistoric artefacts in 1975. The site is just a few hundred metres south of Nevidzany 'Dolné urbáre' (see above). Different investigations suggest intensive prehistoric activity close to the Širočina (Batora, 1976; Gabulová, 2015).

The survey located 452 artefacts, of which 64 ceramic sherds were typologically analysed. One adze and a spindle whorl were also among the finds. A cluster with high artefact density was documented in the north-eastern part, with the density reducing towards the south. The highest concentration was located about 250 m north-west of the Širočina and covered an area of approximately 0.5 ha. Smaller concentrations were distributed in the more eastern parts. Overall, the distribution covered about 3.8 ha. Towards the stream, the distribution stops abruptly, indicative of erosion at the foot of the slope (Fig. 2.3.5). 'Music note' impressions are rare (Pl. 2.3.5, 11), and notches, in different combinations, were found more frequently (Pl. 2.3.5, 8). Two fragments showed decorations on both sides, and another fragment was decorated with a notched rim; these are considered to date to the middle phase of the ŽG (Pavúk, 1969: 290; 327, fig. 37.1, fig. 38.12). A decoration with a long notch interrupting angled bands is dated to the later phase (II) of the ŽG (Pavúk, 1994: 148–149). One pottery fragment was painted red, which has parallels from the early

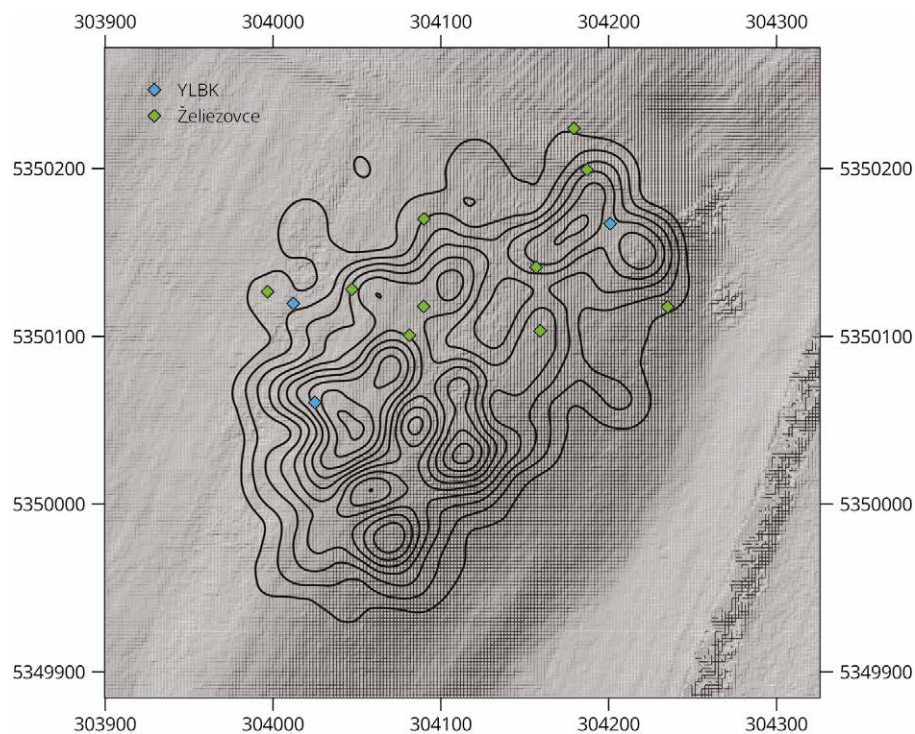


Figure 2.3.5. *Tajná 'Klisovnice'*. Kernel density estimate contour of the pottery distribution with diagnostic sherds marked separately.

phase of the ŽG onwards (Pavúk, 2009). Most of the decorations have parallels in contexts that are thought to date to the developed phase of the ŽG. Some pottery is assigned to the Eneolithic; other fragments are of Slavic origin. Based on typology, younger ornaments dominate the survey finds and multiple developments of the ŽG style were identified. Only a few fragments of the material can be ascribed to the *'Notenkopf'* style. It has not yet been possible to conduct geophysical prospection at this location.

Tajná 'Nad lúkami'

The site was investigated by means of a non-systematic survey. The scarcity of finds obviated further investigations. Some fragments may be from the LBK or ŽG, but no unambiguous decorations were detectable. A few ceramics are ascribed to the Eneolithic Baden culture and the Middle Ages.

Úľany nad Žitavou 'Dolné diely'

Multiple isolated finds were collected in 1998 that are typologically consistent with pottery from the YLBK and the ŽG (Steiner, 2000: 172; fig. 120.2–6; fig. 121.5–6; fig. 122.3). A preliminary survey located densely distributed pottery, which led to an intensive survey of an area of 3.9 ha. The land is in agricultural use and is disturbed by recent house structures. Adjoining the area to the north, railways pass by. The archaeological contexts and surface distribution are expected to be heavily disturbed by construction and agricultural work. A displacement of artefacts is visible in the distribution, as a higher density is documented next to the modern estate at the edge of the parcel. The highest density of artefacts was documented almost in the centre of the investigated area. In either direction, these concentrations drop off quickly. South of the estate, further artefacts were collected, suggesting the interruption of the find cluster by modern structures (Fig. 2.3.6).

The survey located 1185 individual finds, which include flint, obsidian and ground stone artefacts. The pottery is poorly preserved. Only a small proportion of the

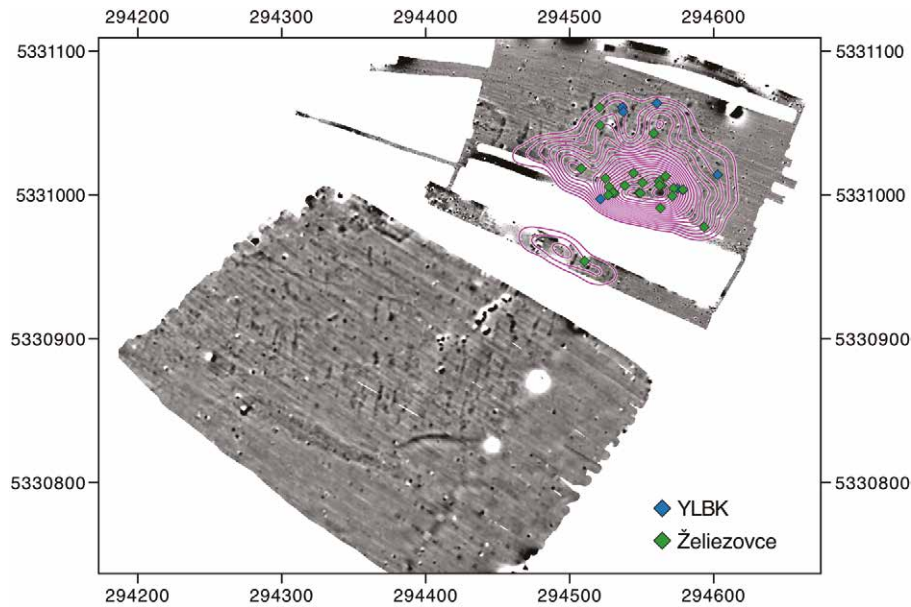


Figure 2.3.6. Úľany nad Žitavou 'Dolné diely'. Combined results of magnetic prospection and find distribution. Kernel density estimate contour of the pottery distribution with diagnostic sherds marked separately. Only the northern part of the settlement was field-walked.

sherds were typologically analysed. A few fragments were ornamented with 'music notes' combined with different compositions of incised lines (Pl. 2.3.7, 5). Again, long notches (Pl. 2.3.7, 15), some combined with wavy lines, are known from the second phase of the ŽG (Pavúk, 1994: 153). Further finds considered to date to this phase are a sherd decorated with double bands each interrupted by notches (Pl. 2.3.8, 6), and a fragment with decorations in red paint on both sides (Pl. 2.3.7, 14). Besides fragments of Neolithic origin, pottery from the Middle Ages was found, which has direct parallels in the Slavic burial grounds located in the same village (Liptáková, 1963; Vlkolinská, 1994).

The site was first prospected with magnetic gradiometry in 2017, covering an area of approximately 2.6 ha. In the summer of 2018, more measurements south of the area of the pedestrian survey covered ca. 5.8 ha. In sum, about 34 houses have been reconstructed. Their orientation is suggestive of a steady settlement occupation from the early to the late phases of the local YLBK and ŽG (Müller-Schneeßel *et al.*, 2020: fig. 9). Additionally, a small excavation was conducted in 2018 (see Chapter 3.1). A direct connection between subsurface contexts and survey materials based on phase-specific clustering is not given for this excavation.

Vlkaš 'Do hulskeho chotára'

The site is located between Úľany nad Žitavou 'Dolné diely' and 'Veľká Maňa', on the eastern bank of the Žitava. Former work recognised intensive prehistoric activity in this area, including the location of Hul, to the south (Točík, 1981; Müller-Schneeßel *et al.*, 2016: fig. 8). An area of approximately 16.6 ha was investigated systematically, yielding more than 1400 individual finds (Fig. 2.3.7). The slope gradient towards the stream characterises the entire site, and especially in the northern part, most finds accumulate in the western end of the slope. These accumulations are oriented on a north-south axis, which is explained by formation processes, especially erosion combined with ploughing. To the east, the artefact density strongly decreases. Other areas of the field towards the south show the same patterns. Most diagnostic material was gathered in the northern part, where artefacts from younger phases slightly outnumber those from older ones. For the most part the material is spatially intermixed. Towards the centre of the survey area, a gap in the accumulations is visible. Here, only pottery ascribed to the ŽG was collected downslope, while pottery ascribed to older phases was collected

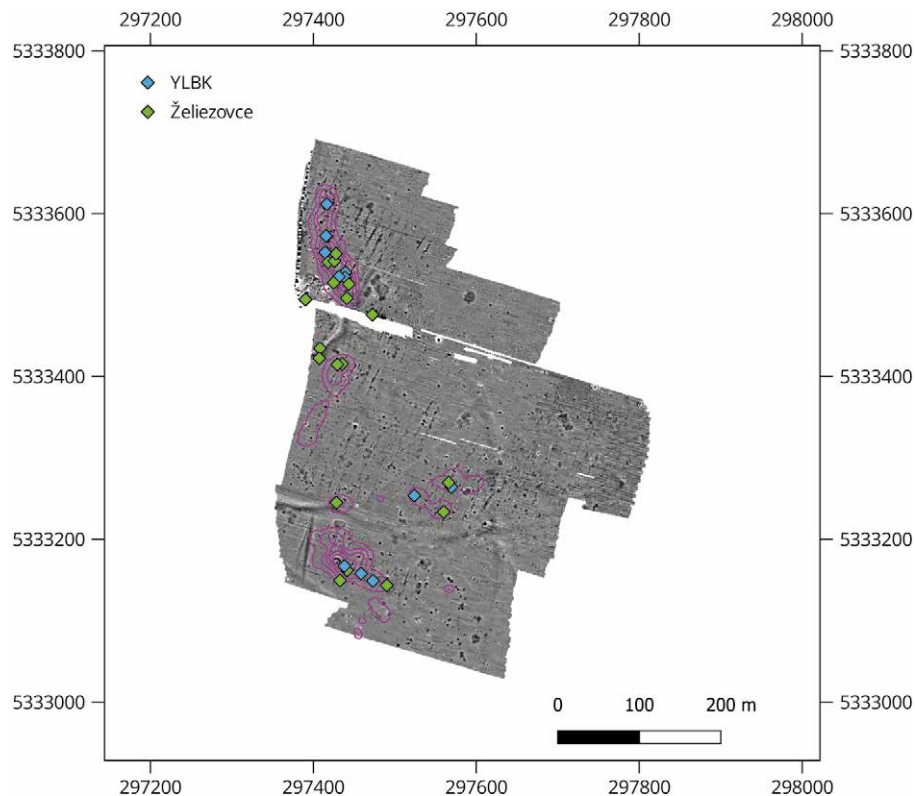


Figure 2.3.7. Vlkas 'Do hulského chotára'. Combined results of magnetic prospection and find distribution. Kernel density estimate contour of the pottery distribution with diagnostic sherds marked separately.

upslope. In the southern parts of the survey, more clusters with high finds densities were explored, which yielded pottery from both older and younger phases. Towards the south, no decrease in artefact density is observed, indicating that the adjoining areas in this direction are part of the prehistoric activity zone.

Overall, 1396 pottery fragments were documented, mostly without diagnostic attributes. More than 230 sherds were analysed. Besides pottery, some flint blades and a fragmented core as well as an adze fragment and a pendant were found. Three fragments of ground stone may belong to mill stones. The pottery shows characteristic decorations of the YLBK. Again, some notched pottery is dated to the ŽG, and developed phases are represented by multiple bands of incised lines and notched rims (Pavúk, 2009). The relatively dated material suggests an occupation spanning multiple phases of the YLBK and ŽG. The younger significantly outnumbers the older material. A small proportion of the pottery is ascribed to the Eneolithic and to the Middle Ages. Multiple investigations with magnetic gradiometry resulted in about 18 ha of measurements. In total, 61 houses were reconstructed (Müller-Scheeßel *et al.*, 2020: table 1).

Discussion

In order to investigate the domestic sites, non-invasive survey methods were combined with relative dating. Pedestrian survey, magnetic prospection and spatial analyses were used to detect, analyse and relate surface find distributions to underlying contexts. Studies investigating this connection come to both positive and negative results (Johnson, 2014), which is supported by our investigations. Artefacts and their quantities on the surface were used as a marker for human activity (Bintliff, 2000). Due to the lack of stratigraphic positioning, the formation processes of the find distribution are of importance. Within the context of the northern Žitava Valley, it is highly likely that artefacts were displaced and transported from subsurface contexts by intensive agricultural ploughing in modern times, while natural processes played

a minor role. Experiments have shown that displacement processes, even ploughing, may exert only little influence (Redman and Watson, 1970; Lewarch and O'Brien, 1981; Banning, 2002), but there are some issues regarding the correlation.

All sites showed non-homogeneous find distributions with above-average concentrations in sub-areas, which led to the hypothesis of increased prehistoric activity and the potential for the connection to contexts. The sometimes relatively high number of diagnostic sherds led to the potential for phase-specific relative dating of subsurface contexts.

The relative dating is based on typological and quantitative analyses. Surface finds tend to be intermixed from different phases, there may be no connection to any contexts, and the quantity of phase-specific artefacts may be skewed. The depth of the contexts may lead to a higher density of younger materials on the surface. Furthermore, over- or underrepresentation of diagnostics may result from inadequate sample sizes (Banning, 2002). These problems are directly connected to culture-specific factors. The regional archaeological research can draw on a large number of studied contexts, and thus the typology and relative chronology have been studied intensively. Culture-specific factors, such as the backfilling of lateral long pits and their general character (Rück, 2009; 2012; Jeunesse, 2016), or the overlap of the two pottery styles (Pavúk, 1994; Cheben *et al.*, 2020), represent issues in the relative dating of contexts. The mixing of phase-specific finds within the lateral long pits is known in the area of south-western Slovakia and is evident in several inventories. So far, there is no evidence for regularity with regard to the duration of backfilling processes, which may also have extended beyond the active use of the house. However, there are excavated pits (*e.g.* Štúrovo and Hurbanovo (Nitriansky kraj, Slovakia)) that can be assigned to a specific phase typologically (Pavúk, 1994; Březinová and Pažinová, 2011). Phase-specific artefacts showed only minor spatial concentrations, which is partly due to the small size of the inventories, the preservation of decoration and chronological overlap among the pottery styles.

A new study shows a counter-clockwise shift in house orientation over time for different LBK settlements (Müller-Scheeßel *et al.*, 2020). Houses with similar orientation are proposed to belong to contemporary building phases, and a hypothetical time frame for the settlements in the region of the Žitava Valley is posited (see Müller-Scheeßel *et al.*, 2020, Fig. 9–10). This gives us the opportunity to discuss the results from the surveyed sites with regard to dating and house orientation.

In the case of Čifáre 'Nad trstím', some of the structures in the south-eastern part tend to deviate more from the north-south axis than those in the western part. An early phase of this settlement would therefore correspond to about 5200 cal BCE. The settlement seems to grow towards 5100 cal BCE and decline afterwards. The relative chronological tendency based on survey artefacts fits well into the modelled occupation phase and is linked to the emergence of the ŽG style (Müller-Scheeßel *et al.*, 2020: 13).

At Veľká Maňa 'Za hlbokou cestou', the house orientations suggest a relatively early occupation, while the highest density is estimated at approximately 5200–5150 cal BCE. Afterwards, a decline in house density is proposed. The pottery typologically attributed to the ŽG slightly outnumbers that with earlier decoration. This itself does not contradict the proposed settlement development; all phases are represented.

The modelled chronological sequence for Nevidzany 'Dolné urbáre' suggests that the settlement gradually grew from ca. 5250 cal BCE towards 5100 cal BCE and slowly declined in the following century (Müller-Scheeßel *et al.*, 2020: fig. 9). Quantitatively, neither older nor younger material dominates the inventory. This is in accordance with the suggested settlement development as well as the chronological overlap among these styles (Furholt *et al.* 2020).

The typological analyses of pottery from Úľany nad Žitavou 'Dolné diely' shows a predominance of diagnostic materials ascribed to the younger local variant. The house orientations as well as the acquired ¹⁴C dates of the excavation support a dating

to the younger LBK. The dominance of diagnostic material dated to the developed ŽG style can be explained by the fact that the survey covered only parts of the settlement.

For the site of Vlkaš 'Do hľského chotára', the settlement development model suggests that within the site most houses were built between ca. 5250–5150 cal BCE, but that the first houses can be expected to date earlier than that (Müller-Scheeßel *et al.*, 2020: fig. 9). With the emergence of the local pottery style, at about 5200 cal BCE, estimated for the Vráble contexts (Furholt *et al.*, 2020), more diagnostic materials from the younger LBK may be expected. Find clusters could not be correlated with individual contexts or with groups of contexts.

Conclusion

Combining the results from non-invasive prospection methods, new information on LBK settlements in the northern Žitava Valley was obtained. Intensive pedestrian survey was conducted at six locations, supplemented by magnetic prospection at five. The results evidence settlements from the younger LBK and their local variant, the Želiezovce Group. All of the investigated sites yielded diagnostic material representative of the older, 'Notenkopf' style and the younger, notched style. While the artefacts were used for relative dating, magnetic prospection was able to reveal the exact location and structure of the settlements, leading to two excavations, at Vlkaš and Úľany nad Žitavou. Overall, a rough correlation is visible in the distribution of the surface finds from the survey and the archaeological contexts, but each site location and its archaeological record is subject to particularistic formation processes. In general, the determined relative dating of the survey sites is in agreement with the house orientation and the houses' modelled chronology. The matches suggest that the results can supplement each other, while slight discrepancies are probably due to missing data. The results expand our knowledge of the relative dating and structure of settlements in the Upper Žitava Valley, exemplifying strong continuity and activity during phases of the younger LBK and Želiezovce group in the Early Neolithic.

The sites of Nevidzany 'Dolné urbáre', Tajná 'Klisovnice' and Horný Ohaj, only hundreds of metres apart, hold great potential for a comprehensive investigation, especially in light of the agglomerated neighbourhoods at Vráble.

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Plate 2.3.1. Selected finds from Velká Maňa 'Za hlbokou cestou'. Scale 1:2 (image: G. Müller-Scheeßel/B. Breitenfeld).

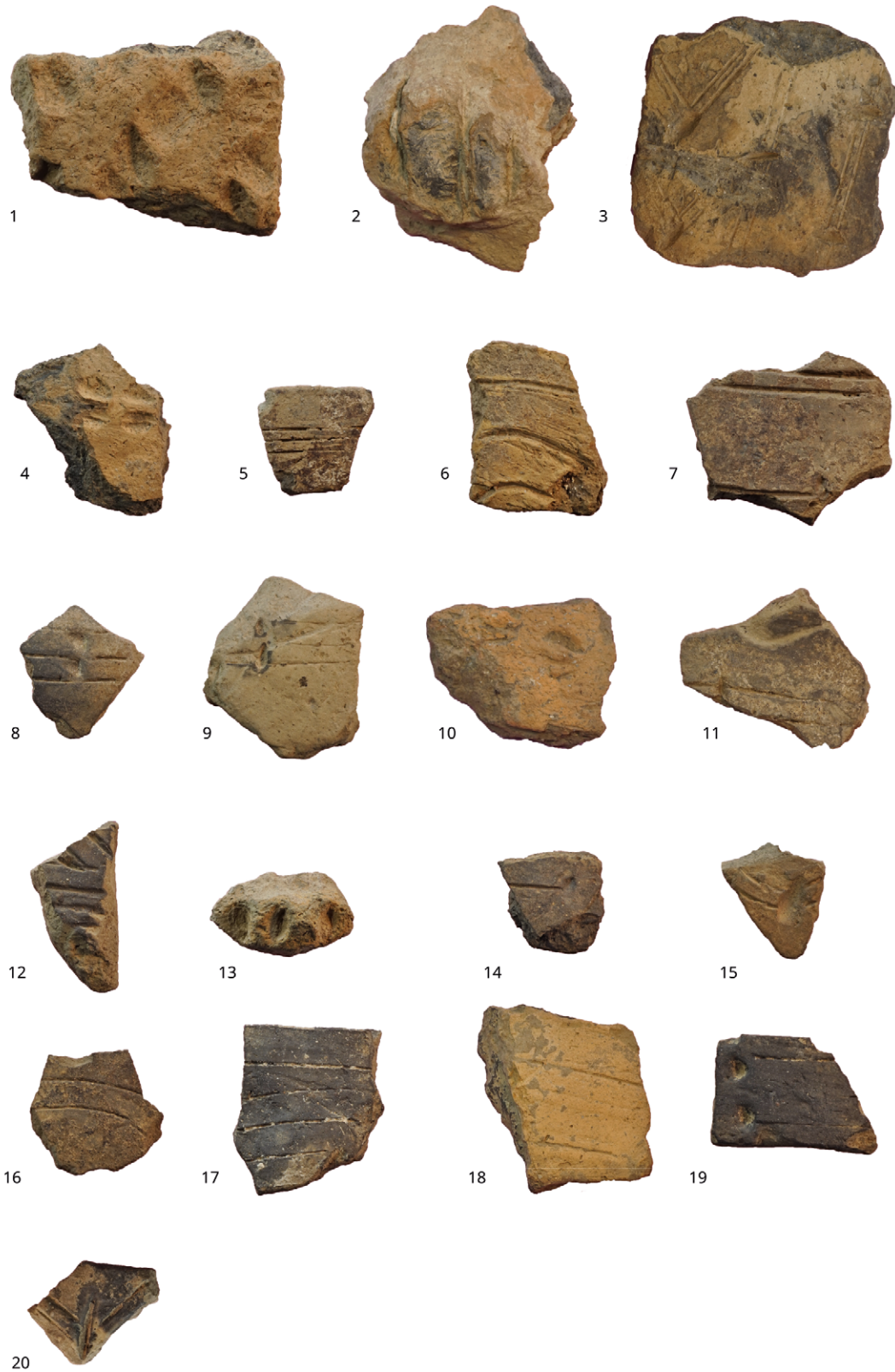


Plate 2.3.2. Selected finds from Velká Maňa 'Za hlbokou cestou'. Scale 1:2 (image: G. Müller-Scheeßel/B. Breitenfeld).

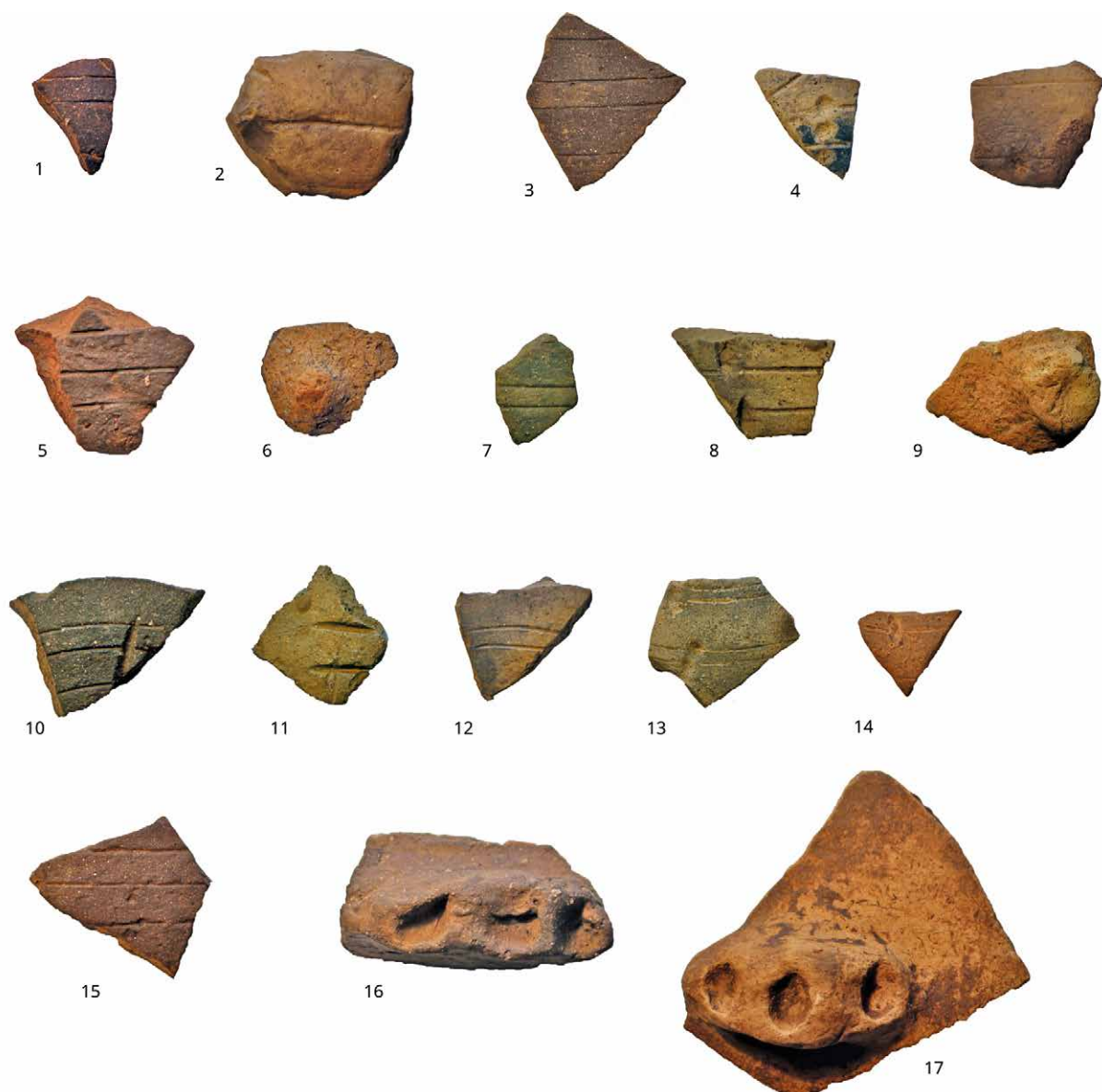


Plate 2.3.3. Selected finds from Nevidzany 'Dolné urbáre'. Scale 1:2 (image: G. Müller-Scheeßel/B. Breitenfeld).



Plate 2.3.4. Selected finds from Nevidzany 'Dolné urbáre'. Scale 1:2 (image: G. Müller-Scheeßel/B. Breitenfeld).



Plate 2.3.5. Selected finds from Tajná 'Klisovnice'. Scale 1:2 (image: G. Müller-Scheeßel/B. Breitenfeld).

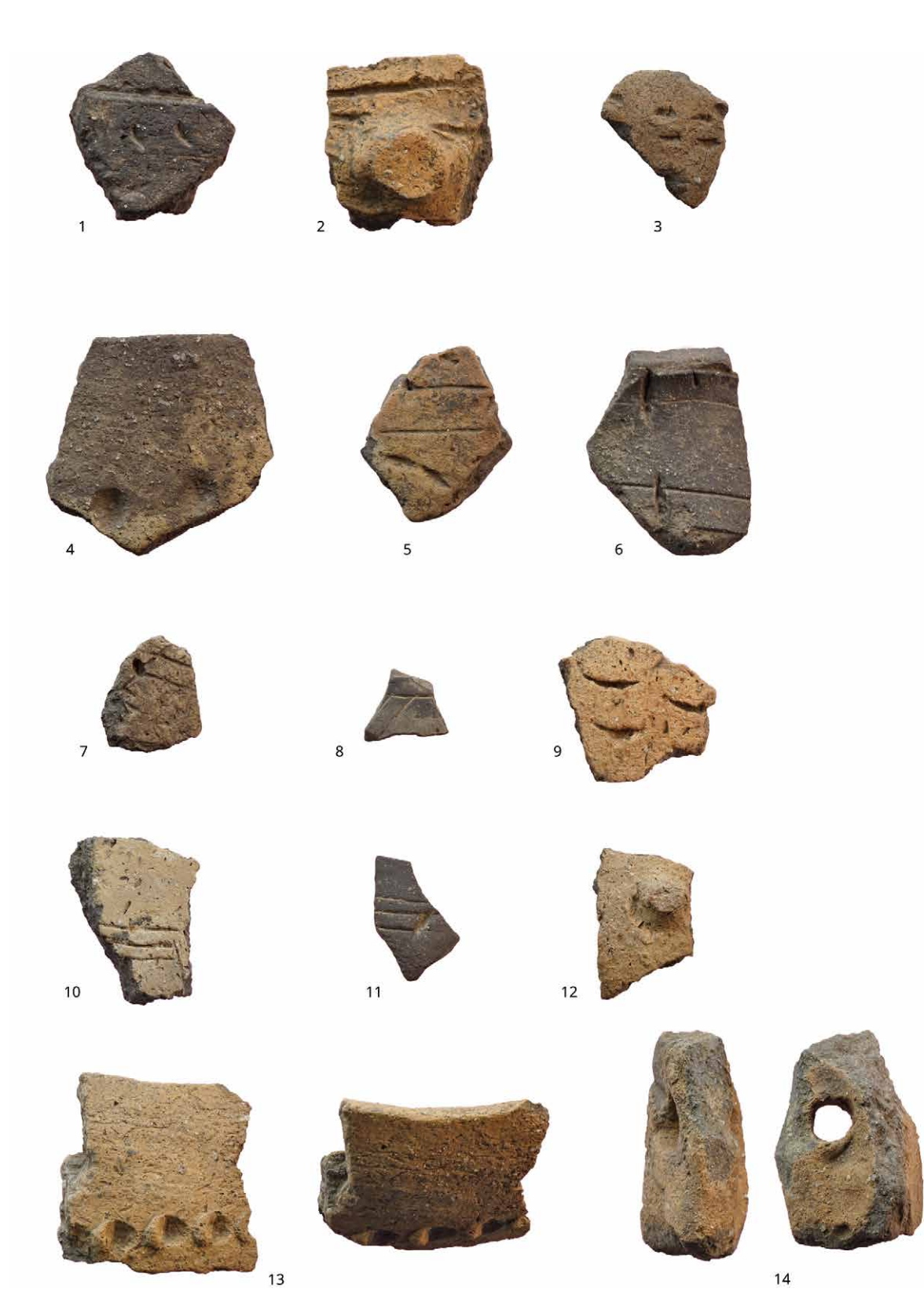


Plate 2.3.6. Selected finds from Úľany nad Žitavou 'Dolné diely'. Scale 1:2 (image: G. Müller-Scheeßel/B. Breitenfeld).

Section 3: Social scales

3.1 Built structures of the Early Neolithic in the Žitava Valley, south-western Slovakia

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Alena Bistáková, Ivan Cheben*

Abstract

We document and describe the archaeological features excavated at the sites of Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľského chotára’ (Nitriansky kraj, Slovakia) in 2018. The presentation of the data is preceded by an outline of the documentation system used in the excavations, as well as a stratigraphic analysis of the two settlements. Afterwards, a characterisation of the discovered house structures is provided, which includes architectural elements, accompanying lateral long pits, and other structures. We also account for the find quantities, relative chronological dating based on pottery ornamentation, and ¹⁴C dating based on Bayesian modelling.

Keywords: LBK, Želiezovce Group, settlement features, houses, find quantities

Introduction

In order to investigate the historical development of the settlement complex at Vráble ‘Veľké Lehemby’/‘Farské’, its impact on the surrounding landscape and the relations among the inhabitants of the Žitava Valley, the subsequent excavations were targeted at recognising the formation of settlements outside of the low-density agglomeration. Two settlements were selected for targeted excavations: Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľského chotára’ (Fig. 3.1.1).

The two sites are located south-west of the main settlement agglomeration, at a distance of ca. 12 km and 15 km, respectively. In both cases the excavations were preceded by geophysical prospection (see also Chapter 2.3). The prospection at Úľany nad Žitavou ‘Dolné diely’ covered an area of approx. 0.11 km² and that at Vlkaš ‘Do hľského chotára’ covered an area of approx. 0.17 km². In both instances, anomalies related to Early Neolithic occupation, *i.e.* rows of long pits, were clearly discernible, indicating a presence of large settlements. Based on the methodology of identifying house structures in between two long pits (Müller-Scheeßel *et al.*, 2020), an estimation of house locations was proposed. Based on the spatial extent of the anomalies, it was possible to estimate that the settlement of Vlkaš ‘Do hľského chotára’ was possibly

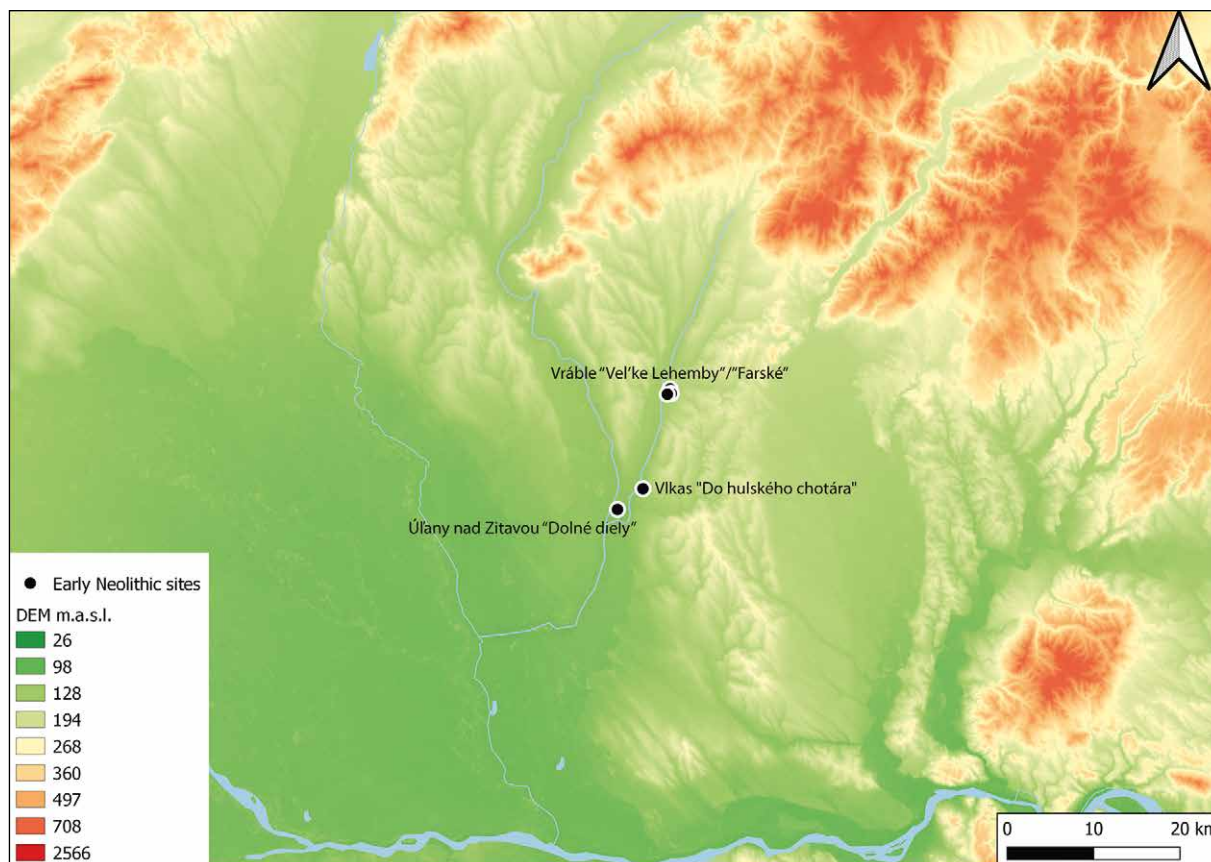


Figure 3.1.1. Location of the sites Úlany nad Žitavou 'Dolné diely' and Vlkaš 'Do hulského chotára' in relation to Vrábě 'Velké Lehemby'/'Farské'.

characterised by 61 house structures and the settlement of Úlany nad Žitavou 'Dolné diely' by 34 house structures. Based on this information, three geophysical anomalies were selected for a chronological determination of site occupation and for acquiring comparative datasets for developing a model of settlement agglomeration on a micro-regional scale. At both sites, excavations took place in 2018, with the site of Vlkaš 'Do hulského chotára' sampled using two trenches and that of Úlany nad Žitavou 'Dolné diely' sampled by means of a single trench.

Similarly to what was found at the Vrábě 'Velké Lehemby'/'Farské' settlement complex, the subsoil was formed on clayish loess, resulting in challenging circumstances for identifying archaeological deposits (Staniuk *et al.*, 2020). While the visibility of postholes was higher, it remained difficult to distinguish long pit fill directly below the humus. Similarly to Vrábě 'Velké Lehemby'/'Farské', the analysis of household structures did not allow identification of house types beyond cross rows and long pits.

Excavation methodology

The excavations followed the methodology developed throughout the research on Early Neolithic communities in the Žitava Valley (Staniuk *et al.*, 2020). After removal of the topsoil, the outlines of the archaeological strata were delimited and the area was divided into research squares in order to excavate only parts of the visible structures. The selection of squares for cutting was conducted in a chequerboard system, to ensure the possibility of later integration of smaller profiles. This system allows complete documentation of the profiles along their greatest length and the possibility of generating cross-sectional profiles. The selected research squares were then excavated in spits of approx. 10–15 cm thickness. Each spit received an individual identifier, in order to

allow later integration of information into meaningful stratigraphic relationships. After complete excavation of the square, the profiles were documented and each visible unit received a single, independent number to connect to the excavated units.

This excavation strategy allowed sampling of the archaeological strata for further research purposes, documentation of the stratigraphic sequences by clearly discernible units, as well as preservation of the archaeological record for future research. As such, the documented features were subject to only partial excavation, with the individual profiles and documentation units undergoing synthesis in the post-excavation process. Last but not least, due to the irregular process of long pit construction, where initial digging and in-filling occurred over a relatively long time span, this strategy provided the possibility of documenting instances of re-cutting and mixing of fills.

Natural factors of soil formation limited our ability to clearly identify features. Beyond the large anomalies, it was often difficult to determine whether the observed discolorations were indeed archaeological features. Our methodology allowed verification of the initial identification in post-processing.

Outline of the documentation system

The stratigraphic analysis is based on the results of the excavations that took place in 2018. It follows the classification system applied at Vrábce, which has a well-defined structure and hierarchy of inference. In order to outline the exact steps in the construction of the stratigraphic model, the components and hierarchy of the system will be discussed first.

Classification system

The classification system used throughout the excavations was based on the distinction between three entities: analytical units, finds and stratigraphic units.

Analytical units

Documentation of all excavated strata was based around the concept of analytical units, which recorded the documentation and excavation technique of the observed archaeological contexts. Three types of units were recognised: planum (documentation of the horizontal representation of archaeological strata), profile (documentation of the vertical representation of archaeological strata), and spit (excavated units). The three forms of documentation represent the primary tools for the identification and documentation of stratigraphic units. The analytical units are not representative of the archaeological character of the features but simply represent the workflow of the excavation campaigns. Since all the observed archaeological contexts were divided into research squares throughout the excavation, the implementation of analytical units provides the means of linking features documented in different squares.

Finds

Artefacts and samples were termed finds. Each find was assigned an individual number, which allowed the investigation of finds irrespective of their stratigraphic association. Stratigraphic information was reported according to the identification of archaeological strata in the field, and was expanded upon once post-processing of the stratigraphic data had been finalised.

Stratigraphic units

The excavated deposits were assigned individual numbers to allow reconstruction of archaeological sequences in the inverted order of excavation. These units were arranged in a hierarchical system of classification, allowing the positioning of each excavated sample in relation to other categories. The following sections describe each level of inference.

Context

The primary unit of archaeological investigation is the context. Contexts represent the basic stratigraphic units, the interpretation of which serves as determination of the formation process resulting in the observed features. Since the excavations followed the principle that every spit received a separate context number, the high number of documented contexts should not be considered as indicative of the complexity of the documented archaeological structures.

Layer

Layers represent aggregation of individual contexts into meaningful categories of observation. This aggregation is important for understanding the formation process beyond individual observations, towards more generalised context formations. The application of the term layer is restricted to groups of observations, where stratigraphic contexts become highly differentiated as a result of cultural and natural formation processes. In some instances, the concept of layer is primarily used to aggregate individual context numbers into meaningful categories related to the formation of archaeological strata.

Object

Objects represent functional interpretation of layers and contexts as standardised types, which allow comparison between different areas and time periods.

Layer formation

The term layer formation represents the functional aggregation of multiple objects. The purpose of implementing layer formations is to aggregate individual archaeological objects into analytically meaningful categories. This particular level of terminology does not follow a strict typological categorisation, although, due to the prevalent type of archaeological contexts, *i.e.* houses, the majority of layer formations are houses.

Phase

Phases represent the final level of stratigraphic association, where layer formations are placed in roughly contemporary groups.

Stratigraphic hierarchy

The stratigraphic system applied in the project is characterised by a hierarchical structure of inference of increasing complexity. The lowest level of inference – the context – is aggregated into layers, which are then aggregated into objects, layer formations, and, finally, phases. The stratigraphic system thus allows us to always infer the significance of individual finds within a stratigraphic interrelationship between units, while maintaining the individual depositional character (Fig. 3.1.2).

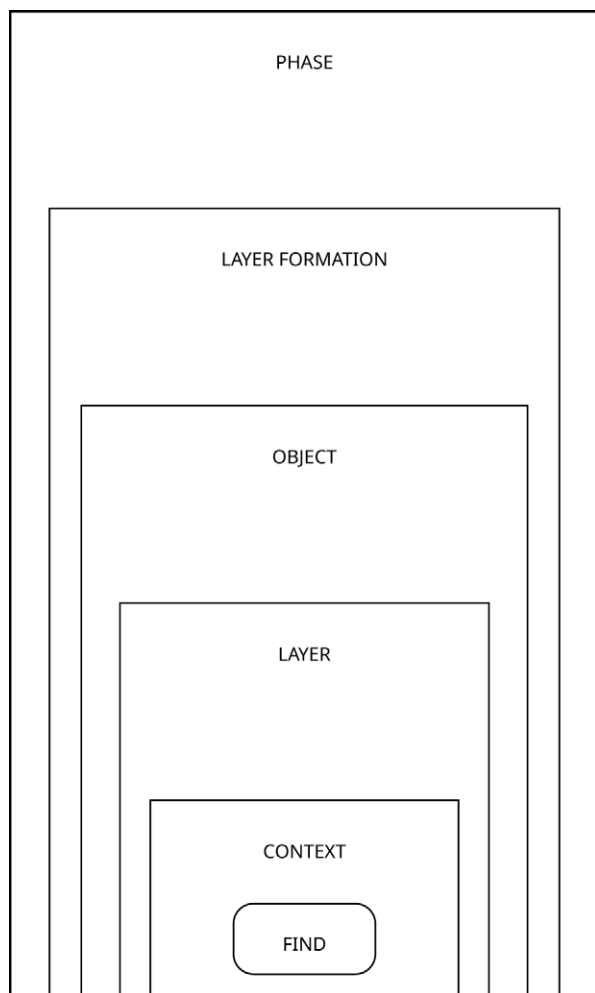


Figure 3.1.2. Classification scheme used in the stratigraphic analysis of Early Neolithic structures in the Žitava Valley.

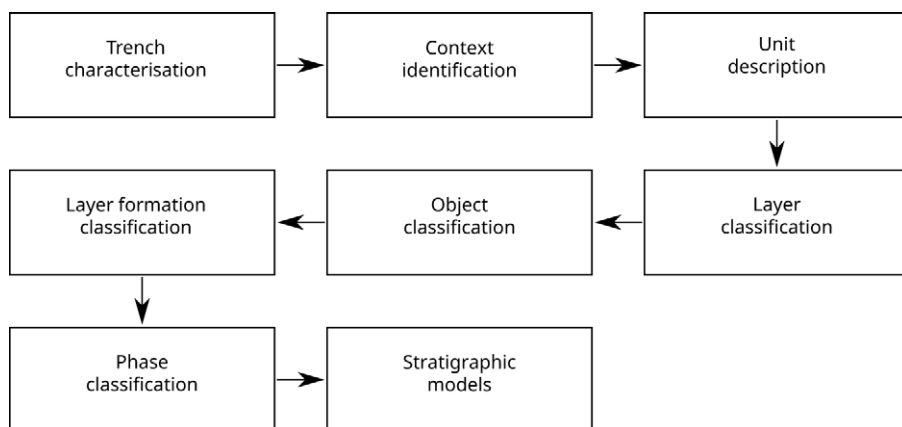


Figure 3.1.3. Workflow of the stratigraphic analysis of Early Neolithic structures in the Žitava Valley.

Stratigraphic analysis

The stratigraphic analysis of Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľského chotára’ is based on the workflow shown in Fig. 3.1.3.

The workflow was initiated with the evaluation of the documented profiles with the described context information, as well as an overview of the changing plans of contexts. The recognised relationships (older than, younger than, contemporary with, identical to) between units were documented and tran-

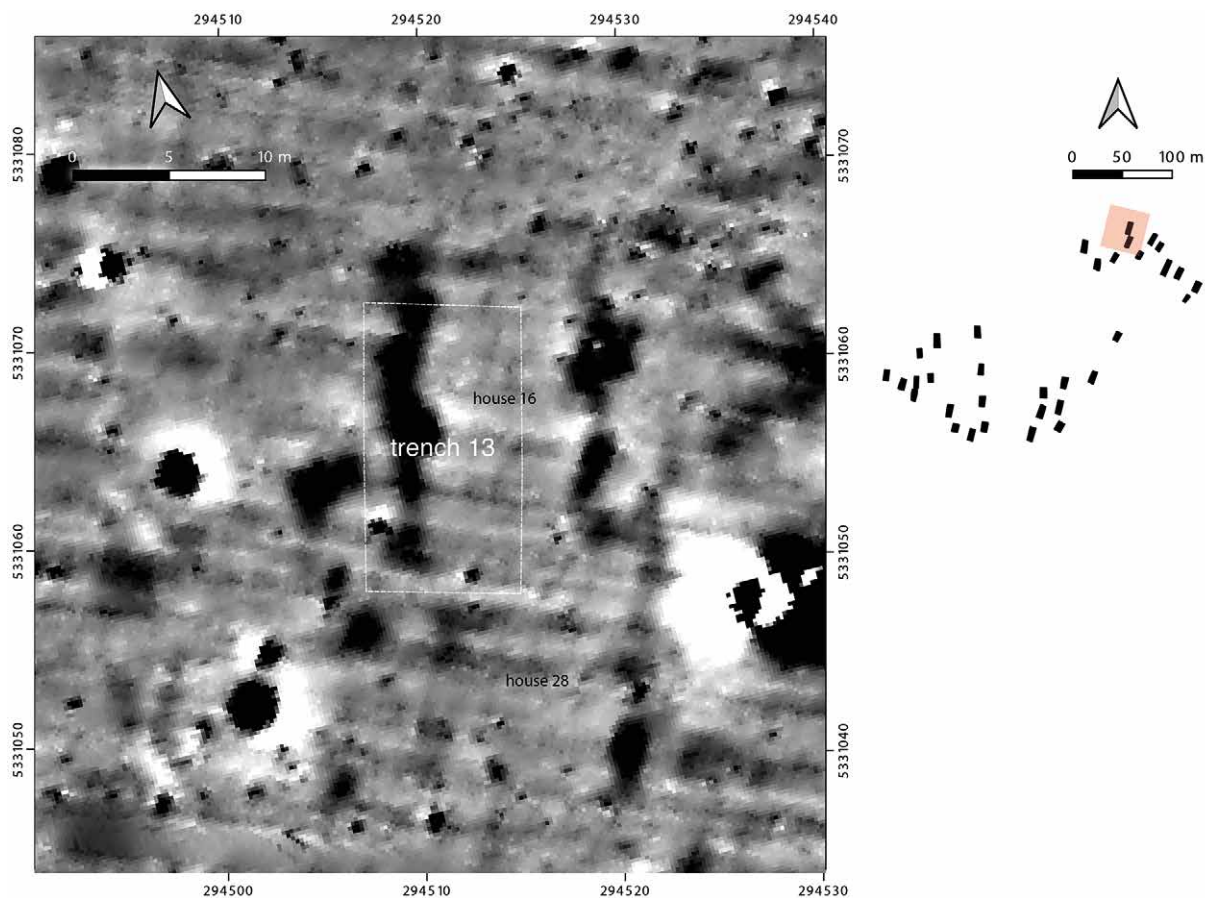


Figure 3.1.4. Úľany nad Žitavou 'Dolné diely'. Area of Trench 13.

scribed into the stratigraphic analysis software Stratify (Herzog 1993; 2010). The software then constructed a Harris matrix based on the defined relationships, testing the proposed model for logically contradictory assignments.

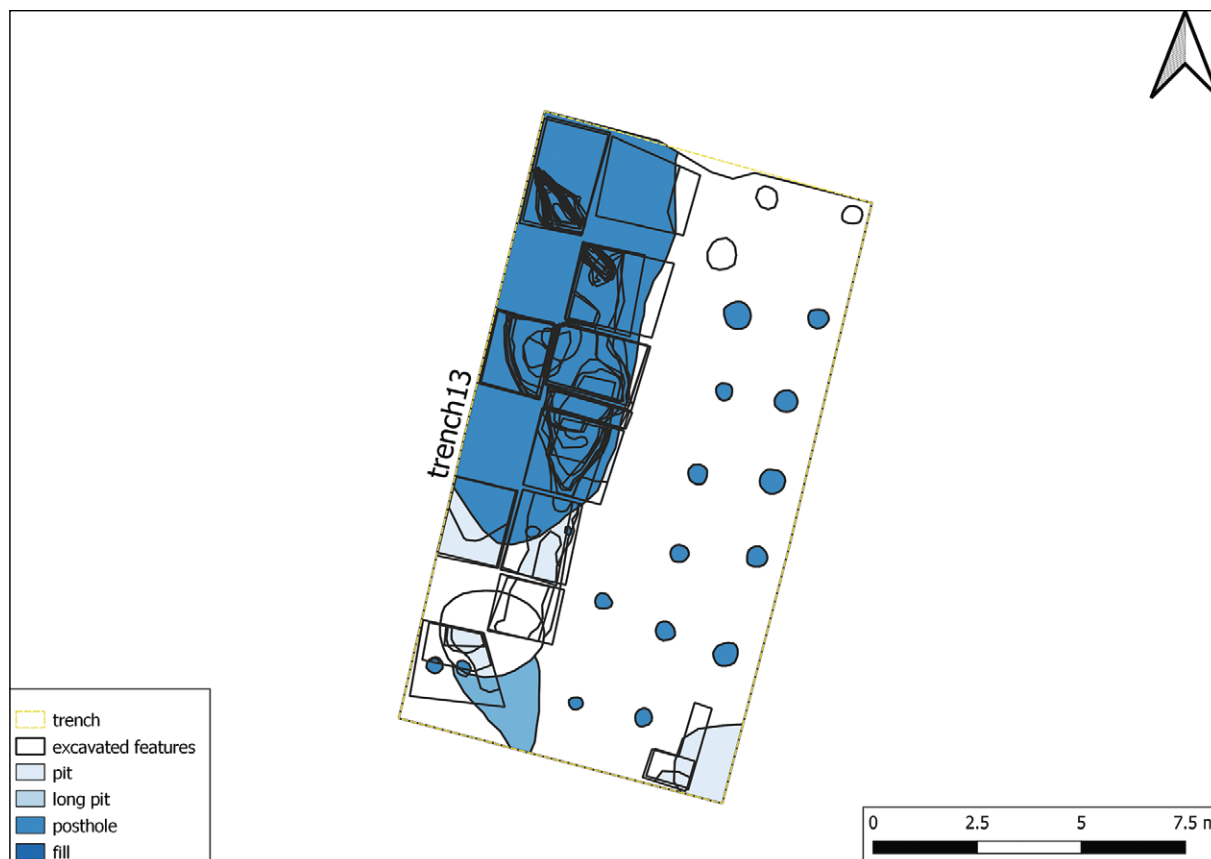
For brevity, the description of the stratigraphic analysis will be initiated with the presentation of defined layers and the increasingly abstract levels of interpretation.

Úľany nad Žitavou 'Dolné diely'

Only one area was selected for excavation: Trench 13 (Fig. 3.1.4). It was located along the western long pit of the assumed House 16 and north-west of the assumed House 28. An area of approx. 121.5 m² was excavated. The selected area allowed investigation of the temporal relationship between the two houses, which are adjacent to each other, primarily to determine their temporal position.

Excavations in Trench 13 were initiated by the removal of the topsoil, followed by cleaning of the surface for the observation of archaeological contexts. Based on the outlines of the visible features, the trench was divided into research squares, numbered 1–14. The research squares covered the main geophysical anomaly, the western long pit of the Linearbandkeramik (LBK) House 16 (Fig. 3.1.5). The only horizontal overlap of features in the trench was related to the discolorations of the western long pit, possibly suggesting a later disturbance of the Early Neolithic deposits. Multiple features were identified at some distance from the large anomalies and were excavated separately.

While the excavation method applied throughout the archaeological research in the Žitava Valley relies on excavating elongated anomalies in research squares with a system of alternating tested squares (the so-called chequerboard system), the



excavation method applied at Úľany nad Žitavou 'Dolné diely' was slightly modified from this system, in the sense that in some cases multiple adjacent squares were excavated, i.e. without alternating. The following research squares were excavated: 1, 2, 4, 5, 6, 8, 9, 10, 12, 13.

Figure 3.1.5. Úľany nad Žitavou 'Dolné diely', Trench 13. Planum 1.

Stratigraphic sequence

In total, 116 contexts, both horizontal and vertical, were used to construct the basic stratigraphic sequence of the site. These individual observations were grouped into 18 layers, 16 objects, 4 layer formations and 3 phases.

The stratigraphic analysis indicates that the majority of settlement activities were related to the digging of four types of archaeological features: long pits, pits, V-shaped pits – *Schlitzgrube* in German (Gerlach, 2014; Eckmeier *et al.*, 2017; Riquier *et al.*, 2017) (in this case only one) – and postholes. While long pits and postholes represent the standard archaeological features related to the construction and maintenance of long houses typical for early agricultural groups in central Europe, the presence of pits can be most likely attributed to activities taking place during the existence of the settlement. The *Schlitzgrube* is unique, in the sense that it was constructed after the in-filling of one of the long pits (i.e. it cuts the long pit).

The formation of the archaeological record at this site is primarily linked to initial digging into the subsoil, followed by what was most likely gradual in-filling of the voids, followed by later re-cutting of the pit and re-depositioning of sediment. In one instance, an older fill, possibly linked to the earliest in-filling of the long pit, was observed. In general, profile analysis suggests that the re-cutting of the southern part of the long pit occurred after the main long pit fill had already been formed. This could suggest the existence of another house south-west of the excavated area.

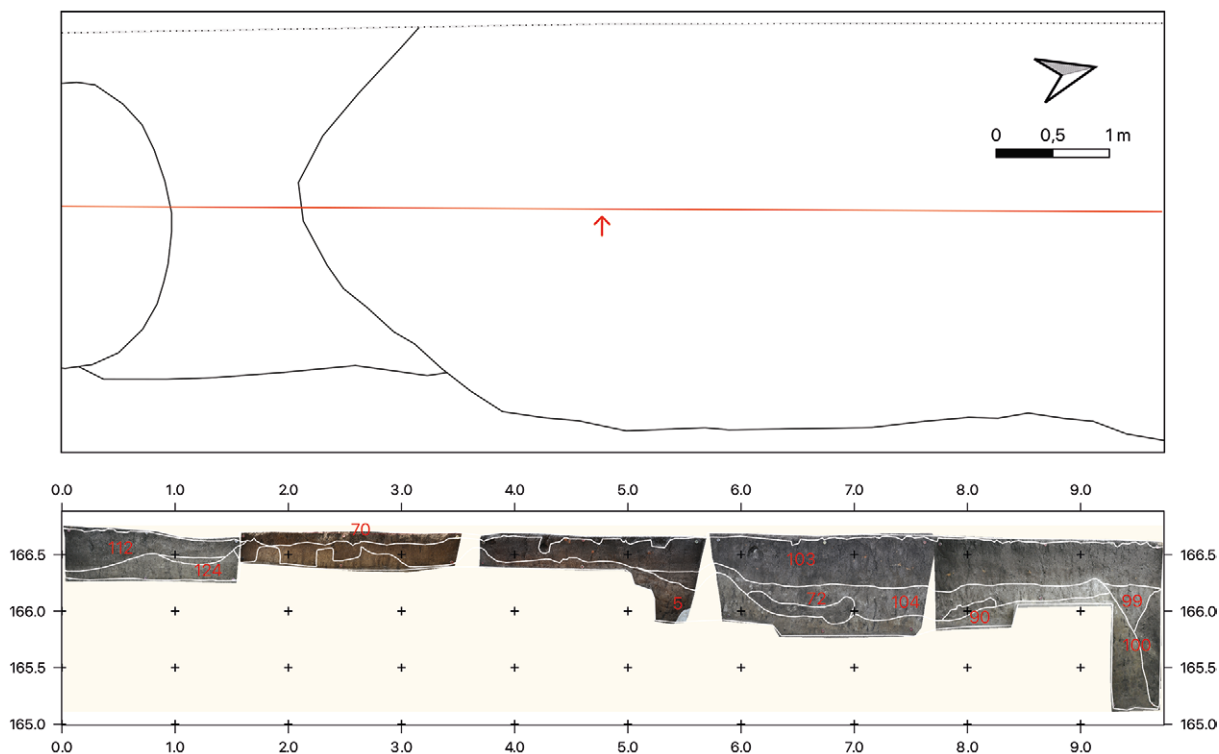


Figure 3.1.6. Úľany nad Žitavou 'Dolné diely', Trench 13. Plan and section of the lateral structure (long pit H16/01). The red arrow in the plan indicates the viewing direction.

The stratigraphic sequence of the investigated area is as follows: its occupation was initiated with the construction of House 16, most likely by delimiting an area for the house, digging postholes (151, 152, 153, 154, 155, 156, 157, 158), and erecting posts. Afterwards, the construction of long pits along the walls of the house was initiated, of which only a single long pit was investigated (H16/01). Although only a single outline was discernible (147), the digging of the long pit most likely occurred in an irregular fashion, as indicated by the changing depth of the structure that is visible in the profile (Fig. 3.1.6). The initial fill was relatively homogeneous and dark (H16/01a), potentially indicating the presence of organic refuse deposited inside the outline. The discontinuities between the fills indicate that the deposit was later re-cut (146) and that this re-cutting was followed by a deposition of a distinct greyish fill (H16/01b). This secondary fill, characterised by a lower presence of organic materials, indicates the deposition of already dissolving waste. After the deposition of the secondary fill, the area was most likely no longer used as the location for a house.

Following the abandonment of the immediate area, a deep, slightly irregular *Schlitzgrube* (145) cut through the existing deposit (Fig. 3.1.7). The outline of the cut suggests that the digging undercut the soil below the long pit. Based on the distribution of different parts of the fill (S13/01), it was determined that after the deposition of primary waste, the secondary fill originating from the older long pit (H16/01) slid into the existing void (Fig. 3.1.6). This allowed the determination of a stratigraphic sequence.

After the in-filling of the *Schlitzgrube*, the area was most likely re-used for the construction of an additional house (H593). This structure could only be linked to the re-cutting of the older long pit H16/01 (144) and the deposition of homogeneous fill (H593/1a) comprising large pieces of archaeological material (Fig. 3.1.6). This deposit was primarily recognised after the removal of the plough zone and led to the initial interpretation that the entire excavated pit corresponds to the single house unit. Most likely the construction of this house took place west of the excavated zone. Since the

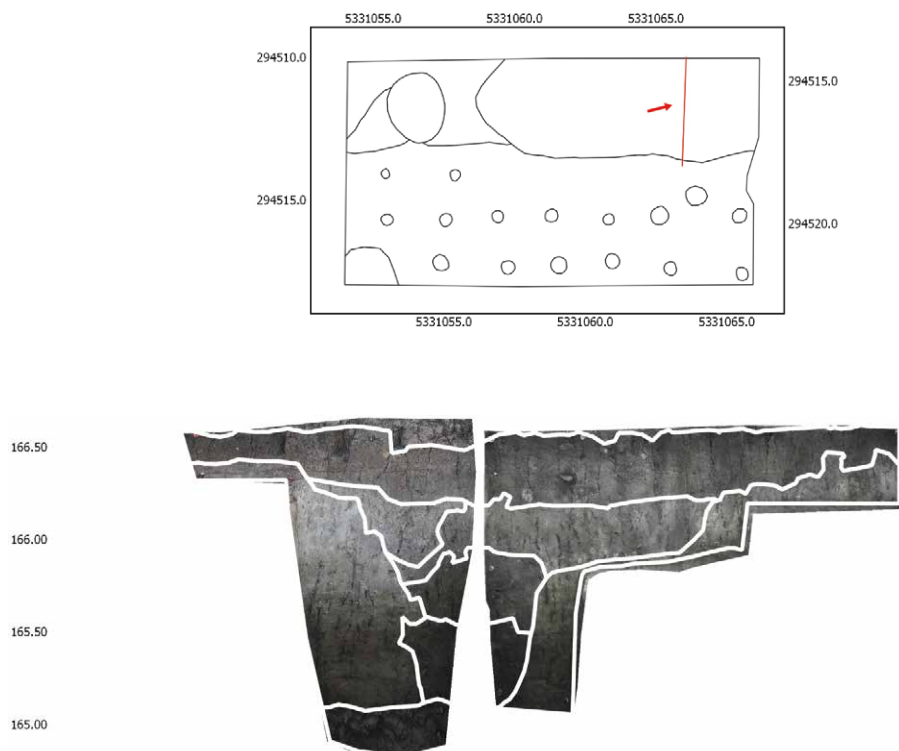


Figure 3.1.7. Úľany nad Žitavou 'Dolné diely', Trench 13. Plan and section of the Schlitzgrube (145). The red arrow in the plan indicates the viewing direction.

entire fill recognised in Trench 13 was found to be comprised of secondary deposit, most likely representing an admixture of the older fill (H16/01b), the dating of this house will prove problematic.

The final occupation sequence of the area was most likely related to the construction of House 594, south-west of House 593. In this case the evidence is two overlapping fills in the lateral structure (Fig. 3.1.6), where a primary (H594/01a) and secondary (H594/01b) fill can be distinguished. Next to the possible location of a long pit was a single posthole (H594/02) with the remains of a post, which would support the interpretation that after House 593 was abandoned, the occupation area shifted southwards.

The creation of long pit H28/01, in the south-eastern corner of the trench, most likely resulted in the destruction of one of the postholes related to House 16. As such, the construction of a house to the east of the excavated area most likely took place after the abandonment of the oldest house. Since only secondary fill (H28/01a) was documented, it is challenging to estimate the chronological position of the construction.

The digging of objects S13/02 and S13/03 most likely took place after House 16 had been destroyed, since they overlap with the House 16 postholes. As such, it is possible that they represent the exploitation of the area after its initial occupation.

The subsequent re-cuttings and fill depositions indicate a gradual, parallel existence of houses in the studied area, and while the intensity of occupation can be linked to at least four structures, the separation between individual houses persisted. Spatial management of the area indicates that decisions about where to erect subsequent structures took into account the visible or known architectural remains, and, in turn, why the overlaps between structures did not result in a duplication of posthole rows.

The stratigraphic sequence presented here was later subject to validation on the basis of radiocarbon dating (Chapter 4.1).

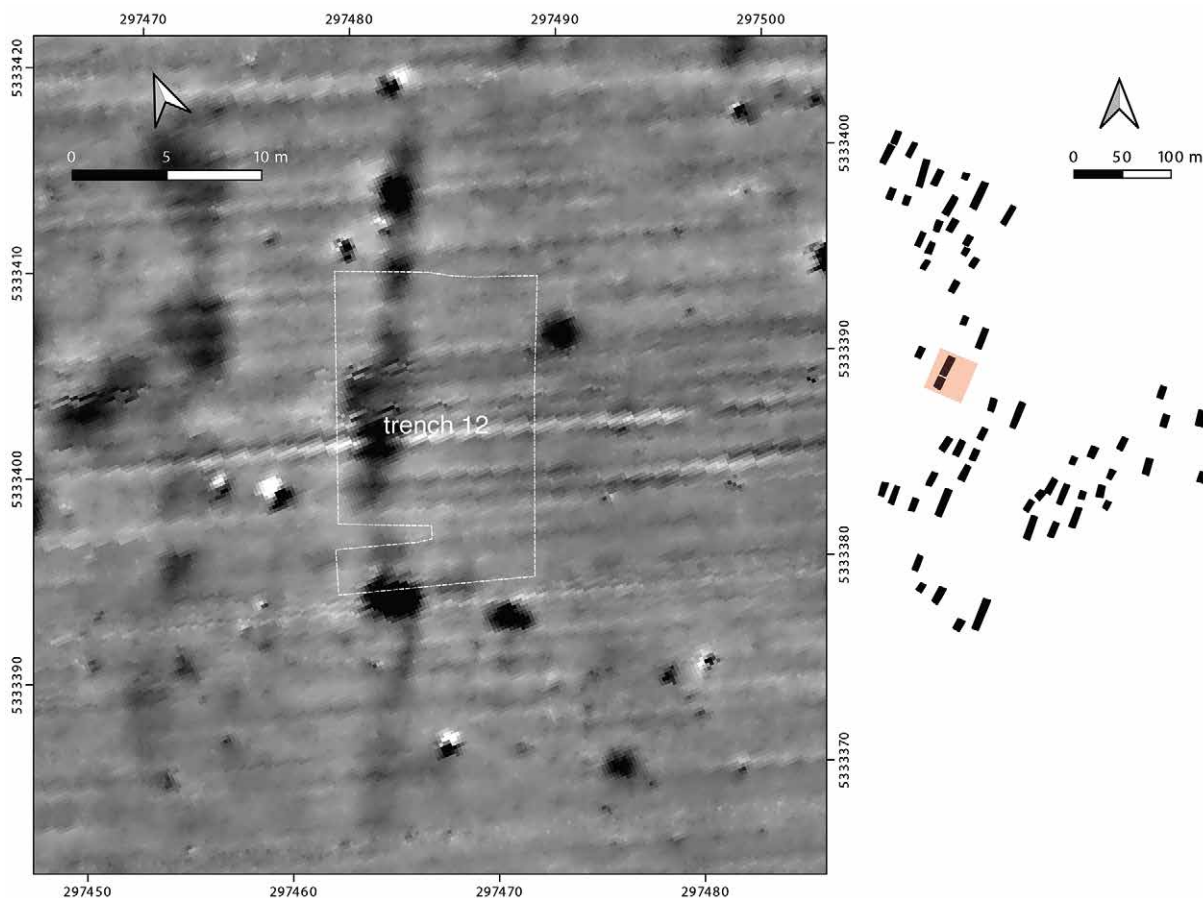


Figure 3.1.8. Vlkas 'Do hulského chotára'. Area of Trench 12.

Vlkas 'Do hulského chotára'

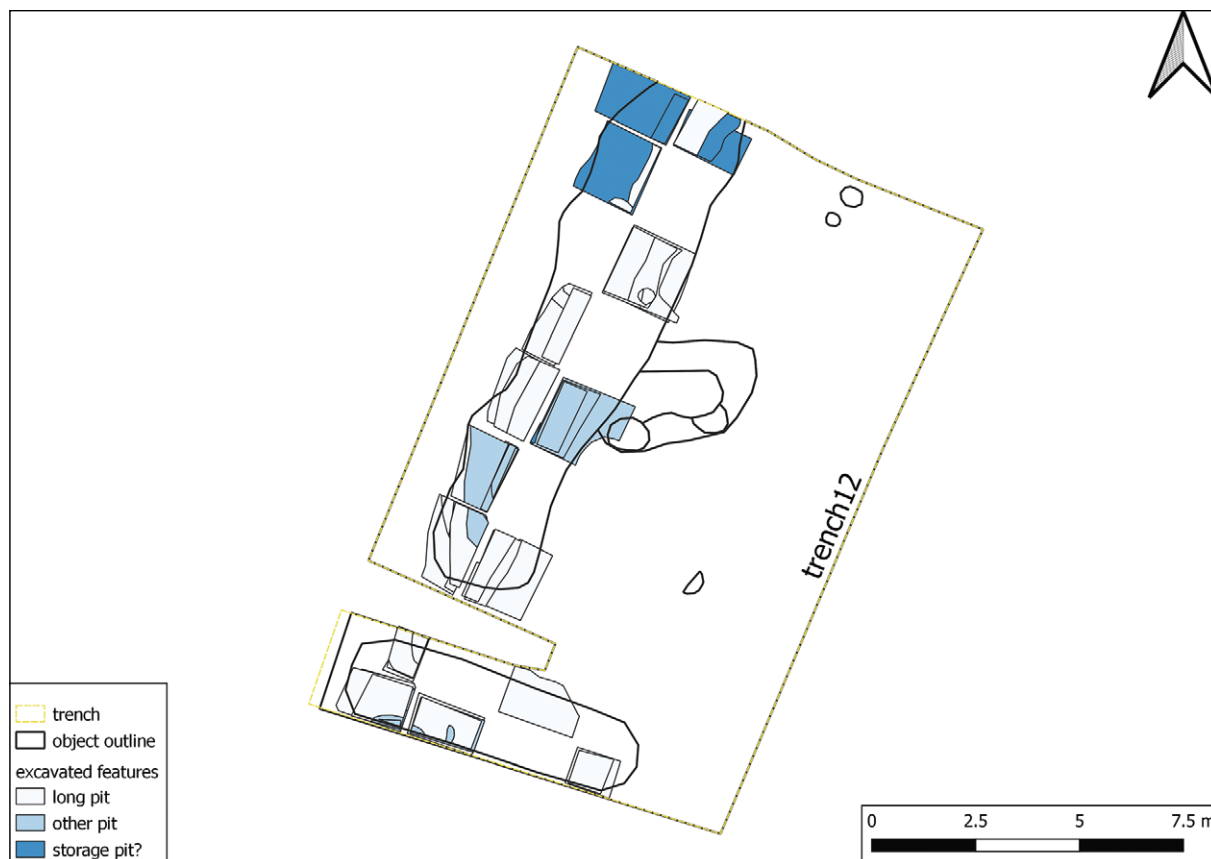
The trenches at this site were located approx. 150 m apart, thus providing a fairly large area for the consideration of the spatial and chronological differences. In both cases, the excavations confirmed the presence of Early Neolithic long pits, which were associated with the early agricultural communities. Since the excavations were divided into two trenches, the presentation of the entire sequence will be preceded by the description of findings according to Trenches 12 and 15.

Trench 12

Excavation and documentation

Trench 12 was located along the eastern long pit of the assumed House 212 and north-west of the assumed House 213 (Fig. 3.1.8). An area of approx. 173.3 m² was excavated. The selected area allowed investigation of the temporal relationship between these two neighbouring houses, primarily to determine their temporal position.

Excavations in Trench 12 were initiated by the removal of the topsoil, followed by cleaning of the surface for the observation of archaeological contexts. Based on the outlines of the visible features, the trench was divided into research squares 1–22. The research squares were divided into two groups corresponding to the large, confirmed magnetic anomalies (Fig. 3.1.9). Squares 1–14 correspond to the elongated anomaly running parallel to the assumed House 19. Squares 15–22 correspond to the elongated anomaly running perpendicular to the first anomaly. The stratigraphic relationship



between the two anomalies is not clear based on the magnetic anomaly. One purpose of the stratigraphic analysis is therefore to recognise the chronological relationship between them. Some features were located at some distance from the large anomalies and were excavated separately. The following research squares were excavated: 1, 2, 4, 5, 6, 8, 9, 12, 13, 14, 15, 16, 17, 20, 22.

Figure 3.1.9. Vlkaš 'Do hľského chatára', Trench 12. Planum 1.

Stratigraphic sequence

In total, 111 contexts, both horizontal and vertical, were used to construct the basic stratigraphic sequence of the site. These individual observations were grouped into 8 layers, 7 objects, 2 layer formations and 3 phases.

The stratigraphic analysis indicates that the majority of settlement activities related to the digging of three types of archaeological features: long pits, pits and beehive-shaped pits. No postholes could be positively verified during excavations, which confirms the interpretation that the location of the trench was in the easternmost part of the house unit. The presence of beehive-shaped pits attributed to both the Early Neolithic and the Early Bronze Age suggests that this type of construction maintained similar functional properties despite its *longue durée* in prehistoric Europe (Kadrow, 1992; Furholt *et al.*, 2020b; Jiménez-Jáimez and Suárez-Padilla, 2020).

Similar to what is proposed for 'Dolné diely', the formation of the archaeological record was primarily linked to the digging of features, followed by in-filling with refuse. The stratigraphic sequence of the investigated area is as follows: its occupation was initiated with the construction of pit S12/1, an Early Neolithic beehive-shaped pit. The presence of such a structure points towards the successful agricultural practice in the area prior to the construction of the house, as well as the possible occurrence of communal activities before any of the documented houses were built. As such, it

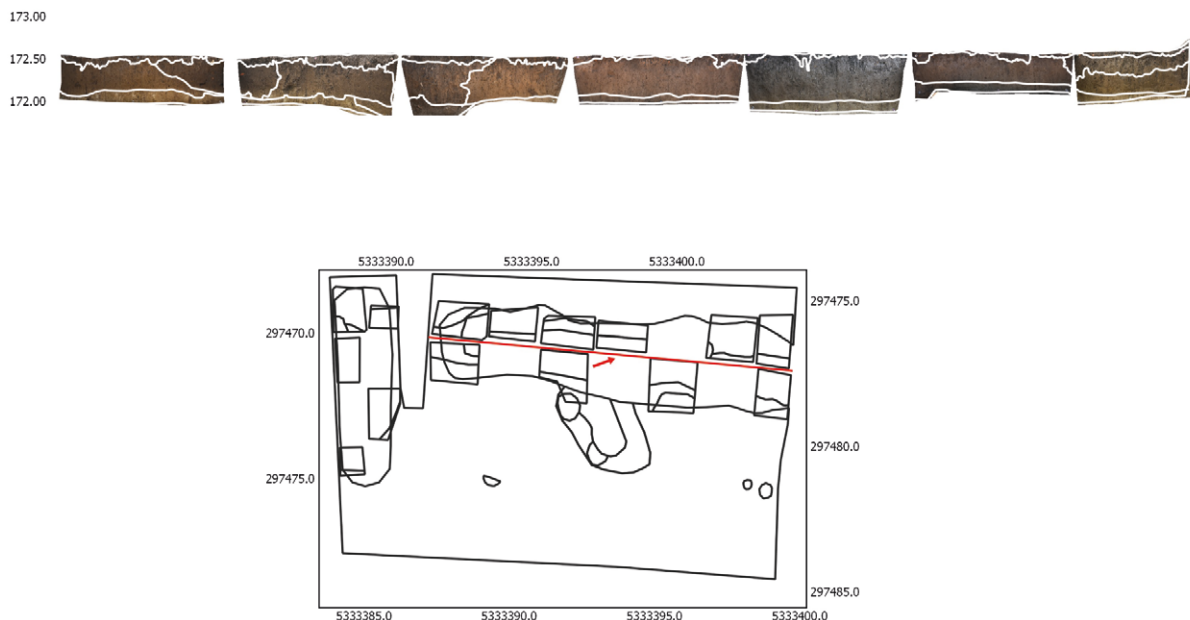


Figure 3.1.10. Vlkaš 'Do hľského chotára', Trench 12. Plan and section of the lateral structure (long pit H212/1). The red arrow in the plan indicates the viewing direction.

has to be assumed that the chronology of the site is at least a couple of years older than indicated by the analysis of house constructions.

The construction of a House 212 most likely took place next, west of the analysed area, followed by the construction of an eastern long pit H212/1 (Fig. 3.1.10). Again, similarly to what is proposed for 'Dolné diely', the digging of the long pit (175) was most likely a gradual process of digging subsequent pits in a row, which, due to the later post-depositional processes, can no longer be individually recognised.

The in-filling of the structure was a three-tiered process, initiated by the deposition of a thick primary fill, almost devoid of archaeological material (H212/1a). Afterwards, the long pit was re-cut (176) and secondary fill was deposited (H212/1b). Due to the modern agricultural activities in the area, the upper part of this fill was most likely destroyed due to ploughing, and therefore only general statements about its presence can be made. Pits S12/3, S12/4 and S12/5 were found cutting long pit H212/1 in a linear fashion. The function of this cutting is rather unclear.

Contemporaneously with the formation of the secondary deposit or immediately after the feature was filled with refuse, a construction of a different, perpendicular long pit took place (H213/1). Unfortunately, the decision to maintain a baulk above the possible intersection of the two structures has hindered the possibility of determining their relationship directly. The excavations of the structure suggest that it belongs to the Early Neolithic, although only primary waste was found inside (H213/1a). No postholes indicating a possible position of the house were recognised, although based on the geophysical prospection, the position of the structure points towards a house structure, 213, located south of the excavated area (cf. Fig. 3.1.8). The in-filling of the structure marks the final stage of the Early Neolithic occupation phase.

The site was re-occupied during the Early Bronze Age, as evidenced by a single beehive-shaped pit. No architectural structures linked to households were documented, although the presence of a storage unit points towards an organised form of occupation and intensive agriculture taking place in the direct vicinity of the site. Beehive-shaped pit S12/2 was found cutting through long pit H213/1.

In general, the findings from Trench 12 indicate a restricted form of spatial occupation in this part of the settlement. While the occupation was most likely initiated ca. 5300 BCE, the individual farmsteads represented the primary form of occupation. The initiation of house construction, with the construction and

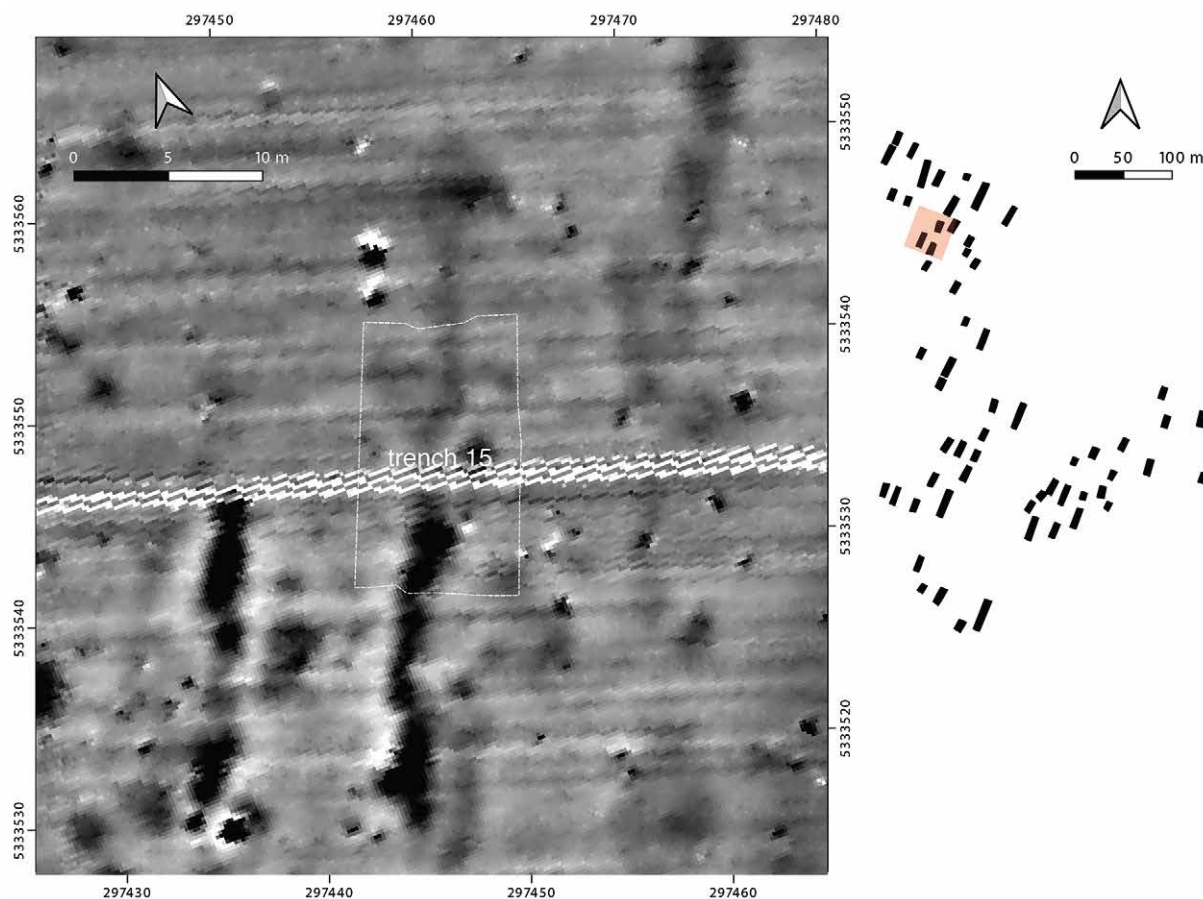


Figure 3.1.11. Vlkaš 'Do hulskeho chotára'. Area of Trench 15.

emptying of a beehive-shaped pit, could be used as an argument for the importance of communal activities involving sharing practices among the inhabitants, incoming or present alike (Wunderlich *et al.*, 2020). Although the presence of a second house, with a distinct positioning of the long pit, suggests a much later re-use of the area, the deviation of its orientation points towards a very distinct form of construction. The Bronze Age stages of occupation indicate a much later re-occupation of the area and an overlap between construction activities, although no clear link to settlement structure can be provided.

The stratigraphic sequence presented here was later subject to validation on the basis of radiocarbon dating (Chapter 4.1).

Trench 15

Excavation and documentation

Trench 15 was located in the area between assumed Houses 201, 202 and 205 (Fig. 3.1.11). An area of approx. 121.5 m² was excavated.

Excavations in Trench 15 were initiated by the removal of the topsoil, followed by cleaning of the surface to enable the observation of archaeological contexts. The uncovered surface on Planum 1 indicated the presence of multiple overlapping archaeological strata. A total of 18 individual numbers were assigned to the documented outlines (1, 2, 3, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 20, 22, 23, 24, 25). The outlines were later divided into research squares 1–31. Research squares 1–8 correspond to the elongated and slightly angular stratum corresponding to outlines 5, 12 and 20.



Figure 3.1.12. Vlčias 'Do hľského chotára', Trench 15. Planum 1.

Research squares 9–12 correspond to outline 7. Research squares 13–31 correspond to multiple outlines found primarily in the north-eastern part of the trench (5, 11, 13, 14, 15, 16, 45). Outlines 1, 2, 3, 8, 10, 23 and 24 were not excavated by means of research squares (Fig. 3.1.12).

Similar to what happened during the excavations in Trench 12, a system of alternating excavated squares was implemented. Multiple adjacent squares were excavated in sequence, *i.e.* without alternating sides. The following research squares were excavated: 1, 4, 5, 6, 8, 10, 11, 14, 16, 17, 18, 19, 20, 22, 23, 24, 25, 27, 29, 31.

Stratigraphic sequence

In total, 225 contexts, both horizontal and vertical, were used to construct the basic stratigraphic sequence of the site. These individual observations were grouped into 23 layers, 15 objects, 6 layer formations and 4 phases.

The stratigraphic analysis indicates that the majority of settlement activities were related to the digging of four types of archaeological features: long pits, pits, beehive-shaped pits and postholes. These types were not equally represented in the different chronological phases of the archaeological record, with the Early Neolithic characterised by long pits, pits and postholes. The Chalcolithic is represented by a single C14 which cannot be linked to a specific feature but might be intrusive. There is a further C14 date belonging to the Early Bronze Age which is associated with a small pit. Although similar in terms of their archaeological descriptions, these features almost certainly represent different forms of social activities taking place in the same area. However, unlike other trenches investigated throughout the project, Trench 15 showed a complex palimpsest of overlapping features, indicating intensive exploitation of the area. This pattern was primarily a result of overlapping long pits

linked to the subsequent construction of houses in their close vicinity. From this standpoint, the settlement of Vlkaš 'Do hľského chotára' is rather different from the settlement complex of 'Veľké Lehemby'/'Farské', where palimpsests of overlapping archaeological structures were infrequent, despite the intensive occupation. Similar stratigraphic observations have been made in Early Neolithic contexts in the Carpathian Basin (Oross *et al.*, 2013: 135, fig. 6; Jakucs *et al.*, 2018, 95, fig. 2), as well as to the north of it (Milisauskas, 1986: 70, fig. 53; Czerniak, 2013: 48, fig. 3; 2016: 55, fig. 7). It has to first be considered that, rather than pointing towards underlying social differences, the complex overlap of features points towards the chronological consecutiveness of activities.

The stratigraphic sequence of Trench 15 is as follows: the occupation of the site was initiated with the construction of the house in the area (H590), followed by the digging of a long pit (306), followed by the deposition of the primary fill (H590/1a). This long pit most likely represents the oldest remains of architectural activities in the area. After the deposition of primary fill, the long pit was re-cut (310) and a secondary deposit (H590/1b) was deposited. Possibly simultaneously, a different long pit (H591/1), related to a second house, House 591, was dug (326) and filled with primary refuse (H591/1a). In this case, the absence of a clearly distinguishable secondary fill is most likely related to the destruction of the archaeological record due to later occupation.

This first occupation stage was followed by the construction of three houses: 201, 202 and 205. Although these constructions belong to a single phase, it is possible that they represent an overlap of stratigraphic features, representing short-term changes between the houses. As such, the formation of a communal refuse area between the structures represents a palimpsest of subsequent occupational stages rather than the formation of a specific form of shared infrastructure. Due to the chronological challenges, the outline of specific house-related formation stages will be presented according to their position in the Harris matrix.

The construction of House 201 took place north-east of the excavated area, indicating that the digging of the long pit (324) resulted in the destruction of the already existing archaeological structure (H590/1). Therefore, it is to be expected that the primary (H201/1a) and secondary (H201/1b) fills are characterised by the re-deposition of older material associated with House 591. Only one posthole cut (322) was recognised, and the remains of the post found inside (H201/3a) confirm this interpretation.

Another major construction was the formation of House 202, to the west of the excavated area. In this instance, there were several postholes documented (315, 320, 321, 328), which would support the relationship between a large house and an adjacent long pit (H202/1). The initial digging of the long pit (327) was followed by the deposition of primary refuse (H202/1a). Afterwards the long pit was re-cut (318) and a secondary deposit was made (H202/1b). Although the distinction between the two fills can be made on the basis of sediment characteristics, it has to be stressed that the contents of the structure most likely comprised older material originating from long pit H590/1. As such, any samples recovered from the structure need to be considered secondary.

House 205 was located south-east of the excavated area. The only evidence for this house located inside the trench was linked to the long pit H205/1. Its construction was most likely preceded by the erection of postholes and house construction. The digging of the long pit (323) was followed by the deposition of a primary deposit (H205/1). Afterwards the feature was re-cut and a secondary deposit was placed in the void. In this case, there is no direct evidence of an older long pit located in the area, which could suggest that the material found inside the long pit may be related to the occupants of the house.

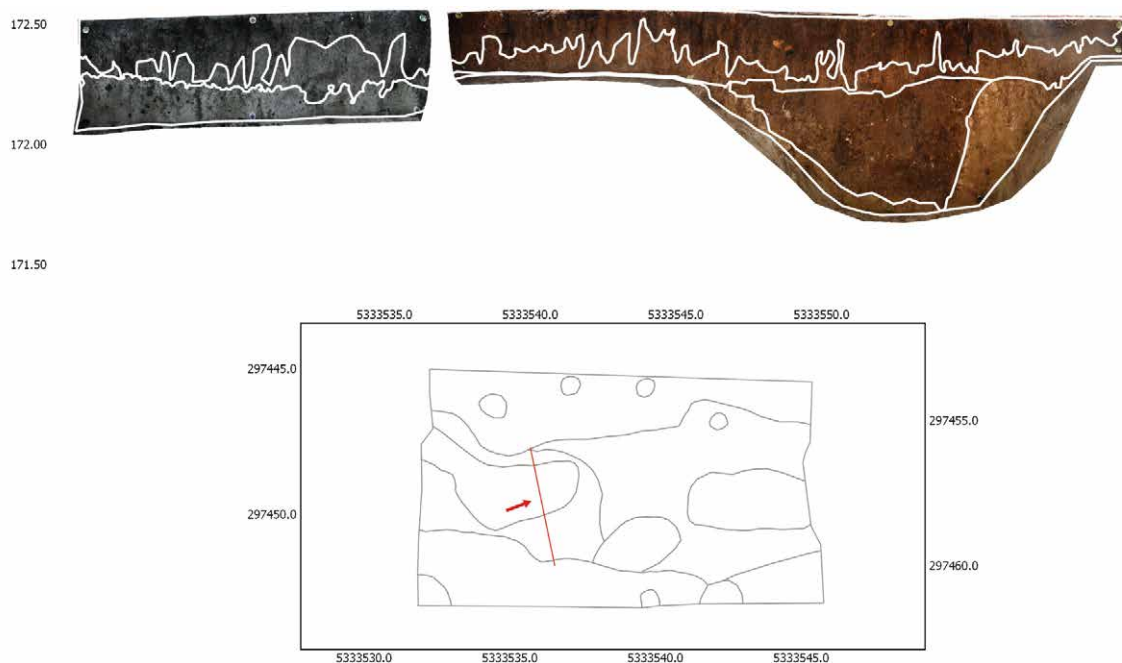


Figure 3.1.13. Vlkaš 'Do hulského chotára', Trench 15. Plan and section of the Early Bronze Age pit S15/12. The red arrow in the plan indicates the viewing direction.

The final stage of the Early Neolithic sequence most likely related to the construction of a single pit, S15/6. Its formation was related to digging of the void (323) and the deposition of primary fill (S15/6a), followed by re-cutting (317) and the deposition of secondary fill. The function of the pit and its possible association with any of the houses remains uncertain.

The Early Bronze Age phase was characterised by a single pit, S15/12, located in the central part of the excavated area (Fig. 3.1.13). The pit was characterised by a single, primary fill (S15/12a). Based on the location of the structure, the sediment found inside the structure is expected to include re-deposited, Early Neolithic material.

To sum up: the palimpsest-like characteristics found in Trench 15 relate to an intensive sequence of spatial occupation, resulting from a repeated cycle of house construction and abandonment. The continuous use of the area would suggest that the area represents one of the densely occupied parts of the Vlkaš 'Do hulského chotára' settlement. The contrast in the structuring of space between the different sites in the Žitava Valley suggests that choices relating to the structuring of space made in the different communities are the result of subtle difference in the idea how to maintain distance between households.

The stratigraphic sequence presented here was later subject to validation on the basis of radiocarbon dating (Chapter 4.1).

Early Neolithic household and inventory analysis

While the concept of the house as the primary, autonomous unit of Early Neolithic groups is maintained across studies of different LBK sites (Zimmermann, 2012; Hachem and Hamon, 2014; Furholt *et al.*, 2020b), the integration of the persistent house characteristics with the variability of individual houses continues to be an obstacle for conceptualising large- and small-scale interaction across Neolithic Europe. While the relative homogeneity of the archaeological record, where the similarity of certain material constants (rectangular outlines, posthole rows, long pits, aisle-based divisions, orientation following cardinal directions, *etc.*) was considered a reified proof of a widespread and shared idea of what constituted a house (Waterbolk and Modderman, 1958; Coudart, 2014; Czerniak, 2016), the site-based investigations

have often provided evidence of variability in terms of how the aforementioned houses were affected by settlement structure, display individual biographies and point towards small-scale differences among the inhabitants (Oross, 2013; Hachem and Hamon, 2014; Hofmann and Lenneis, 2017; Cheben and Bistáková, 2020).

Recent explorations of the variability in material culture among early agricultural groups have shifted the focus, from being LBK-centric to recognising the historical formation of specific communities (Coudart, 2014; Hofmann and Lenneis, 2017; Furholt *et al.*, 2019; Hofmann, 2020). Although these approaches re-affirm the shared notion of early agricultural identity, the presence of this shared identity is explained by reference to specific anthropological phenomena and theories: practice-based formation of social groups via engagement in house formation and maintenance (Coudart, 2014); the historical trajectory of power-based interactions affecting communal organisation (Furholt *et al.*, 2019; Wunderlich *et al.*, 2020); and, finally, the presence of shared magical reasoning among the different communities (Hofmann, 2020). While arguing for a certain uniformity across the Early Neolithic communities in central Europe, these perspectives acknowledge the importance of localised cultural manifestations for maintaining the shared cultural background and the incorporation of change in particular communities.

From this standpoint, the archaeological significance of the house becomes somewhat reduced, as houses are no longer the primary argument for the existence of a shared identity but serve as focal point for tying the existing social developments – such as migration history, political organisation, kinship structure and practices – to a persistent *locale* (Giddens, 1984). This approach substantiates the similarity of experiences linked to social formation across the different regions, with a recurring unit of shared characteristics. As such, one goal of the following analysis is to investigate the shared aspects of house structures discovered in the Žitava Valley and to explore the potential implications for developing a regional perspective on the social processes taking place in the second half of the sixth millennium BCE.

The investigation will emphasise the archaeologically documented characteristics of the houses discovered at Úľany nad Žitavou ‘Dolné diely’, Vlkaš ‘Do hľuského chotára’ and Vráble ‘Veľké Lehemby’/‘Farské’ (Furholt *et al.*, 2020a), as well as the investigation of waste disposal practices related to houses, neighbourhoods and settlements. The investigation is based on the following premise: assuming that the formation of individual settlements and households was tied to the formation of individual household groups, the potential similarity of socio-economic characteristics should not be taken as evidence of similar social interactions across all areas. In addition, how a preceding occupation affected the dynamics of everyday existence, needs to be taken into consideration, since the inhabitants of specific settlements were occupying a historically transformed environment, which, especially for large settlements, meant living in particularly organised settlements, often among abandoned or deconstructed houses. The small-scale level of maintained mutual dependencies between the inhabitants was most likely the everyday reality of engaging in labour, celebrations or conflicts.

While the significance of such dependencies and their embeddedness in the existing social structure, such as gender formation (Müller-Scheeßel, 2019) and conflict-based interaction (Golitzko, 2015), has gained increasing attention, our interpretation of the reality of Early Neolithic lifestyle remains tied to the qualitative study of resource-based investigations of material culture deposited as a result of negative selection (Schiffer, 1976: 30–31; Kadrow, 1992). Such studies remain valid for a qualitative assessment of activities taking place throughout the life of the settlement and allow an exploration of links between different communities. However, apart from the challenges involved in relating refuse to households, this approach favours the assessment of selected finds as isolated phenomena, rather a consideration of the overall approach of societies towards discard.

Quantitative studies of refuse practices in general can allow us to identify shifts in the social practices taking place in the settlements, especially in instances where the archaeological record is generally interpreted as being relatively homogeneous. In such cases the analytical challenges include the problem of attributing waste to specific houses as indices for activities (Rathje and Murphy, 1992); the unclear function of long pits and the materials found inside them (Řídký *et al.*, 2020); the impact of post-depositional processes on the formation of the archaeological record (Schiffer, 1996); and, finally, the importance of recognising the historical developments taking place in community life in terms of the depositional practices (Květina and Řídký, 2017). All of these factors need to be taken into consideration when one aims to assess the absolute quantities of artefacts disposed of inside structures that were potentially used for waste disposal.

Before such an analysis can be carried out, however, it is necessary to supplement the stratigraphic models of the sites with the contextual characterisation of architectural structures and find summaries for Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľuského chotára’ (Tables 3.1.1–22).

Úľany nad Žitavou ‘Dolné diely’

House no.	16
Dating	relative chronology: older Želiezovce absolute chronology: unknown
Orientation	16.1°
Length in m	12.95
Number of cross rows documented	5
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	western: H16/01
Postholes	roof-bearing: H16/02, H16/03, H16/04, H16/05, H16/06, H16/07, H16/08, H16/09
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H39/01: 76.5 posthole: H16/02: 26.07, H16/03: 19.53, H16/04: 42.21, H16/05: 36.45, H16/06: 45.02, H16/07: 20.79, H16/08: 32.98, H16/09: 17.58
Excavated volume in m ³	long pit: H16/01: 2.99

Table 3.1.1. Úľany nad Žitavou ‘Dolné diely’, House 16. Contextual, chronological and architectural information.

Category	Number	Weight (g)
Decorated ceramics	38	828
Undecorated ceramics	36	1626
Chipped stone	3	0.6
Ground stone	7	44
Bone	131	3630
Daub	-	14482

Table 3.1.2. Úľany nad Žitavou ‘Dolné diely’, House 16. Summarised find information.

House no.	593
Dating	relative chronology: 5200–5050 absolute chronology: 5300–5200
Orientation	11.5°
Length in m	ca. 13.06
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	eastern: H593/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H593/01: 50.03
Excavated volume in m ³	long pit: H593/01: 3.19

Table 3.1.3. Úľany nad Žitavou
'Dolné diely', House 593.
Contextual, chronological and
architectural information.

Category	Number	Weight (g)
Decorated ceramics	84	1215
Undecorated ceramics	44	1882
Chipped stone	5	16.5
Ground stone	10	132
Bone	24	29
Daub	-	6076

Table 3.1.4. Úľany nad Žitavou
'Dolné diely', House 593.
Summarised find information.

House no.	594
Dating	relative chronology: unknown absolute chronology: unknown
Orientation	14.9°
Length in m	ca. 10.46
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	eastern: H594/01
Postholes	H594/02
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H594/01: 40.01 posthole: H594/02: 19.03
Excavated volume in m ³	long pit: H594/01: 1.34

Table 3.1.5. Úľany nad Žitavou
'Dolné diely', House 594.
Contextual, chronological and
architectural information.

Category	Number	Weight (g)
Decorated ceramics	1	37
Undecorated ceramics	4	63
Chipped stone	-	-
Ground stone	1	432
Bone	14	544
Daub	-	14

Table 3.1.6. Úľany nad Žitavou
'Dolné diely', House 594.
Summarised find information.

House no.	28
Dating	relative chronology: unknown absolute chronology: unknown
Orientation	22.3°
Length in m	11.84
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	western: H28/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H28/01: 22.9
Excavated volume in m³	long pit: H28/01: 0.39

Table 3.1.7. Úľany nad Žitavou
'Dolné diely', House 28.
Contextual, chronological and
architectural information.

Category	Number	Weight (g)
Decorated ceramics	2	39
Undecorated ceramics	7	217
Chipped stone	-	-
Ground stone	-	-
Bone	-	-
Daub	-	-

Table 3.1.8. Úľany nad Žitavou
'Dolné diely', House 28.
Summarised find information.

Vlkas 'Do hulského chotára'

House no.	212
Dating	relative chronology: unknown absolute chronology: 5200–5000
Orientation	22.1°
Length in m	11.85
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	eastern: H212/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H212/01:58.30
Excavated volume in m ³	long pit: H212/01: 27.00

Table 3.1.9. Vlkas 'Do hulského chotára', House 212. Contextual, chronological and architectural information.

Category	Number	Weight (g)
Decorated ceramics	43	747
Undecorated ceramics	32	1455
Chipped stone	-	-
Ground stone	-	-
Bone	542	797
Daub	-	1978

Table 3.1.10. Vlkas 'Do hulského chotára', House 212. Summarised find information.

House no.	213
Dating	relative chronology: unknown absolute chronology: unknown
Orientation	22.1°
Length in m	11.85
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	northern: H213/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H213/01: 57.80
Excavated volume in m ³	long pit: H213/01: 15.00

Table 3.1.11. Vlkas 'Do hulského chotára', House 213. Contextual, chronological and architectural information.

Category	Number	Weight (g)
Decorated ceramics	44	750
Undecorated ceramics	34	1482
Chipped stone	3	5
Ground stone	1	75
Bone	4	94
Daub	-	814

Table 3.1.12. Vlkas 'Do hulského chotára', House 213. Summarised find information.

Table 3.1.13. Vlkaš 'Do hulského chotára', House 590. Contextual, chronological and architectural information.

House no.	590
Dating	relative chronology: unknown absolute chronology: unknown
Orientation	17.4°
Length in m	16.27
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	eastern: 590/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H590/01: 38.7
Excavated volume in m ³	long pit: H590/01: 17.00

Table 3.1.14. Vlkaš 'Do hulského chotára', House 590. Summarised find information.

Category	Number	Weight (g)
Decorated ceramics	32	1427
Undecorated ceramics	46	4128
Chipped stone	-	-
Ground stone	49	5854
Bone	19	1425
Daub	-	117684

Table 3.1.15. Vlkaš 'Do hulského chotára', House 591. Contextual, chronological and architectural information.

House no.	591
Dating	relative chronology: unknown absolute chronology: unknown
Orientation	44.5°
Length in m	-
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	eastern: H591/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H591/01: 85.6
Excavated volume in m ³	long pit: H591/02: 6.00

Table 3.1.16. Vlkaš 'Do hulského chotára', House 591. Summarised find information.

Category	Number	Weight (g)
Decorated ceramics	5	605
Undecorated ceramics	10	1023
Chipped stone	-	-
Ground stone	-	-
Bone	1	38
Daub	-	2765

House no.	201
Dating	relative chronology: unknown absolute chronology: 5200–5000
Orientation	20.1°
Length in m	15.73
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	western: H201/01
Postholes	H201/03
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H201/01: 47.7 posthole: H201/03: 23.4
Excavated volume in m ³	long pit: H201/01: 7.00

Table 3.1.17. Vlkaš 'Do hľuského chotára', House 201. Contextual, chronological and architectural information.

Category	Number	Weight (g)
Decorated ceramics	5	605
Undecorated ceramics	10	1023
Chipped stone	-	-
Ground stone	-	-
Bone	5	50
Daub	-	13775

Table 3.1.18. Vlkaš 'Do hľuského chotára', House 201. Summarised find information.

House no.	202
Dating	relative chronology: unknown absolute chronology: unknown
Orientation	21.3°
Length in m	25.27
Number of cross rows documented	4
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	eastern: 202/01
Postholes	H202/3, H202/4, H202/5, H202/6
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H202/01: 66.4 posthole: H202/3: 25.4, H202/4: 41.7, H202/5: 25.6, H202/6: 58.6
Excavated volume in m ³	long pit: H202/01: 10.00

Table 3.1.19. Vlkaš 'Do hľuského chotára', House 202. Contextual, chronological and architectural information.

Category	Number	Weight (g)
Decorated ceramics	106	3758
Undecorated ceramics	79	8144
Chipped stone	-	-
Ground stone	192	7200
Bone	262	1555
Daub	-	382136

Table 3.1.20. Vlkaš 'Do hľuského chotára', House 202. Summarised find information.

Table 3.1.21. Vlkaš 'Do hulského chotára', House 205. Contextual, chronological and architectural information.

House no.	205
Dating	relative chronology: unknown absolute chronology: 5200–5050
Orientation	27.0°
Length in m	13.05
Number of cross rows documented	-
Width between house walls in m	-
Average width of cross rows in m	-
Distance between cross rows (from south to north) in m	-
Long pits	western: H205/01
Postholes	-
Other features	-
Maximum depth of features from Planum 1 in cm	long pit: H205/01: 95.01
Excavated volume in m ³	long pit: H205/01: 2.00

Table 3.1.22. Vlkaš 'Do hulského chotára', House 205. Summarised find information.

Category	Number	Weight (g)
Decorated ceramics	8	206
Undecorated ceramics	5	184
Chipped stone	-	-
Ground stone	-	-
Bone	332	281
Daub	-	2026

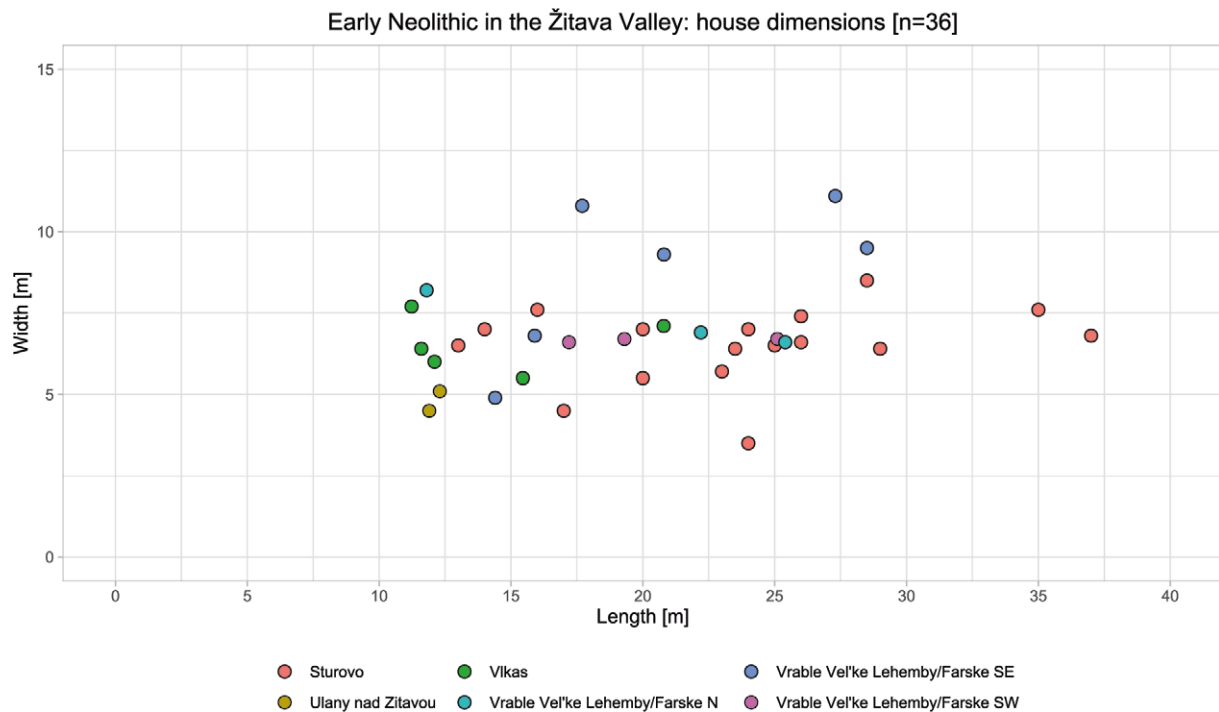
Architectural and find data

While the integration of geophysical prospection (see Chapter 2.3; Pickartz *et al.*, 2020; Winkelmann *et al.*, 2020) allowed a site-wide investigation of the subterranean features found across the entire area of the site, it also provides the means to estimate the number of houses and to infer their sizes on the basis of geophysical imagery. Although house analysis as a means of identifying activity areas and house divisions represents a common thread in Early Neolithic studies (Pavúk, 1994; Oross, 2013; Coudart, 2014), in the Žitava Valley specifically, the low visibility of postholes during excavations severely affected the possibility of investigating the structural differences between houses on the basis of architectural characteristics. This aspect of the archaeological record proves challenging for several typical analytical directions of LBK settlements:

1. The estimation of house sizes must be made on the basis of long pit extent rather than the extent of posthole rows.
2. Investigation of structural differences between the different houses is not possible.
3. Identification of storage spaces in the front part of the houses is not possible.
4. Household analysis of structures is limited to analysis of spatio-temporal factors (settlement organisation) and depositional practices.

Contrary to such sites as Štúrovo, where the documentation of specific house constituents was possible (Pavúk, 1994), or Bajč, where hardly any typical house structures were documented (Cheben, 2000), the following study of house-related aspects was aimed at comparing the documented or estimated characteristics of domestic architecture over time, to answer the following questions:

1. Were there substantial differences between the sites in terms of house sizes?
2. Did the construction of the ditch around Vráble 'Veľké Lehembý'/'Farské' lead to changes in house size?



Analysis of architectural practices

A total of 19 excavated house plans from the Žitava Valley were available for the investigation of house dimensions. For a regional comparison, the findings from Štúrovo (17 house plans) were also included in the study. The house size analysis indicated that the primary means of differentiation between houses was the length of the structures, ranging from ca. 11 to 37 m (Fig. 3.1.14). Almost no small houses, as encountered in other LBK settlements, were documented, suggesting that at this point in time, the presence of such structures had not yet been ‘invented’ in this part of central Europe. At the same time, the houses display inter-site variability in terms of size, with Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľského chotára’ representing the shorter end of the size spectrum.

Investigating house length as the main axis of potential differentiation between inhabitants of the Žitava Valley shows that the distribution of length is a right-skewed unimodal distribution with majority of house length falling between 15 and 25 m (Fig. 3.1.15). While the longest constructions have received attention as possible indicators of communal centres or axes of prestige-based relationships among the different occupants (Pechtl, 2009; Coudart, 2014; Hofmann and Lenneis, 2017), their incidence in the Žitava Valley is low in comparison with smaller structures.

Despite the limited sample size, the site-based investigation of house length displays links with different settlements, pointing towards specific intra-site practices related to architecture: Although the larger settlements, such as Štúrovo and Vráble ‘Veľké Lehemby’/‘Farské’, display a wider spectrum of house sizes, they include no house sizes as small as the ones documented at Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľského chotára’ (Fig. 3.1.16). Regardless of whether these differences in house size can be explained by the greater effort available through the greater availability of human power on larger settlements (Pechtl, 2009: 193), this observation points towards substantial, social differences in everyday life between superficially similar groups. Since no major evidence of Early Neolithic impact on the natural environment was documented around Vráble ‘Veľké Lehemby’/‘Farské’ (Dreibrodt and Bork, 2020), especially considering that this settlement complex represents the

Figure 3.1.14. Early Neolithic long house dimensions in the Žitava Valley.

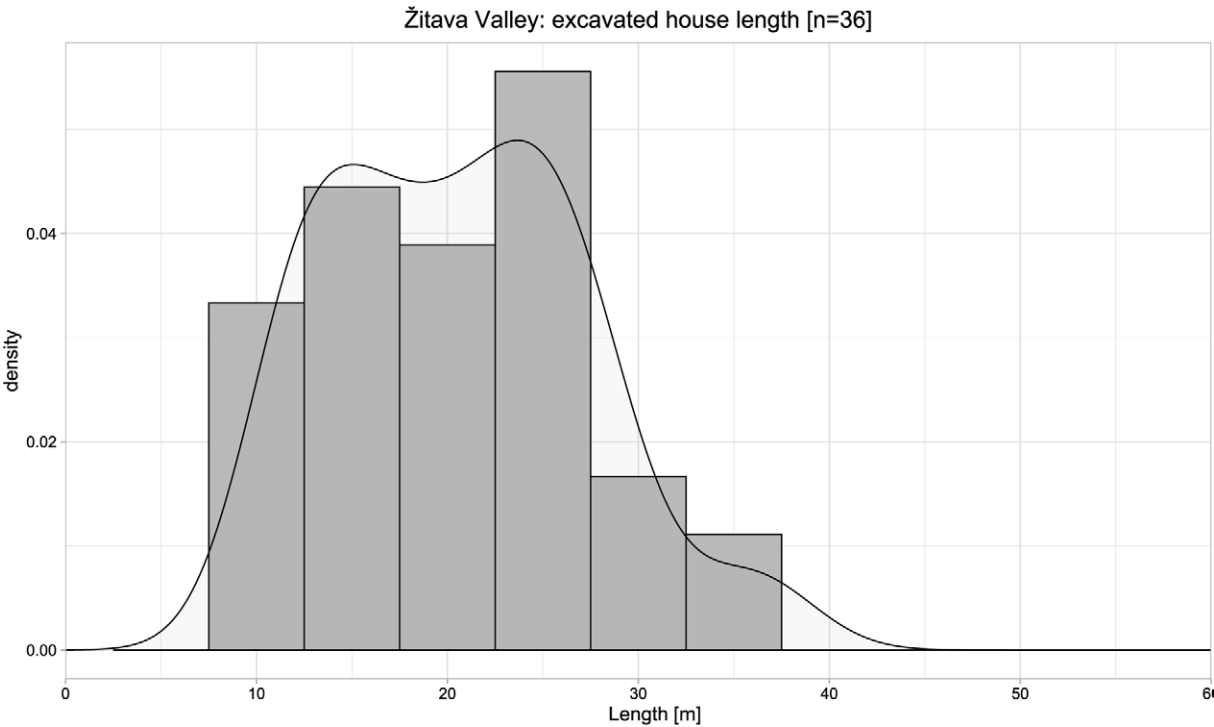
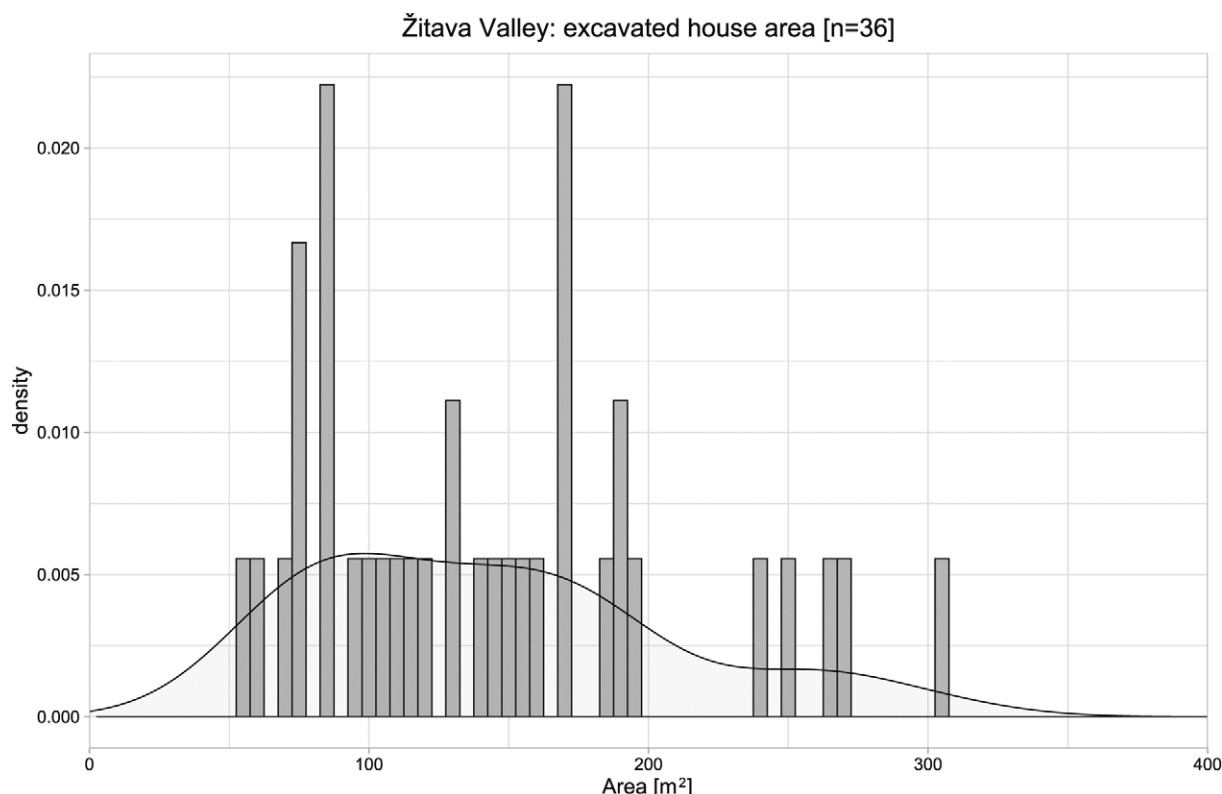


Figure 3.1.15. Early Neolithic house length in the Žitava Valley.



Figure 3.1.16. Early Neolithic house length in the Žitava Valley, by site.



largest concentration of houses in the Žitava Valley, the availability of resources for construction should not be considered as the key limiting factor for house size. Instead, potential social factors, such as group identity, *e.g.* related to the importance of housing animals in houses, could be expected to contribute to the discrepancies in house sizes.

While the length of the houses can be used for investigation of the house structures in terms of their modules and for easily recognisable size estimation, an analysis of the floor area of each house can be used to conceptualise the differences in terms of available space. The analysis re-affirms the existence of three house sizes in the Žitava Valley and points towards potential differentiation across settlements in terms of house area (Fig. 3.1.17). Following the premises of demographic modelling of Early Neolithic groups in the Žitava Valley (Müller *et al.*, 2020), this observation suggests that different household groups were existing across the area. Assuming that these constructions were indeed used for housing and that inhabitants of house groups correspond to familial structures (Yanagisako, 1979), it would suggest the potential existence of different kinship groups across the entire area (Sahlins, 2013). If kinship primarily involved engaging in social ties in direct proximity, the inhabitants of different settlements would most likely maintain stronger ties with their immediate neighbours, and only afterwards, with the larger extended groups found living in different parts of the valley.

This observation is further supported by the site-based analysis, where differences between the surface area available in the houses are highlighted (Fig. 3.1.18). While the differences in house surface areas at Štúrovo, Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Do hľského chotára’ remain similar in comparison to house length, the differences between the neighbourhoods within the site of Vráble ‘Veľké Lehemby’/‘Farské’ stand out. Overall, the south-eastern neighbourhood is characterised by houses with the largest floor sizes of all the settlements analysed here. The discrepancies in terms of available space within the houses suggests the presence of major differences between

Figure 3.1.17. Early Neolithic house area in the Žitava Valley.



Figure 3.1.18. Early Neolithic house surface area in the Žitava Valley, by site.



Figure 3.1.19. Chronological dynamics of house sizes in the Žitava Valley.

the communities in the Žitava Valley and of potential sources of discord in instances when the sheer number of occupants would emerge as a key factor for negotiations among the inhabitants.

Because of the small sample size, currently no major temporal changes can be observed (Fig. 3.1.19). Even at the point in time when the construction of the ditch took place, ca. 5070 BCE, house size corresponded to one of the three main size categories ($< 100 \text{ m}^2$, $100\text{--}200 \text{ m}^2$, $> 200 \text{ m}^2$). From this standpoint, the low impact of the changing social relations between the different groups of inhabitants of the Žitava Valley on the house surface areas suggests that the construction of houses most likely

functioned without the involvement of the other neighbourhood communities. This upholding of architectural practices points towards the maintenance of cohesion within the already differentiated groups.

Despite the overall similarity of house structures excavated in the Žitava Valley, there are differences in house length and surface area within and between settlements. Analysis of house length indicates that houses in the two categories of medium length were primarily used for occupation, and large (>30 m) houses were less prevalent. Smaller houses predominate at Úľany nad Žitavou 'Dolné diely' and Vlkaš 'Do hľského chotára'. The analysis of floor area indicates that there were observable differences between the different houses in the Žitava Valley in terms of space available to the inhabitants. In the absence of evidence of anthropogenic impact on the environment, the differences in house sizes are most likely evidence of social differentiation between the settlements. If house area was correlated with familial groups and larger kinship structures, the ensuing different demographic potential indicates the presence of distinctly large and small groups of inhabitants, affecting the interaction form between the different settlements and indicating a potential arena for continuing differentiation of the different communities. Rather than indicating homogenous practices, the architectural reality of Early Neolithic occupants of the Žitava Valley indicates the existence of visible differences between settlements and could imply that the formation of settlements was a process primarily driven by historically constructed groups, who maintained a certain level of differentiation despite their shared migratory background. These differences do not seem to be affected by large-scale works related to the construction of the enclosure at Vráble 'Veľké Lehemby'/'Farské', indicating that inter-group conflict did not affect the overall architectural practices or lead to the re-affirmation of community-based dependencies between the inhabitants of distinct neighbourhoods.

Analysis of waste disposal practices

The analysis of disposal practices has recently gained increased attention as a possible avenue for investigating house-specific practices across Early Neolithic communities (Květina, 2010; Sommer and Astaloş, 2015; Květina and Řídký, 2017; Hofmann, 2020). In the absence of internal house architecture, waste disposal analysis can provide insight into intra-settlement differences and help us understand the everyday reality of early agricultural communities. For this reason, the following section will investigate the quantitative differences in waste disposal between houses, neighbourhoods and settlements in order to recognise potential differences in terms of access to resources, essential constituents of economic practices and possible links to consumption. The primary aims are:

1. To determine whether specific waste disposal patterns display inter-household differences.
2. To determine whether depositional patterns remained stable throughout the Early Neolithic in the Žitava Valley.
3. Investigate the potential social differences in house-related practices.

For the purpose of the analysis, the finds recovered from Early Neolithic contexts were assigned to six distinct categories: (1) undecorated ceramics; (2) decorated ceramics; (3) chipped stone; (4) ground stone; (5) animal bones; and (6) daub.

Items in each category were counted and weighed, apart from daub, which, due to its state of preservation, is susceptible to crumbling, and thus was only weighed. The resource-based classification system represents the first stage of material culture investigation and allows a robust estimation of the depositional patterns related to household structures. While not exhaustive, it provides the means to determine the intensity of activities related to households and document inter-household variability in waste disposal practices.

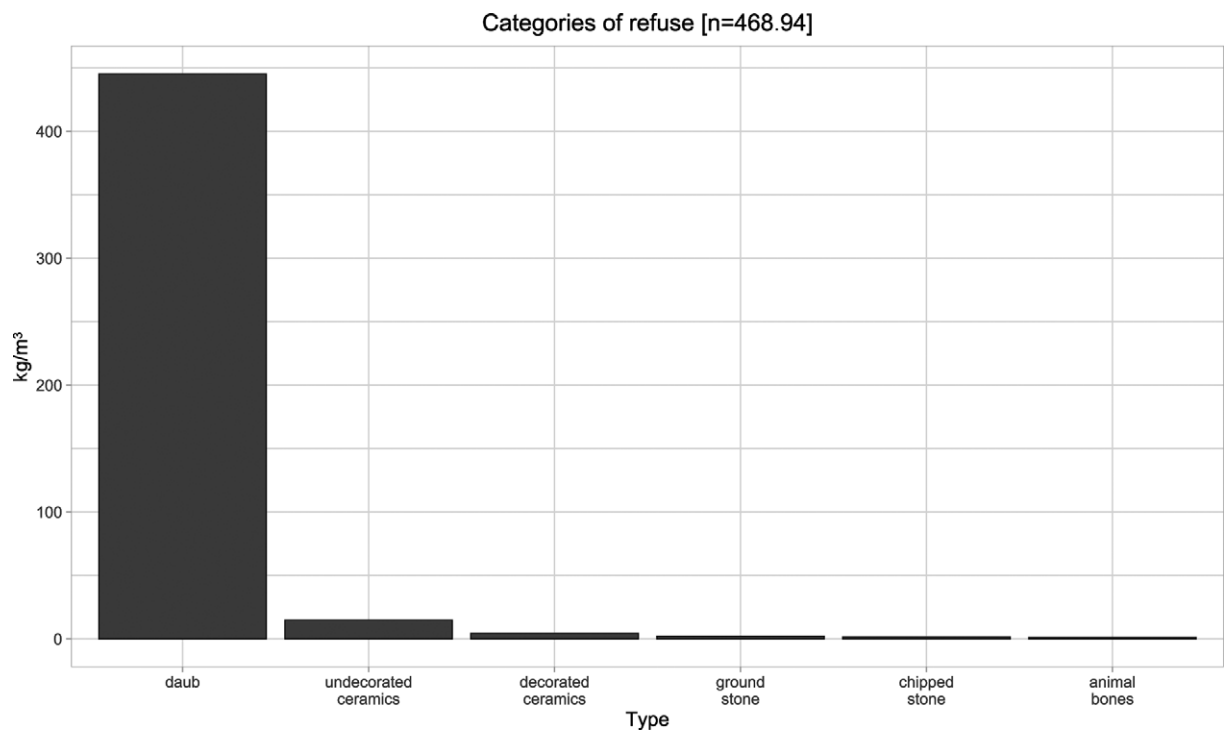


Figure 3.1.20. Distribution of resource-based categories.

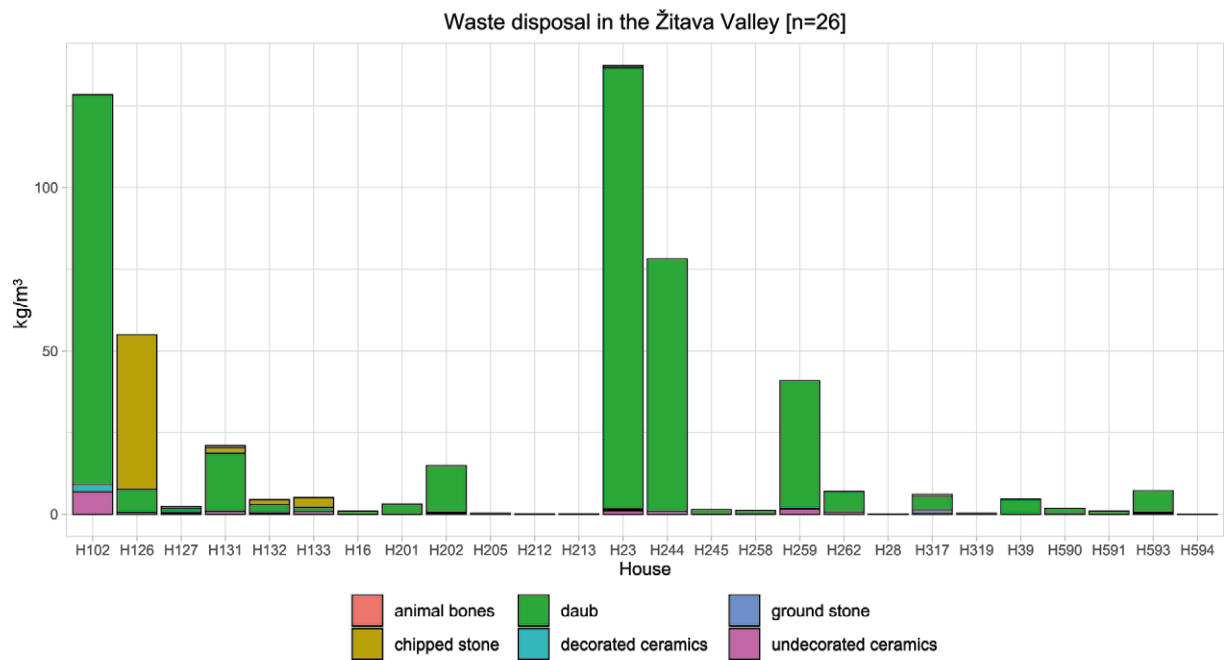


Figure 3.1.21. Early Neolithic waste disposal per excavated house.

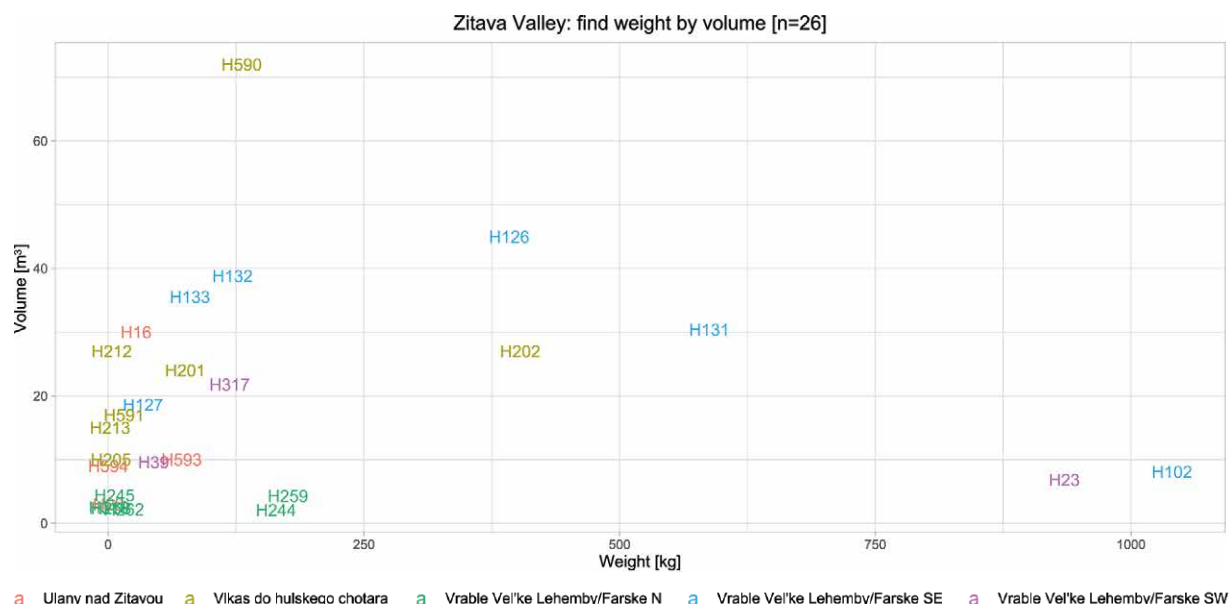


Figure 3.1.22. Early Neolithic long house find weight by excavated volume.

The differences in excavation strategy, especially when it comes to the excavation coverage of objects adjacent to selected houses, significantly affected the quantities of documented finds that could be documented. In some instances, both long pits were selected for excavation; in others only one of the long pits. Therefore, in the following analysis, the primary analytical unit is the weight of artefacts (in kg) by excavated feature volume (in m³), which serves as an estimate of the amount of refuse deposited per volume of soil. Rather than amplifying the impact of sampling, this value provides a more reliable comparison of values between houses.

Although in the previous section the findings from Štúrovo were incorporated to investigate house sizes, the absence of weight values regarding finds from house units means we cannot use this site to investigate cross-site similarities in disposal practices.

Overall, the vast majority of the archaeological material recovered from the pits was daub from the abandoned adjacent houses (Fig. 3.1.20). Daub represents approx. 95% of all recovered refuse. Assuming that the deposition of daub represents the final stage of the house's life cycle, the accompanying refuse had to have been deposited only slightly earlier. As such, the documented refuse should be considered as a pre-final snapshot of activities taking place inside the houses. This leads us to two points to consider:

1. The majority of everyday waste disposal took place outside of the excavated areas. The absence of accumulated waste areas points towards an organised system of managing waste.
2. Rather than using waste disposal practices as durable markers for the practices of the inhabitants, it might prove more useful to, instead, use the documented waste as a marker of pre-abandonment activities.

The structure of refuse disposal across different house units re-affirms the impact of demolition-related refuse in archaeological deposits (Fig. 3.1.21). In the majority of cases (ca. 80%), the largest proportion of finds per cubic metre documented inside archaeological structures is daub. This pattern was not documented in units H28, H126, H133, H212 and H594. Very few finds were documented in H28, H12 and H594, and H126 and H133 are dominated by chipped stone, suggesting remarkably intensive pre-depositional activity in terms of artefact production.

The relationship between the combined weight of the finds and the excavated volume indicates that the majority of excavated units fall within a range of up to 250 kg of refuse found inside a volume of up to 40 m³ (Fig. 3.1.22). This group

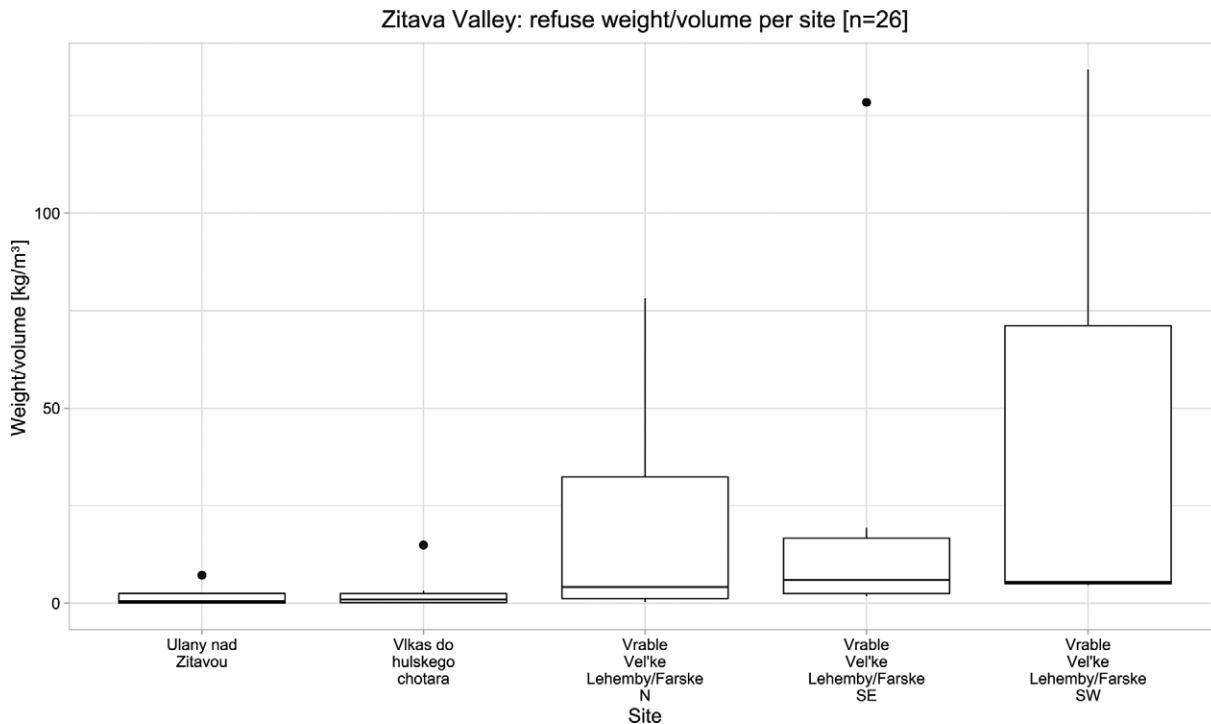


Figure 3.1.23. Excavated find weight by feature volume, by site.

comprises refuse found across all the excavated neighbourhoods and could be considered a regional standard in terms of waste disposal taking place in the Early Neolithic Žitava Valley. Several outliers were documented: H590, H202, H126, H131, H23 and H102, where either the excavated volume was much larger or the weight of the documented refuse exceeded the regional baseline. In the case of House 102, its value is caused by the overlap of two house structures, 102 and 103, and the impossibility of separating finds found inside the younger context, House 103 (Staniuk *et al.*, 2020). The remaining units should be considered outliers.

Although the majority of houses within each site show small differences in terms of the relative amount of refuse, there are marked differences between the neighbourhoods of Vráble ‘Velké Lehembý’/‘Farské’ (Fig. 3.1.23). While the settlements of Úlany nad Žitavou and Vlkaš ‘Do hlukského chotára’ and the south-eastern neighbourhood of Vráble ‘Velké Lehembý’/‘Farské’ show a comparable low level, the northern and south-western neighbourhoods of Vráble are characterised by a much higher rate of waste disposal. If house-related refuse can be directly equated with the communal activities taking place prior to the house’s destruction, the results indicate the presence of a constantly visible ceremony, which could be used to be amplify intra-group ties while re-enforcing inter-group distinctions.

The occupation dates of the houses were estimated, based on their orientation, in order to investigate changes in waste disposal practices over time (Fig. 3.1.24). The chronological trend indicates an increase in the deposition of waste until ca. 5150 BCE, followed by a rapid decline ca. 5070 BCE – coinciding with the construction of the enclosure around the south-western neighbourhood of Vráble ‘Velké Lehembý’/‘Farské’. Although the current calculations are based on a random sample of houses from the entire region, they reveal the remarkable contribution of this south-western part of the Vráble settlement complex over this relatively short time span. The drop in waste disposal ca. 5070 BCE could represent a change in waste management, whereby, after a brief exposure of the ditch, it soon began to be filled in with settlement refuse. This way, the relatively small values documented in the south-western neighbourhood could have an explanation: the inhabitants simply altered

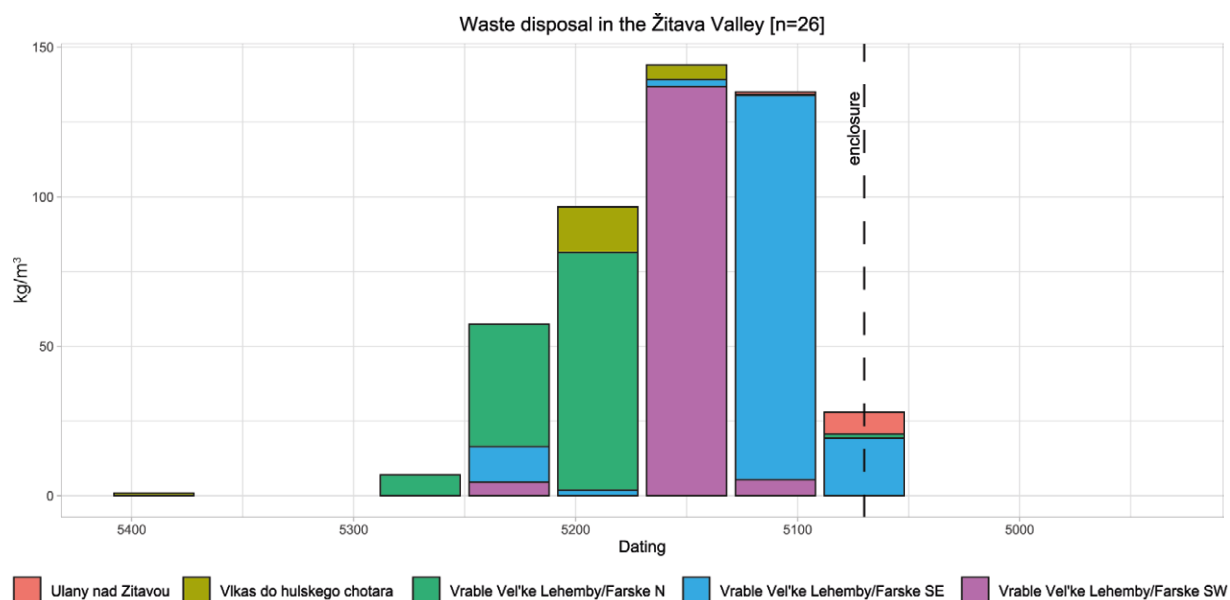


Figure 3.1.24. Chronological development of waste disposal in the Early Neolithic Žitava Valley.

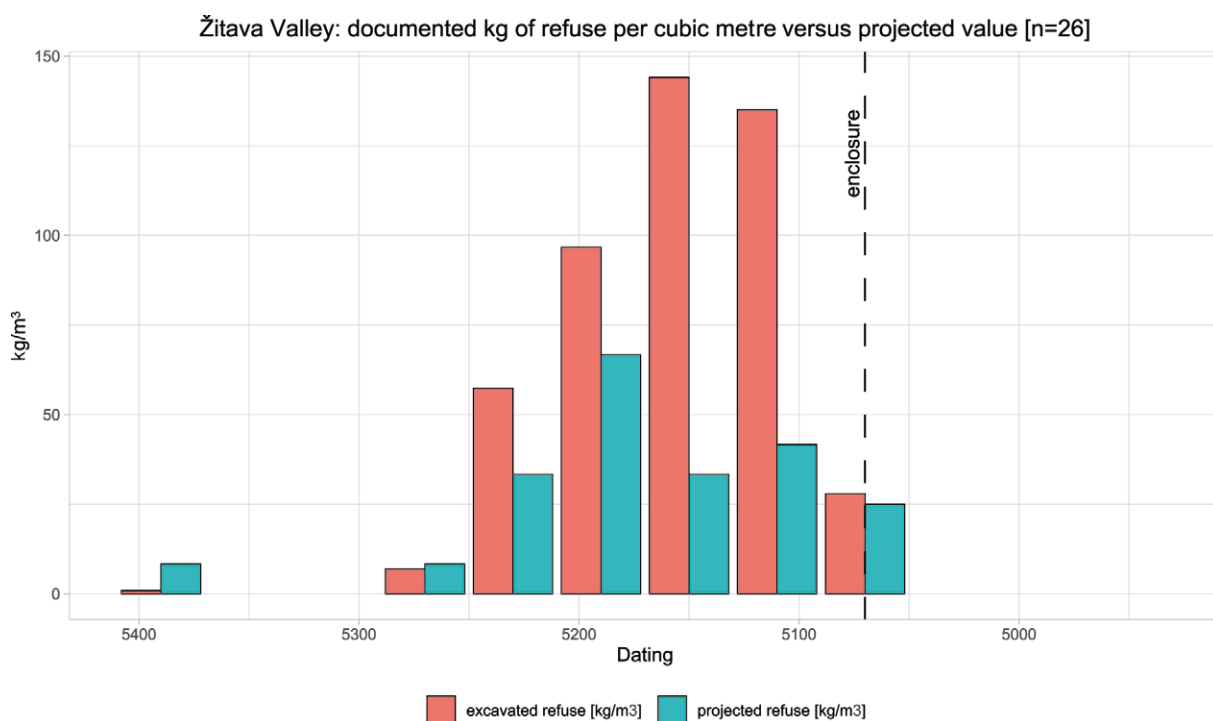


Figure 3.1.25. Projected and documented values of excavated refuse in the Early Neolithic Žitava Valley.

the *locale* of their regular practices in order to display their increasing differentiation from other groups.

The collected values allowed a calculation of an average find weight by volume value to investigate whether the documented values display stable increase in depositional practices. The calculation was based on the third quartile of the overall index (8.33 kg/m³), which was multiplied by the number of excavated houses.

The results indicate that during nearly all occupation stages of the Žitava Valley, the documented amount of deposited refuse exceeded the estimated values (Fig. 3.1.25). Since Early Neolithic LBK houses are generally considered as relatively

uniform, the results indicate that the practices of the communities were far from standardised. In spite of the overall similarity in house structures (cf. Analysis of architectural practices), the activities of individual households show differences in waste disposal behaviour. If house-related refuse can, indeed, be directly equated with the communal activities taking place prior to the house's destruction, this would indicate that the similarities were superficially similar – *i.e.* revolving around houses, involving inhabitants and the shared idea of commemorating the abandonment of a house – but would, in fact, engage communities in a specific, contextualised fashion (possibly the availability of food, seasonal variation in activities, individual relations between the inhabitants and their relatives, *etc.*).

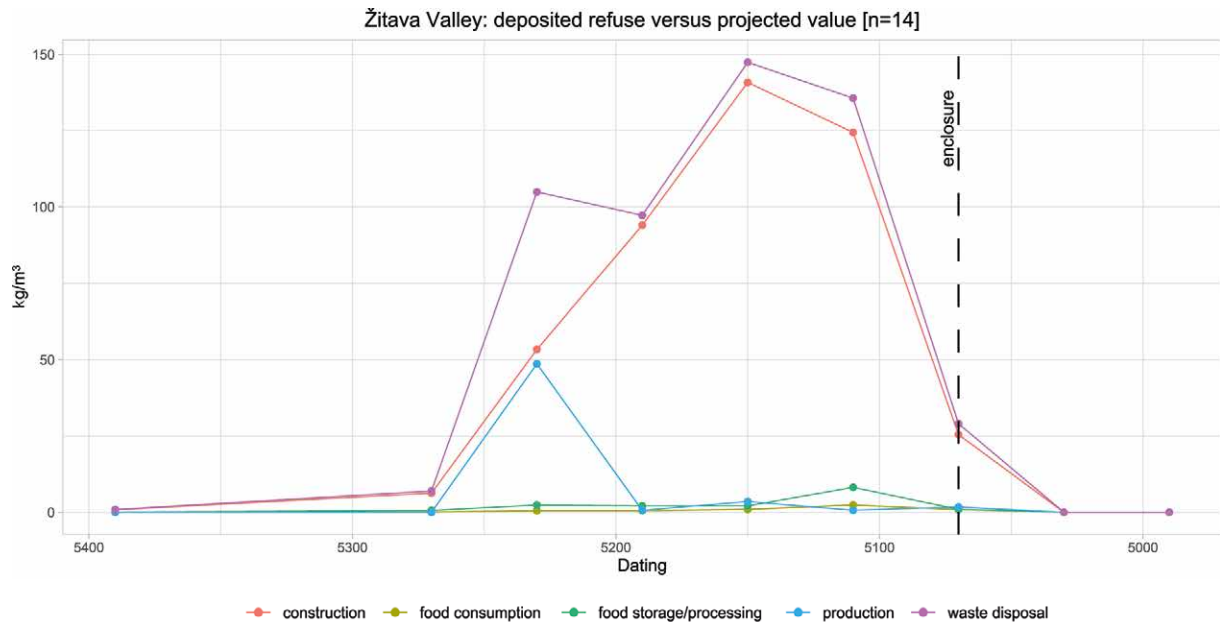
The overwhelming majority of disposed-of waste was house debris, indicating that if house-adjacent archaeological features are used for investigating house-specific practices, it is most prudent to assume that the depositions occurred shortly before constructions were destroyed. Under this assumption, the documented refuse should be considered as part of communal activities linked to the house's destruction and representing context-specific deposition of refuse related to a form of pre-abandonment events of coming together. The absence of clearly distinguishable waste disposal areas indicates that managing refuse was most likely part of the organisational structure, as no major refuse areas were documented in either the geophysical prospection or the excavations. The divergences in terms of the find weight by feature volume point towards small-scale differences, possibly representative of the relationships of the inhabitants within the settlement networks. These differences become more noticeable once the perspective shifts towards sites, where the discrepancies among the three neighbourhoods of Vráble 'Velké Lehemby'/'Farské' are particularly marked. Overall, the south-western part of the settlement complex was characterised by the largest relative amount of deposited refuse, followed by the northern neighbourhood. The relatively low amount of refuse linked to the south-eastern neighbourhood could be explained by a changing form of waste disposal once the enclosure was no longer used for its initial function.

Returning to the questions presented in the beginning of this section, we can answer these as follows: While differences between households were documented for Houses 590, 202, 126, 131, 23 and 102, the vast majority were relatively uniform. Then the deposition seems to have changed, with the majority of documented finds originating from only four houses, dated to ca. 5150 BCE. Despite the uniformity of architectural structures, the process of their abandonment varied over time, followed by a decline in depositional practices that preceded the construction of the ditch by approx. 80 years.

Analysis of social practices

For the investigation of intra-site social differentiation in terms of household abandonment activities, the resource-based categories (cf. Analysis of waste disposal practices) were attributed to specific practices: food storage/processing (1, 4), food consumption (2, 5), production (3), and construction (6). Rather than emphasising material differences, this re-classification allows comparisons among the activities that resulted in the formation of the archaeological record. Due to the overall similarities in the distribution of house-based observations and neighbourhood-based observations, only the findings for the entire Žitava Valley are reported.

The investigation of social practices indicates that although the majority of activities were related to the construction of houses, minor changes in relation to communal activities took place prior to house abandonment (Fig. 3.1.26). The simultaneous affirmation of house construction and of deposition of pre-abandonment waste in the adjacent long pits point towards an already established social practice. While the increase in the number of houses over time contributes to the increase in the values



of deposited refuse, the rapid emergence and disappearance of production-related refuse ca. 5230 BCE points towards a potential short-term modification of the existing rite of conduct. The large amount of production-related finds and their subsequent disappearance could suggest that this depositional practice was actively countered by the actors involved in the house's abandonment. But rather than altering the existing form of social engagement, these actors countered the drop in the amount of production-based refuse, as documented archaeologically, by increasing food processing practices. This may indicate that the instances of house destruction were used as occasions for engaging in cooperative activities. Assuming that the emergence of storage pits and their opening represented a vital part of communal activities (Wunderlich *et al.*, 2020), the increasing amount of processing refuse may relate to events of increased processing for consumption. This practice remained essential until ca. 5110 BCE, when all remaining indices start to decline and the enclosure was constructed. With the emergence of burial practices in the settlement context ca. 5110 BCE (Müller-Scheeßel *et al.*, 2021), a potential shift in communal activities is documented, where the emergence of human remains start to signal a more individualised affiliation between the abandoned houses, the deceased and the inhabitants, and thereby an embrace of practices that had not previously occurred.

Figure 3.1.26. The dynamics of social practices in the Early Neolithic Žitava Valley.

Summary: exploring the dynamics of early agricultural social practices

The early agricultural communities inhabiting the Žitava Valley in the Early Neolithic inherited and maintained practices, undergoing change as new regions were settled. Although similar in terms of their architectural practices, these communities were groups with a diverging historical background, attaching significance to specific practices and altering them by means of social discourse. Although they were living side by side, these groups executed their practices differently, embracing neighbourhood-specific forms, which eventually led to discrepancies in the archaeological record. The initiation of architectural practices was most likely a significant event engaging all inhabitants alike, and the destruction and abandonment of houses would most likely draw attention as a final instance for celebrating a past effort. Our investigation of waste management suggests that, rather than considering house refuse as an

indicator of domestic activities, we should consider it as an indicator of the communal celebration of a house's destruction, whereby the end of the house's life cycle allowed the inhabitants to strengthen their inter- and intra-group ties. The evidence for the preparation of food and the sharing of produce stored in large storage pits points towards an established sharing economy, which was only temporarily affected by the emergence of new resources. The changing perception of houses, initially a marker of communal effort and later a marker of individual loss, and the potential differentiation from celebrating effort to commemorating individuals, mark the essential transition of social practices taking place in the Žitava Valley during the Early Neolithic.

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3.2 The pottery and ornamental styles of the Early Neolithic in the Žitava Valley, south-western Slovakia

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Abstract

The analysis of Linear Pottery culture (LBK) and Želiezovce Group ceramics focuses on decorative motifs and vessel typology. Engraved lines, often paired, characterize thin- and medium-walled ceramics of the LBK, while later LBK phases introduce music note head motifs. The Želiezovce Group distinguishes itself with notches interrupting engraved lines, with combined motifs appearing in transitional periods. Larger, thick-walled vessels feature plastic or applied ornamentation. These stylistic elements serve as chronological markers. The frequency of ceramic finds correlates with research intensity, particularly in the Upper Žitava Valley. Even single decorated fragments confirm the existence of settlement sites, guiding targeted surveys and prospection. Ceramics remain key indicators of settlement density, despite many finds originating from surface collections rather than excavations.

Keywords: LBK, Želiezovce Group, ceramics, chronology, ornamentation

Introduction

From the studied area of the upper reaches of the Žitava, which forms a closed geographical unit bounded by mountain ranges, finds of the LBK and Želiezovce Group were until recently obtained mainly through activities associated with surface collection. A certain proportion of the find inventories comes from accidental finds discovered during construction activities, and these lack field documentation (Gabulová, 2015: 102, fig. 3). A comprehensive database of sites from the Upper Žitava Valley assigned to the older Neolithic period, based on published contributions and available sources, was prepared by M. Gabulová (2015, 149–164, Appendix 1).

Field activities and systematic research relating to the LBK and Želiezovce Group settlement sites of Vráble ‘Veľké Lehemby’ and Vráble ‘Farské’ (Furholt *et al.*, 2014; Furholt *et al.*, 2020; Cheben and Furholt, 2018; 2019; 2020; 2023a) included detailed

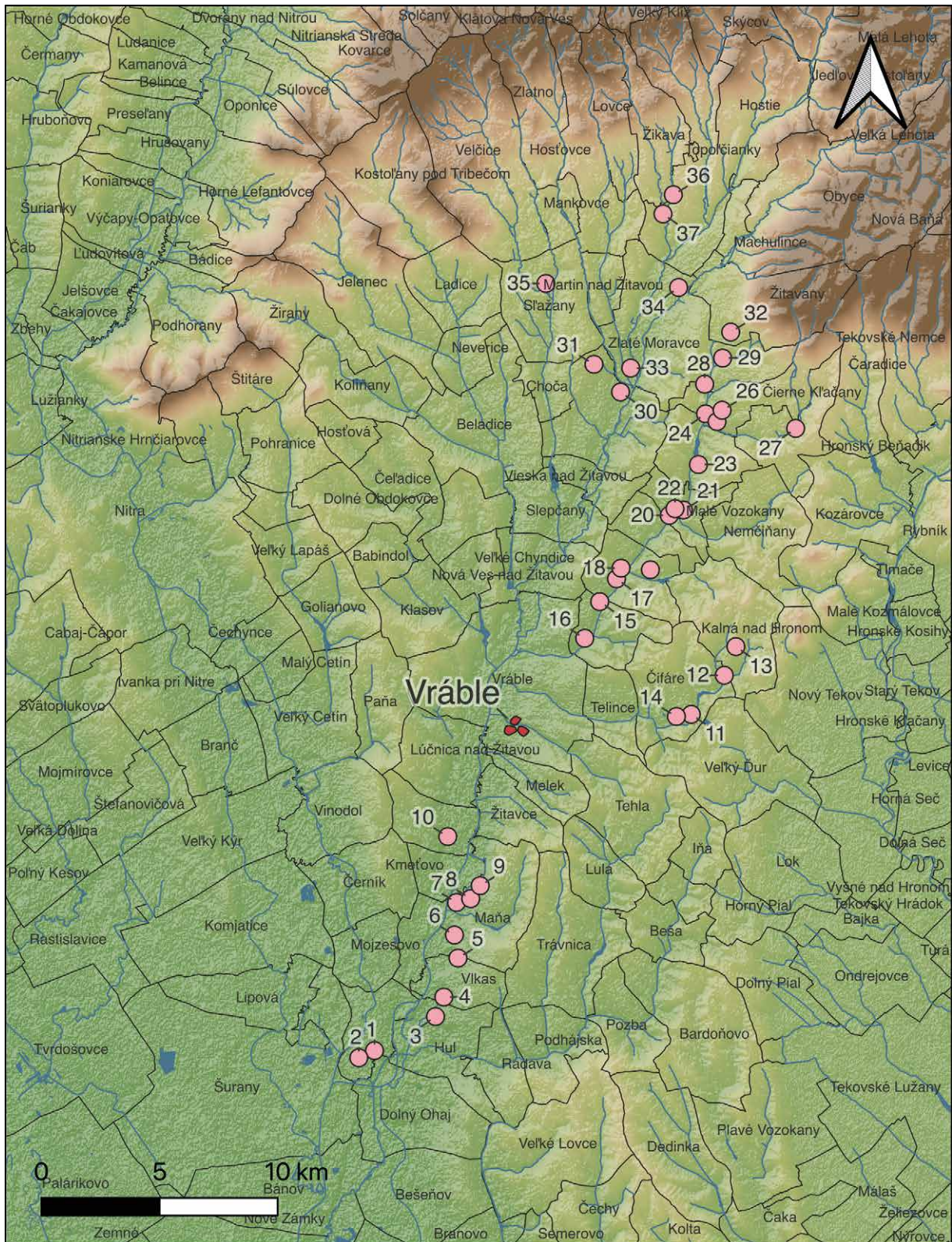


Figure 3.2.1. LBK and Želiezovce Group sites in the Upper Žitava Valley discussed in the text.

surface collecting associated with magnetic measurements and pedological drillings of a selected number of other sites of the LBK and the Želiezovce Group in the valley of the Žitava River and its tributaries (Cheben and Furholt 2023b). The project has so far carried out two systematic surface survey campaigns (see Chapter 2.3). We present an analysis of ceramic shapes and ornamentations of the LBK and the Želiezovce Group based on the find inventories from the excavations at Úľany nad Žitavou and Vlkaš, in 2018. In addition, we present the results of systematic surface collections of a number of sites, which were carried out in the spring campaigns of 2017 and 2018. Finally, we present the published pottery material of the LBK and the Želiezovce Group.

As a starting point for the analysis of the ceramic inventories, the database of localities compiled by M. Gabulová (2015) appeared to be the most suitable. It comprises 52 LBK settlements and 24 settlements of the Želiezovce Group. Overall, in the Žitava Valley, only a small proportion of the LBK and Želiezovce Group ceramic inventory comes from research carried out during the past decades.

The sites in this chapter are described in the sequence in which they occur along the streambed of the Žitava and its individual tributaries, *i.e.* from south to north (Fig. 3.2.1). Given the overall direction of LBK expansion, this could also have been one of the directions in the gradual settlement of the territory. Along the middle reaches of the Žitava (from Úľany nad Žitavou to Vráble) localities are less frequently documented on the right bank; in most cases, they are on its left (eastern) bank, where they are concentrated on a slightly elevated terrace above the river. The valley is relatively narrow in this section of the river, and at the same time there is only a small number of tributaries. Therefore, there are no valleys created by streams unlike what can be observed in the northern part of the Žitava river.

Because many finds stem from surface collection, the typological evaluation of ceramics from both the excavations and the surface collections presented here is based on observation of decorative motifs, which are the most important factor in determining the chronological developments at individual sites. However, the typology and ornamentation of the ceramic inventory coming from the excavations at Vlkaš ‘Do hľského chotára’ and Úľany nad Žitavou ‘Dolné diely’ are analysed in more detail than those from surface collection. Typological data from previous surface surveys were also included in the evaluation if they were published in a form that made it possible to determine the cultural classification on the basis of the description or representation of the decoration.

Úľany nad Žitavou ‘Dolné diely’

Located in the basin of two rivers, in the southern part of the Žitava floodplain, the settlement site at ‘Dolné diely’ is located on an oval dune that stretches in a SSW direction and that in some sections is significantly elevated above the terrain. The site is largely situated between the Šurany–Vráble railway line and the Nové Zámky–Levice road, but its southern part extends to the south of the road. The eastern edge of the site is on the left bank of Žitava, less than 1 km away from its present riverbed. The western edge of the inhabited area is on the right bank of the Nitra River, more than 500 m away from the present riverbed. During a flood in 2010, the water level of the Žitava (Fig. 3.2.2) did not reach the site, nor did it reach the nearby site ‘Dolné rakytiny’ (Kuzma and Bartík, 2015: 143, fig. 69.2; fig. 70.1) so that it seems obvious that the sites were founded at this elevation to avoid the risk of flooding. It cannot be ruled out that these two localities form a single settlement, spread over several elevated loess dunes.



Figure 3.2.2. Úľany nad Žitavou 'Dolné diely' (centre) shown during flooding of the Žitava River in 2010.

Systematic prospection

The ceramic inventory obtained during surface collection is dominated mainly by undecorated fragments from the bodies of medium-thick-walled and thick-walled vessels. Significantly smaller in number are the fragments with ornamentation. Among the decorative elements applied to the vessels, pairs of engraved lines interrupted by a notch (Pl. 3.2.2, 3, 9) are attested, exceptionally with a triangular depression (Pl. 3.2.2, 8). Among the forms of plastic decoration, applied mainly on thick-walled and otherwise undecorated vessels, are three types of lugs. Only a few fragments indicate the composition of the ornamentation (Pl. 3.2.2, 8). A rare find is a fragment of a figurine (Pl. 3.2.2, 13), on which part of the legs and buttocks are most likely depicted.

The ceramic inventory found in the western part of the settlement area, during earlier field seasons, consists of fragments of vessels on which engraved decoration was applied in the form of pairs of lines interrupted by a notch or terminated by an oval depression. Rare decorative elements on the vessels of the Želiezovce Group from this find spot include a wavy line and zoomorphic eyelet (Steiner, 2000: figs. 121.5–6, 122.3, 123.5).

Excavations

In the course of our excavation in 2018, 645 ceramic fragments were registered from Trench 13. The excavation work was focused mainly on the long pit (Object 1) situated at the western wall of the house (Fig. 3.2.3; see Chapter 3.1 for more details). The ceramic fragments were found in a pit (Object 2) situated south of the long pit and also in an object (Object 3) looming in the south-east corner of the trench. The objects were excavated by defined sectors, in artificial layers of 15 cm thickness. Up to 92 per cent of the ceramic material obtained (total approx. 553 pcs = 6850 g) came from

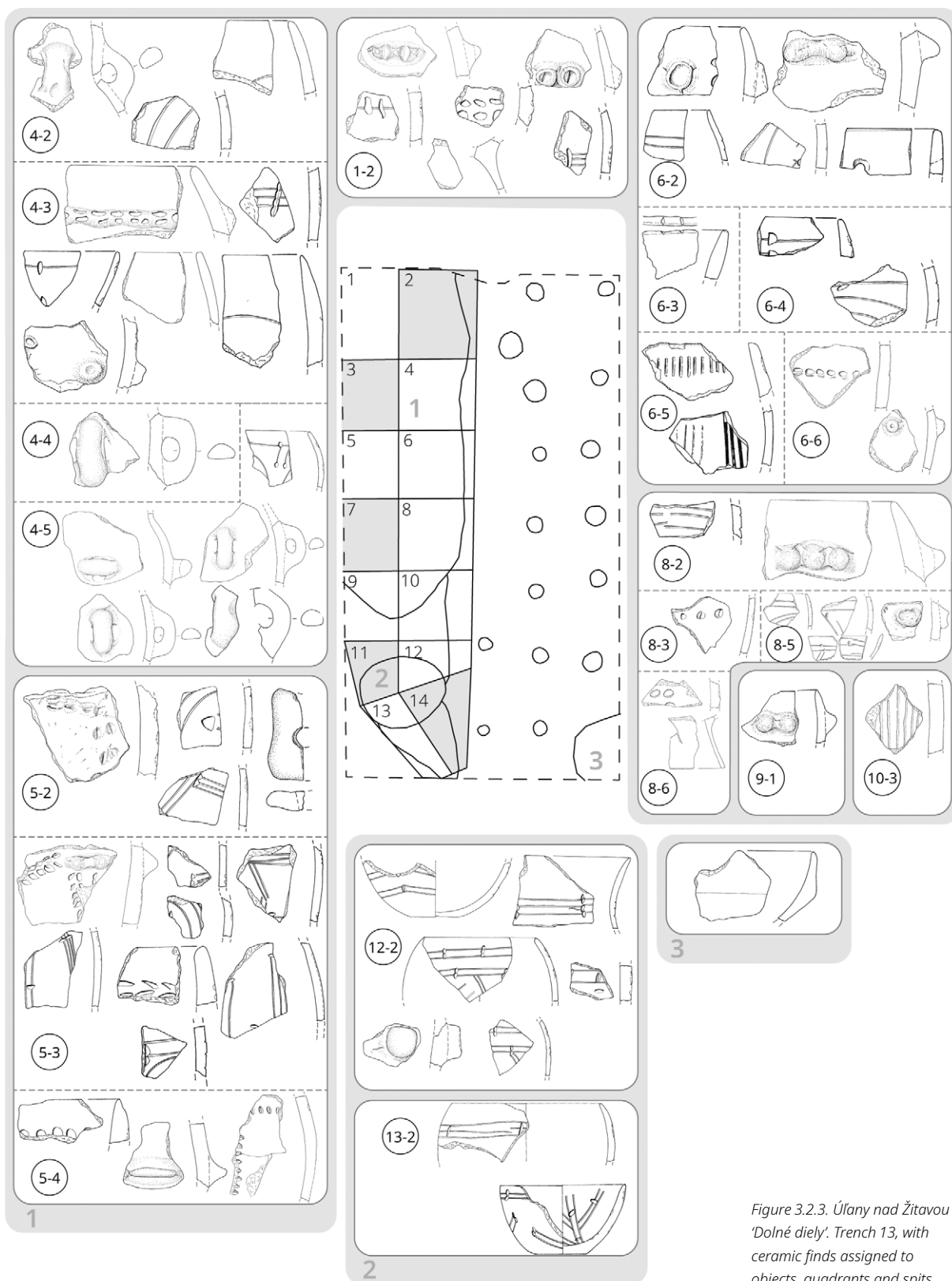


Figure 3.2.3. Úľany nad Žitavou 'Dolné diely'. Trench 13, with ceramic finds assigned to objects, quadrants and spits.

sectors 1, 4, 5, 6 and 8. Sectors 2, 9 and 10, which were partially examined, yielded less than 5 per cent of the ceramic fragments from this object. Several additional fragments were detected after initial cleaning of the trench (Planum 1).

Object 1

A total of 98 fragments, belonging to 86 vessels, were assessed, representing 18 per cent of the object inventory. The vessels are very fragmented, and in most cases it was not possible to determine vessel type or decorative motif. Only 10 vessels are represented by multiple fragments (up to 4 per vessel). A total of 38 sherds originated from the body of the vessel. A total of 30 vessels were identified through their rims. These are of different variants, and two of the rims are notched (Pl. 3.2.7, 9). In three cases, a foot was registered (Pl. 3.2.7, 11, 13, 20).

It was possible to determine with certainty the type of vessel in only one third of the vessels analysed. The collection is dominated by vessels of globular shape, including hemispherical vessels with rounded walls and a gently retracted mouth (Pl. 3.2.5, 4, 6, 7; Pl. 3.2.6, 3), bowls (Pl. 3.2.5, 2), and bowls with a hollow base (Pl. 3.2.7, 11, 20). At least four vessels with a neck are represented in the assemblage (Pl. 3.2.5, 11, 14, 16; Pl. 3.2.7, 24).

Both thin-walled (41 individual vessels) and thick-walled (45 individual vessels) ceramics were included in the analysis. In terms of technology, fine-grained material was used for the production of fine ceramics, whereas larger gravel or other organic or inorganic substances were used as an admixture for coarse ceramics. The surface colour of the outer wall of the containers was grey or brown, but most often light brown to orange. The inner walls of the vessels are most often dark grey.

Due to the high degree of fragmentation of the material, the informational value of the decorative elements applied to the vessels is limited and, accordingly, their statistical evaluation is also limited. A good example is, for instance, evidence of separate horizontal and arched grooves (18 times), where it can only be assumed that the engraved decoration on the vessel was complemented by elements of impressed decoration (Pl. 3.2.5, 12, 13; Pl. 3.2.6, 8). A series of regular notches was noted below the edge of a taller, bowl-shaped vessel (Pl. 3.2.7, 8). Thick vertical lines were found on a fragment from the body of a thick-walled vessel (Pl. 3.2.7, 6). Less clear is the overall decorative scheme of one thin-walled vessel, a fragment of which exhibits a group of both fine and thick lines. The indented decoration that can be assumed to be present at the end of the lines is very poorly legible (Pl. 3.2.7, 10). Separate indented decoration was present on the surface of about 17 per cent of the decorated vessels. It was applied just below the rim, in the form of hemispherical grooves (Pl. 3.2.6, 18), fingernail-impressed notches (Pl. 3.2.6, 20), notches (Pl. 3.2.7, 8) and pinching in double rows (Pl. 3.2.5, 23, 26; Pl. 3.2.7, 17). Impressions in the shape of coffee beans were also recorded (Pl. 3.2.6, 23; Pl. 3.2.7, 17). In some instances, the indented decoration on the body of the vessel was combined with unperforated protrusions (Pl. 3.2.7, 1, 14).

Most of the vessels ($n = 21$) exhibited a combination of engraved and impressed decoration on the outer surface of the vessels. It consists of one or two horizontal engraved lines below the rim of thin-walled vessels of hemispherical shape with an inwardly retracted edge (Pl. 3.2.5, 7, 27) or bowls of conical shape (Pl. 3.2.5, 2). The lines are interrupted by indentations of round, longitudinal or semicircular shape. The decoration of these vessels was complemented by an arched line (Pl. 3.2.5, 7, 18). Several fragments from the bodies of fine ceramic vessels exhibited one or two horizontal and arched lines (Pl. 3.2.5, 17, 20; Pl. 3.2.6, 4, 8; Pl. 3.2.6, 17, 21; Pl. 3.2.7.3). Several fragments also contained a trio of horizontal, oblique and arched engraved lines, punctuated by two longitudinal indentations (Pl. 3.2.6, 22, 25; Pl. 3.2.7.2). Exceptionally, a cut passing through a trio of engraved lines (Pl. 3.2.5, 22) or through

four oval impressions passing through a trio of horizontal lines (Pl. 3.2.5, 3) was found. The lines were engraved separately, but also with a three-pronged instrument. At their end, indentations of longitudinal (Pl. 3.2.6, 25) or triangular (Pl. 3.2.7, 4) shape were applied. Decoration was detected on the inner wall of three vessels, in the form of very fine, irregular engraved lines. In the case of one bowl, these lines are supplemented by an impressed decoration formed by three merging indentations (Pl. 3.2.7, 15). No painting of the vessel interior or exterior was detected.

Plastic decorative elements and functional accessories were applied to 26 per cent of the thick-walled ceramics. In one case, an unperforated protrusion was noted on what was probably a smaller vessel. Of the functional applications, protrusions without a hole ($n = 15$), eyelets ($n = 7$) and a plastic bar ($n = 1$) were found in the inventory. Among the unperforated protrusions, unpaired or paired cylindrical protrusions are the most common (Pl. 3.2.6, 6, 9), sometimes together with an impressed decoration formed by pinching (Pl. 3.2.7, 1, 17), but also with conical and cylindrical protrusions with a slight (Pl. 3.2.6, 6) or deep (Pl. 3.2.6, 3; Pl. 3.2.7, 5, 14) depression. Hemispherical (Pl. 3.2.5, 21), loaf-shaped protrusions with notches (Pl. 3.2.5, 19; Pl. 3.2.6, 1); horizontal, angular saddle-shaped protrusions (Pl. 3.2.6, 19); and vertically oriented flat, elongated protrusions were also occasionally encountered.

More than one quarter of the functional applications are eyelets of various types. They are present on fragments from containers with necks or from vessels of thick-walled pottery of unknown shape. Typologically, these are mainly arched eyelets (Pl. 3.2.5, 8, 9, 11, 25). A rounded eyelet with a vertical hole (Pl. 3.2.6, 24) and a relatively rare angular and flat eyelet with a horizontally drilled hole (Pl. 3.2.5, 16) were also detected. An analogy to this latter, rare type can be found on an amphora from the grave at Dvory nad Žitavou (Pavúk, 1964, fig. 1.2, fig. 2.3). A plastic strip was detected under the rim of a thick-walled globular vessel (Pl. 3.2.5, 6).

Object 2

As already mentioned, during the excavation in Trench 13, the north-eastern and south-eastern parts of the pit designated as Object 2 were also explored. A total of 129 sherds (approx. 1437 g) were registered, all of which came from the upper layers. Up to half of them are small pieces less than 1.5×1.5 cm in size. A total of 59 fragments (45 per cent) are suitable for typological analysis. Most are fragments from the body of vessels ($n = 44$), 12 are from the rim, and 3 are from the bottom of a vessel, representing at least 41 individual vessels. Vessels of spherical and hemispherical shape and an amphora-shaped vessel with a neck are represented. Only in one case was it possible to reconstruct the entire shape of the vessel. It was a smaller, decorated bowl, with a rim diameter of 7.5 cm (Pl. 3.2.5, 10).

The ratio of thin-walled to thick-walled ceramics (19:22) is balanced in this assemblage. The matrix of this pottery is characterised by fluted and non-fluted material with an admixture of pebbles and mica. In some cases, organic material has also been added as temper. The surface of the vessels was treated by smoothing. Polishing of both the outer and inner surfaces of the vessels, it is difficult to detect polishing if there is damage to the surface of the sherds, was recorded for approximately one quarter of the fragments. The surface of the vessels exhibited various shades of brown, orange-brown and grey.

Decoration was recorded on 15 vessels, in particular, a combination of engraved and impressed decoration. Pointed tools were used to create double and triple engraved lines. Up to three oval or triangular indentations were inserted between the predominantly horizontal lines. Ornamentation consisting of a double oblique engraved line was recorded in only five cases (e.g. Pl. 3.2.5, 10; Pl. 3.2.6, 10; Pl. 3.2.6, 13). Among the fragments with oblique lines, we note an engraved decoration with

dimples at their end (Pl. 3.2.5, 10). Despite the fragmentary nature of the vessels, it was possible to note combinations of different numbers of holes, whereby combinations of both two and three oval indentations were used on the same vessel (Pl. 3.2.6, 15). In one case, an abortive execution of a triple engraved line is visible under the rim of a hemispherical vessel, but this abortive attempt apparently did not prevent the decoration from being completed (Pl. 3.2.6, 16).

The decorative motif that was captured in part on a thin-walled, hemispherical vessel consists of two horizontal pairs of engraved lines at the top of the vessel, between which two to three indentations were applied. The lower part of the vessel decorated with a pair of oblique engraved lines (Pl. 3.2.6, 15). A more detailed decorative motif applied to the inner and outer surface of the vessel is present on a smaller bowl, reconstructed on the basis of two fragments (Pl. 3.2.5, 10). Its outer face exhibits a double engraved line under the rim, with two oval dimples located below each other on the lines. The lower part of the bowl is decorated with a motif formed in several places by a double oblique line terminated by a pair of oval (longitudinal) indentations. The inside of the bowl is decorated with engraved pairs of lines shaped in the form of a twig (twig motif). The individual pairs are regularly connected by oval indentations. Interior decoration is recorded on five additional vessels. Here, it consists of fine engraved lines, in the form of double or triple horizontal grooves. At the same time, only in two cases the outer surface was decorated with impressions, in the form of an indentation, a triangular shape or fine pinching.

Plastic decorative or functional shapes were also recorded on thick-walled ceramics, in the form of two plastic protrusions of cylindrical shape, in one case with a slight depression (Pl. 3.2.6, 14) and in the other with a lug on a semi-thick-walled container.

Object 3

Object 3, in the south-east corner of Trench 13, contained 28 fragments of pottery (about 274 g). Most (n = 25) are unidentifiable sherds, 2 are rim fragments, and 1 was a part of a biconical vessel (Pl. 3.2.7, 12).

Summarising observations

Although the excavation of Úľany nad Žitavou 'Dolné diely' has not revealed a complete picture of the fill of the settlement pits near the house, the obtained sample allows a first view of the settlement ceramics of the community inhabiting the surveyed area in the Middle Neolithic. Most fragments of pottery came from a depth of 0–30 cm below Planum 1. The ceramic material obtained was very fragmentary, and it was possible to reconstruct the entire vessel in only one case (Pl. 3.2.5, 10). In Object 2, small fragments made up half of the sherds retrieved. The ratio of thick-walled to thin-walled ceramics was balanced in all three objects.

Thick-walled ceramics are represented by vessels of spherical and hemispherical shapes, bowls and vessels with necks. On the outer surface of the vessels, decoration (mainly indented) was applied by pinching, fingernail notching, and impression, often together with functional, plastic protrusions. The size of some of these elements may indicate that children participated in the decoration of the vessels. Similar features in the execution of pottery decoration have been observed in other Neolithic cultures. In addition to the division of work tasks in the family, however, differences in the method of making clay objects are also observed here (Niklová and Beljak Pažinová, 2018: 89).

Although the inventory of thin-walled ceramics consists mainly of parts of the vessel body that do not allow us to reconstruct the type of vessel, in a few cases it was

possible for us to identify thin-walled to semi-thick-walled parts of hemispherical or spherical vessels, as well as vessels with a hollow base. Fragments of small, mostly decorated vessels were recorded both in building 2 and in the north-eastern part of the long pit (Object 1, quadrant 4). No unusual shapes of ceramics, including sieves or lids, were identified in the collection. A hole, drilled mainly under the rim, known from other sites, was found on only 1 sherd from Úľany nad Žitavou 'Dolné diely'. Drilling was carried out from the outside of the vessel, with a tapered tool (Pl. 3.2.7, 7).

The surface of the walls of the vessels was predominantly smoothed. However, the often-observed damage on the surface makes it impossible to determine the percentage of vessels with polishing of the surface. On the vessels showing polishing, it is preserved only fragmentarily.

Although most of the thin-walled sherds were decorated mainly with a combination of engraved and impressed decoration, motifs are only minimally observable. The best collection of decorations is provided by finds from Object 2. There are vessels decorated under the rim with a trio of horizontal engraved lines interrupted by pairs of indentations or cuts, as well as double lines placed horizontally under the rim or obliquely on the body. The decoration was again complemented by double and triple dimples. Horizontal lines are complemented by oblique lines applied to the body. The decoration of the vessels from Object 1 indicates the application of a different number of horizontal engraved lines, with a combination of oblique and arched lines on the body of the vessels. The course of the lines was interrupted by deep dimples of various variants, in a few cases also notches or cuts. Less than 7 per cent of the vessels are also decorated on the inner wall, but the twig motif consisting of engraved and impressed elements is the only more continuous decoration (Pl. 3.2.5, 10). In other cases, fine engraved lines were identified, rarely with dimples (Pl. 3.2.9, 17).

In a few cases, one can observe an imperfect execution of the decoration, especially noticeable for the engraved lines. These included, for example, a break in a line that was not directly linked again (Pl. 3.2.6, 16; Pl. 3.2.7, 10, 15) and an irregular execution of one part of multiple lines (Pl. 3.2.6, 25). A similar inconsistency in decoration was also recorded for the site of Vráble 'Veľké Lehemby' (Cheben and Bistáková, 2020: 280). However, it is also quite common in other LBK and Želiezovce Group localities, such as in Bajč 'Medzi kanálmi' (Cheben, 2000), Bajč 'Vlkanovo' (Bistáková and Nevizánsky, 2013), Cífer-Pác (Kolník, 1978), Hurbanovo (Pažinová, 2011), Štúrovo (Pavúk, 1994). At other sites, pre-drawings of lines on the body of the vessel is rarely observed, as is engraving that was eventually carried out elsewhere on the vessel, as documented, for example, at Štúrovo (Pavúk, 1994: pl. 10, 18) or at Zvolen 'Podborová' (Beljak Pažinová and Javorek, 2018: 194, pl. I, 19). However, we did not encounter these phenomena in the ensemble of 'Dolné diely'.

In the decoration of vessels from Úľany nad Žitavou 'Dolné diely', we can observe still-surviving elements of the younger LBK style, such as the use of indentations in the form of 'music note-heads' placed on an engraved line under the rim of thin-walled hemispherical vessels, or terminating an oblique line (Pl. 3.2.5, 7). The decoration of these vessels is complemented by arched engraved lines. Decorative elements of triple lines with two to four oval indentations merging as if into one notch, double lines made with a two-pronged complement, or triple lines combined with indentations point to the advent of Želiezovce decoration styles. Decoration on the inner walls of the vessels or the plastic shaping of the rim, typical of the period of the Želiezovce Group, was also registered, although rarely.

The composition and decoration of the ceramic collections obtained by examining the long pit (Object 1) and a further pit (Object 2) at the western wall of the house, with their survival of elements of the younger LBK, allows these objects to be dated to an older stage of the Želiezovce Group. For Object 3, a closer chronological classification is not possible due to the fragmentariness of the ceramic ensemble.

The finds from this site certainly have the potential to further our knowledge, not only of the chronology of the Middle Neolithic but also of the everyday life of this prehistoric community. The current sample offers a first look at the ceramic vessels used in the house in question.

Úľany nad Žitavou ‘Dolné rakytiny’

A settlement of the Želiezovce Group was also present at Úľany nad Žitavou ‘Dolné rakytiny’, which is situated south of Úľany nad Žitavou ‘Dolné diely’. From this locality, P. Steiner (2002: fig. 155) reports the occurrence of a large number of finds of pottery of the Želiezovce Group, which probably come from an object partly disturbed by ploughing. This is indicated by the fact that the assemblage includes several fragments belonging to a single larger, thick-walled vessel. Thin-walled ceramics, represented by spherical and hemispherical shapes, bear engraved decorations in the form of horizontal and arched lines, which on some specimens are complemented by a notch or music note head. Also, an engraved wavy line occurs in this ensemble (Steiner, 2002: fig. 155.1, fig. 155.3–6, fig. 155.11). In addition to spherical, thick-walled vessels, there is also a bowl with a low, hollow base. Surface prospections in spring 2017 did not produce any additional ceramic material.

Hul ‘Dolné diely’

A short distance north-east of the two site locations at Úľany nad Žitavou, Š. Janšák (1931) identified a multicomponent settlement, known as Hul ‘Dolné diely’. This settlement of Neolithic, Eneolithic and Early Bronze Age date is located on the north-western terrace of a former streambed of the Žitava. Currently the regulated Hulský Channel flows in the location of the streambed. Repeated later surface surveys north of the village covering an area of 200 × 350 m documented finds of the LBK and the Želiezovce Group (Samuel, 1995; Samuel, 2001a; Müller-Scheeßel *et al.*, 2016). Spherical, hemispherical and bowl-shaped vessels are represented. Some of the younger LBK vessels feature engraved ornamentation forming a separate line or a pair of lines, arranged horizontally or in an arc. Music note-heads have been placed on the line or lightly touching it (Samuel, 1995, fig. 88.1–5, fig. 88.8, fig. 88.9). Unique shapes include a fragment from the body and a hollow base of a bowl, the ornamentation of which consists of short oblique grooves with small dimples at the start (Samuel, 2001a: fig. 100.1). As a rule, the engraved decorations on the vessels of the Želiezovce Group are made with a two-pronged instrument and are terminated or interrupted by a notch (Samuel, 1995: fig. 88.6, fig. 88.7, fig. 88.10–12). Plastic decoration is also present, on fragments depicting animal heads (Samuel, 2001a: fig. 100.2; Müller-Scheeßel *et al.*, 2016: 86, fig. 8).

Vlkaš ‘Do hulského chotára’

The settlement of Vlkaš ‘Do hulského chotára’ is located south of the village of Vlkaš, on gently sloping terrain, 700 m away from the left bank of today’s course of the Žitava. Today, the regulated Hulský Channel flows below the terrace. Part of the settlement was disturbed by sand mining. The boundary of the sand dune, where an inhumation grave from the migration period was found (Točík, 1962: 203), is clearly captured on a geophysical plan. From this location, A. Točík (1981: 302) obtained ceramics decorated with engraved lines with music note-heads and a stone axe belonging to the Želiezovce Group, from a large pit that was cut by a drainage ditch.

Systematic prospection

In 2017, a detailed and systematic surface prospection was carried out. Similar to the site at Úľany nad Žitavou, the finds were recorded individually and their location marked. The resulting map (see Chapter 2.3) made it possible to mark the estimated boundaries of the settled area, which occupies approximately 300 × 600 m (almost 20 ha). Based on this finding, a geophysical survey of the site was implemented. The plan (Fig. 2.3.7) allows us to determine the number, orientation and size of the houses based on the occurrence of pairs of long pits. The ceramic material makes it possible to assign the settlement to the LBK and the Želiezovce Group, but ceramic sherds belonging to the Baden culture and the High Middle Ages have also appeared sporadically (Cheben and Furholt, 2023b).

Among the Neolithic ceramic material obtained, undecorated fragments of vessels clearly dominate. From a morphological point of view, among the 1400 registered individuals, vessels of spherical or hemispherical shape are the most numerous. Vessels with a neck and fragments from thick-walled vessels are represented to a lesser extent. Exceptional is a bowl with a hollow base. In most cases, the vessel fragments are small, probably due to intensive agricultural activity. The fragmentariness of the sherds allows for only general conclusions about the decoration. Engraved pairs of lines complemented by a shallow indentation or interrupted by a notch prevail. Plastic decoration, which is observable on both medium-thick- and thick-walled shapes, shows different lugs and the application of extruded clay strips. On this type of vessel, semi-arched notches and impressed rows of indentations were also applied. Small numbers of fragments from vessel bodies provided with an eyelet were also found. If an engraved decoration appeared that presented a more continuous part of the ornament, it was formed by individual lines (Pl. 3.2.1, 4) or pairs of lines that are supplemented by dimples (Pl. 3.2.1, 3, 13). The ornamentation on larger shapes consists of wider engraved lines (Pl. 3.2.1.2), sometimes supplemented by a protrusion (Pl. 3.2.1, 5). A horizontal row of notches located below a notched rim also appeared (Pl. 3.2.1, 6). Plastic decoration was limited to single lugs or strips (Pl. 3.2.1, 7). The ceramic inventory of the site includes a perforated object of hemispherical shape (Pl. 3.2.1, 12), which may also be related to the younger settlement of the site. The find inventory obtained by surface collection is complemented by a chipped industry on obsidian and chert of domestic and foreign provenance. Mainly flakes are represented, but there are also blades or fragments and blades. One polished implement, a flat axe (Pl. 3.2.1, 9), can be attributed to a younger settlement.

Excavations

During the 2018 excavation at Vlkaš, two trenches, designated 12 and 15, measuring 9 × 15 m each, targeted parts of the long pits and the interior and exterior spaces of two longhouses (see Chapter 3.1). Trench 12 was positioned to capture the eastern part of the lateral long pit of a house and the space east of the identified floor plan of the house. Outside the defined area of the long house, seven objects were uncovered in the course of the excavation. In contrast, Trench 15 was located in the area where the long pit of a house showed the most pronounced magnetic signal.

Trench 12

Trench 12 revealed the southern end of the eastern long pit of the house and the objects located below and next to it (Fig. 3.2.4). The long pit, Object 12/1, was divided into 14 sectors, which were excavated in artificial spits to identify and photogrammetrically document the transverse as well as the overall longitudinal profile. Just below the end of the long pit, Object 12/8 was identified, which contained

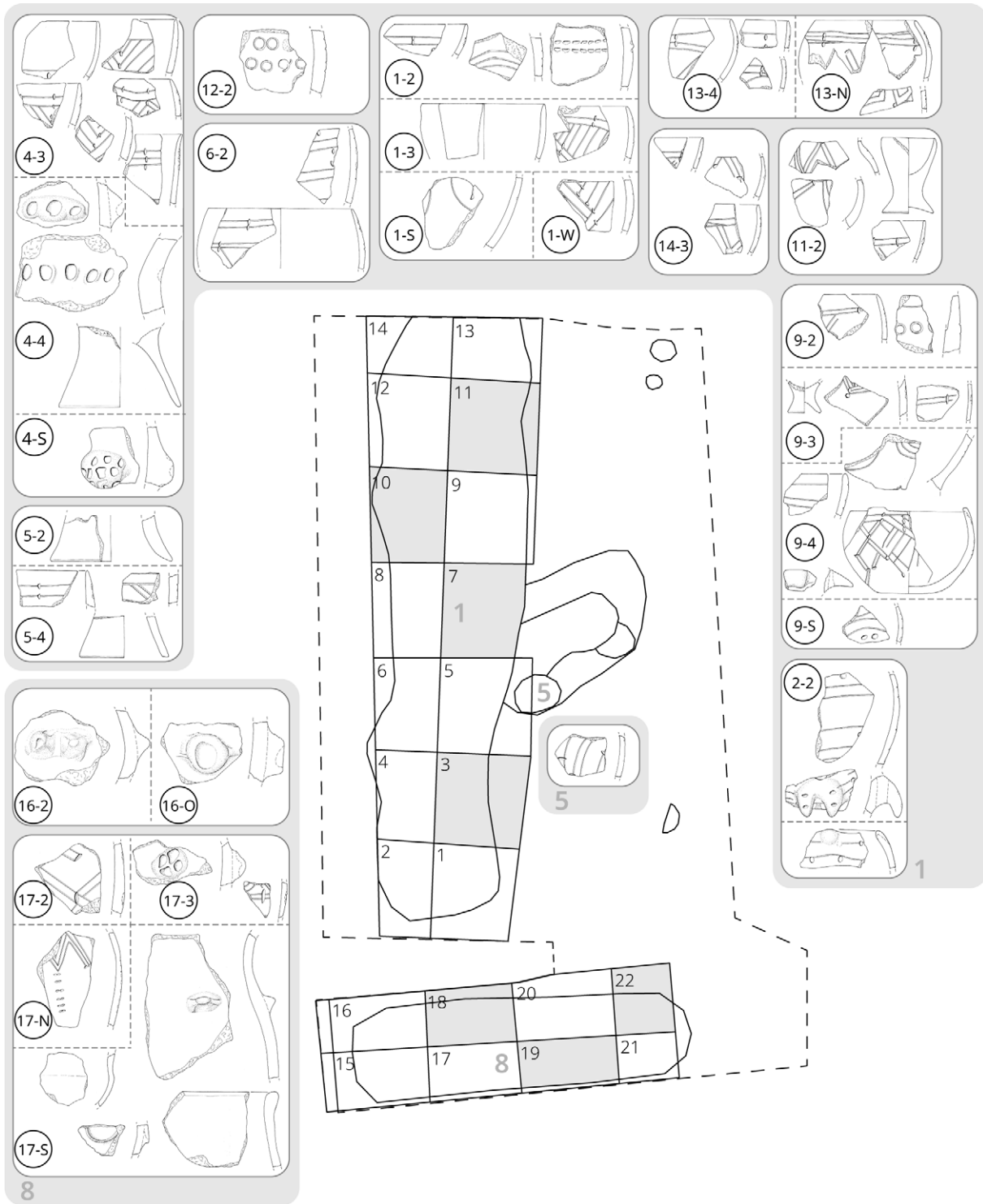


Figure 3.2.4. Vlkaš 'Do hulského chotára'. Trench 12, with ceramic finds assigned to objects, quadrants and spits.

a ceramic inventory of the Baden culture (Pl. 3.2.10, 4, 5). To the east of the edge of the long pit of the house, in Object S12/1, was a row of six circular pits with a diameter ranging from 35 to 105 cm. Only Objects 12/4 and 12/5 contained ceramic fragments, originating from spherical vessels.

A more representative set of ceramics of the younger LBK was obtained from Object 12/1. Spherical and bowl-shaped vessels are present, ornamented with pairs (Pl. 3.2.8, 2, 4, 6, 11, 13, 16; Pl. 3.2.9, 16) or triplets (Pl. 3.2.8, 10; Pl. 3.2.9, 1) of circumferential lines below the rim, but there are also sherds with single circumferential lines below the rim (Pl. 3.2.8, 7; Pl. 3.2.9, 13). The main ornamentation, placed below or emerging from the circumferential lines, consists of engraved pairs of oblique lines (Pl. 3.2.8, 2, 4, 11, 13; Pl. 3.2.9, 1, 7) or groups of lines (Pl. 3.2.8, 16). The engraved lines are terminated or interrupted by a music note-head impression (Pl. 3.2.8, 12, 14; Pl. 3.2.9, 8, 15). They also appear on an eyelet, probably an amphora-shaped vessel (Pl. 3.2.9, 23). All elements of the ornamentation scheme are preserved on one hemispherical vessel. It which consists of a circumferential line below the rim and irregularly arranged pairs of lines on the body, terminated with music note-head impressions (Pl. 3.2.8, 26). There was also a bowl with a hollow base (Pl. 3.2.9, 2), as well as a miniaturised bowl with a hollow base (Pl. 3.2.9, 11). The plastic decoration on thick-walled ceramics consists of differently shaped lugs (Pl. 3.2.8, 21; Pl. 3.2.9, 20; Pl. 3.2.10, 6, 8).

In Object 12/1, there was also a rare notch that is characteristic of the decorative style of the Želiezovce Group (Pl. 3.2.9, 22). Its occurrence suggests that the object belongs to the final stage of the younger LBK, when new ornamentation elements began to appear. Such a method of engraved decoration was also found, likely in secondary position, in the inventory of Object 12/8 (Pl. 3.2.9, 24, 26), which was otherwise filled with Baden culture materials.

Trench 15

In the centre of Trench 15 was a long pit of a house, which was narrower in the southern part than in the northern part (Fig. 3.2.5). Four postholes were identified along the western edge of the long pit (Objects 15/2, 15/3, 15/4 and 15/5). In each of them a ceramic inventory was found that consists of several fragments of thick-walled vessels. In two cases, Objects 15/2 and 15/3, plastic decoration appeared, consisting of an oval lug or a pair of protrusions with indentations. Object 15/4 yielded part of the rim of a hemispherical vessel, and Object 15/5 yielded a fragment with engraved lines resembling grooves (Pl. 3.2.14, 20).

Three settlement structures were also found near the western edge of the trench. The largest ceramic inventory was provided by Object 15/1, comprising a larger, thick-walled vessel with neck; a spherical vessel, the ornamentation of which consists of two pairs of circumferential lines below the rim, interrupted by triangular indentations, with under the lower horizontal pair of engraved lines an oblique pair (Pl. 3.2.13, 6); a fragment from a bowl with a hollow base decorated with obliquely arranged engraved lines with three indentations (Pl. 3.2.14, 1); and a fragment of the base of a bowl with hollow base or a small lid from cleaning the trench (Pl. 3.2.11, 5). Object 15/6 yielded the rim of a larger hemispherical unadorned vessel (Pl. 3.2.14, 2) and a fragment from the body of a vessel decorated with vertical and horizontal pairs of lines terminated with a notch (Pl. 3.2.11, 2).

The lateral long pit was divided into two objects, of which Object 15/10 disturbed Object 15/8, which is also reflected in the chronology of their ceramic inventories. From a typological point of view, spherical vessels (Pl. 3.2.14, 10, 18; Pl. 3.2.15, 13, 17), hemispherical bowls (Pl. 3.2.14, 12; Pl. 3.2.15, 3), bowls with hollow base (Pl. 3.2.15, 2; Pl. 3.2.16, 3, 5, 7), vessels with necks (Pl. 3.2.14, 17; Pl. 3.2.15, 19) and amphora-shaped vessels (Pl. 3.2.15, 20) are represented in Object 15/8. Commonly, the engraved

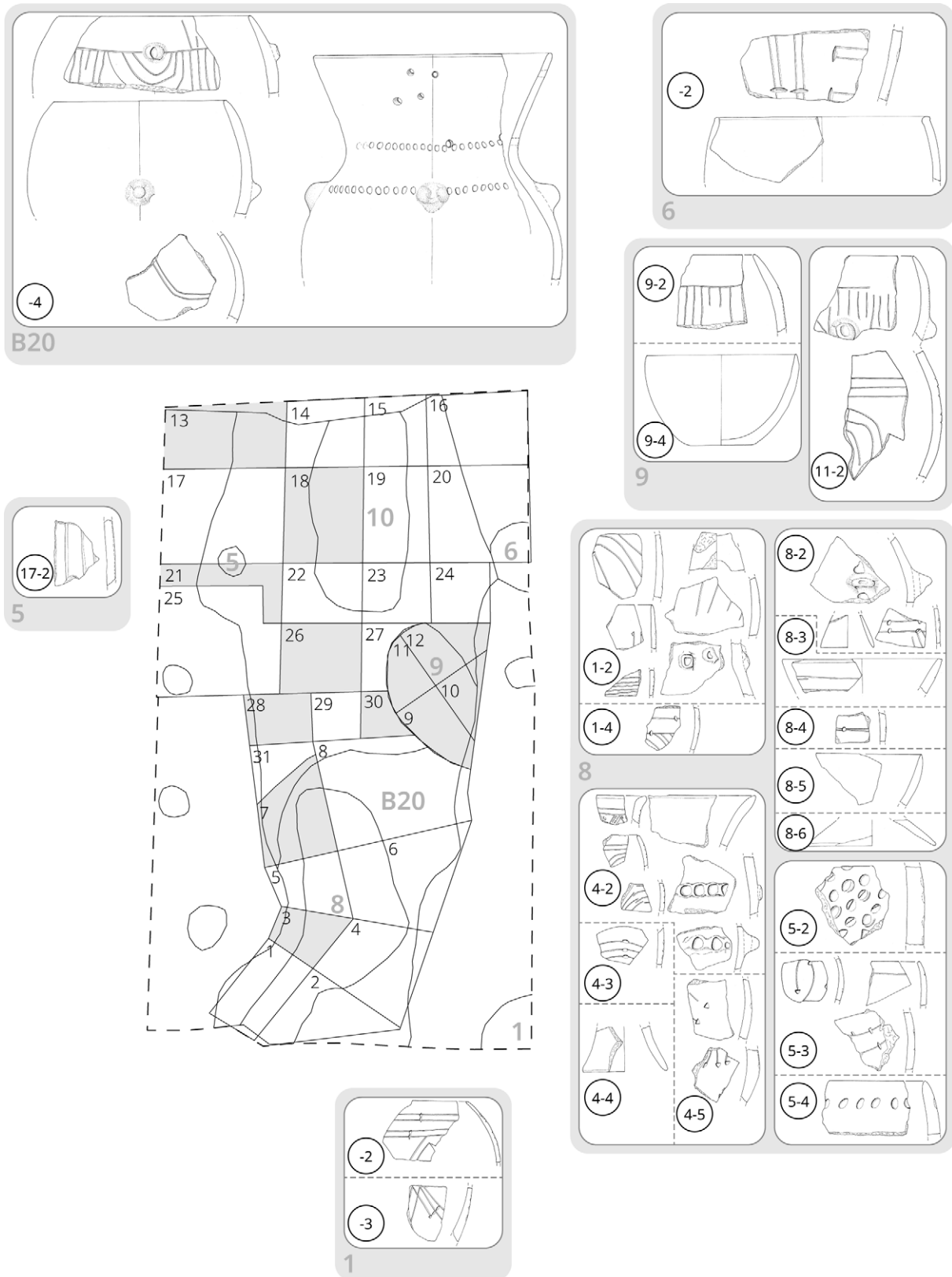


Figure 3.2.5. Vlkaš 'Do hulského chotára'. Trench 15, with ceramic finds assigned to objects, quadrants and spits (without Object 15/10).

ornamentation consists of a circumferential line under the rim (Pl. 3.2.14, 10; Pl. 3.2.15, 3, 17), under which the main motif was applied. The latter consists of engraved lines on which oval impressions occur (Pl. 3.2.16, 6, 10, 12), or which are terminated with a triangular impression (Pl. 3.2.14, 14, 15; Pl. 3.2.15, 13). In one case, there is a hint of an engraved wavy line on the body of the vessel (Pl. 3.2.14, 16). Plastic decoration on thick-walled vessels consists of extruded, impressed strips (Pl. 3.2.14, 19) or of lugs (Pl. 3.2.15, 16, 19). On thick-walled vessels, impressed decorations also appeared, in the form of a row of fingertip impressions under the rim (Pl. 3.2.14, 13) or oblique rows of fingernail-shaped notches (Pl. 3.2.16, 2).

In Object 15/10, sherds were much more numerous than in Object 15/8. Both objects yielded identical ceramic shapes and similar ornamentations, except that Object 15/10 lacks examples of a bowl with hollow base. On larger fragments of spherical vessels, an engraved circumferential pair of lines was applied below the rim, and the motif consists of a horizontal pair of lines from which oblique engraved lines emerge (Pl. 3.2.16, 12; Pl. 3.2.17, 3, 28; Pl. 3.2.18, 8, 14; Pl. 3.2.11, 7). Pairs of lines complemented by a notch or by a pair of indentations appear on hemispherical bowls (Pl. 3.2.16, 15, 19; Pl. 3.2.17, 26; Pl. 3.2.18, 11; Pl. 3.2.13, 8). In one case, pairs of engraved lines also occur on the inside of a hemispherical bowl (Pl. 3.2.16, 19). A rare, probably 'technical' element is an elongated plastic protrusion on the inside of a hemispherical bowl (Pl. 3.2.20, 2). Two medium-thick-walled hemispherical bowls come from Q19, one of which has a pair of protrusions below the rim (Pl. 3.2.20, 4; Pl. 3.2.13, 7). Higher hemispherical vessels with an almost horizontal (Pl. 3.2.16.11; Pl. 3.2.17.25) or slightly outward-curving neck (Pl. 3.2.18, 9) also appear in the inventory. An amphora-like shape is represented by one specimen. Its decoration consists of a triplet of horizontally engraved lines, under which multiple engraved wavy lines are interrupted at the fracture site by a notch (Pl. 3.2.10, 2). Multiple engraved wavy lines also occur on a higher hemispherical vessel (Pl. 3.2.16, 11) and on the inside of a hemispherical bowl (Pl. 3.2.17, 13).

Thick-walled ceramics are associated with spherical shapes on which extruded plastic strips and several types of lugs were placed below the rim of the vessel (Pl. 3.2.18, 13; Pl. 3.2.20, 6), but also above the base (Pl. 3.2.11, 10). Impressed decorations are represented by rows of what look to be fingernail-impressed notches below the rim (Pl. 3.2.19, 7). The shape range of thick-walled ceramics in Object 15/10 is complemented by an unadorned vessel with a neck (Pl. 3.2.19, 11).

At the site of the strongest magnetic anomaly was Object 15/9, situated in the long pit. It contained a layer of sherds formed by multiple fragments of vessels. The most striking is the rim and part of the body of a large, thick-walled vessel with neck (Pl. 3.2.12, 2). Its decoration consists of two horizontal rows of impressed indentations located on the neck and shoulder. The lower row of indentations is complemented by a massive lug. It is noteworthy that the vessel shows signs of repair, as indicated by two pairs of holes below the rim. The inventory of the object is complemented by a spherical vessel with an engraved circumferential line below the rim interrupted by a lug, below which are three asymmetrical semi-arc lines and vertical grooves emerging from the circumferential line (Pl. 3.2.16, 8; Pl. 3.2.17, 1; Pl. 3.2.18, 1). An engraved ornamentation in the form of three horizontal and three arched lines is attested on a fragment of what is probably a spherical vessel (Pl. 3.2.13, 10). The inventory is completed by an unadorned hemispherical bowl (Pl. 3.2.16, 16). In addition to large fragments of pottery, there were also larger pieces of burnt daub in the fill, which contributed to the very significant anomaly on the magnetic plan.



Figure 3.2.6. Vlčias 'Do hľského chotára'. Trench 15, with ceramic finds assigned to objects, quadrants and spits (only Object 15/10). For the location of the quadrants, cf. Fig. 3.2.5.

Summary

Based on the analysis of the ceramic inventory of the two long pits uncovered in Trenches 12 and 15, it appears that the settlement at this location began in the younger LBK and that the last longhouses were built during the Želiezovce Group.

Vlkas/Veľká Maňa ‘Spodné pole’/‘Za hlbokou cestou’

Surface collection combined with geophysical measurements was also carried out north of the village of Vlkas, at the sites ‘Spodné pole’ and ‘Za hlbokou cestou’. The find inventory stems from a gentle slope leading down into the flooding zone of the Žitava. The site itself extends beyond the southern border of the cadastre border of the village of Veľká Maňa. However, no finds were made at the site of ‘Dlhé’, on a slope leading down to the southern edge of the village of Veľká Maňa, from which finds of ceramics have already been published by Š. Janšák (1931: 52) and from which A. Točík (1981: 302, 303), in addition to fragments from spherical LBK vessels, also documented ceramic material belonging to the 12th and 13th centuries CE.

Based on the distribution of sherds and chipped stones, a settlement area of 700 × 230 m was identified, on which geophysical measurements were subsequently carried out (Chapter 2.3). On the geophysical plan, pairs of long pits, belonging to longhouses of the LBK and the Želiezovce Group, can be clearly identified. Compared with the settlement of Vlkas, among the finds there are also some larger fragments of vessels, which provided a more complete picture of the composition of the decorations. The most striking is a fragment from the body of a vessel decorated with pairs of engraved horizontal and zigzag lines punctuated by elongated notches (Pl. 3.2.2, 22). On another sherd are three semi-arc engraved lines (Pl. 3.2.2, 20). A vertically perforated eyelet with short grooves near the rim can be attributed to the Želiezovce Group (Pl. 3.2.2, 23). A substantial part of the ceramic inventory consists of small fragments, on which the remains of engraved ornamentations and, exceptionally, an indentation or notch are preserved. On fragments from the bodies of thick-walled vessels, several types of lugs were applied. Eyelets are also rare. The finds are complemented by chipped stone made of several types of chert and obsidian. Clay finds include an incomplete flat clay weight (Pl. 3.2.2, 19). In addition to fragments of vessels of the LBK and the Želiezovce Group, the surface collected material also contained finds of the Baden culture (Pl. 3.2.2, 21) and from the Middle Ages.

Veľká Maňa

Ceramic finds that, based on the description of their decorative motifs, can be attributed to the LBK and the Želiezovce Group, are known from at least three sites within the municipality of Veľká Maňa. The first is situated between the village of Gedra and the houses in the northern part of the village of Veľká Maňa. The first finds, from a pit intended for clay extraction, were published by J. Eisner (1936: 76). During later extraction activities, other fragments of vessels were collected by A. Točík (1981: 300–301, figs. 170–171).

Another prehistoric site in Veľká Maňa was located near the eastern edge of the built-up area (Točík, 1981: fig. 170.12). It was discovered by building activities in the 1980s. During earthworks, archaeological objects were disturbed, from which a sherd inventory of the LBK and the Želiezovce Group was obtained. Fragments of vessels decorated with engraved ornamentations formed by pairs of lines

complemented by notches are represented. Thick-walled, spherical vessels are decorated with fingernail-impressed notches, plastic extruded strips and spherical pieces (Točík, 1981: 300–301, figs. 170.1–8).

From the soil excavated for the foundations of a family house in Velká Maňa, a ceramic inventory was collected that is dominated by a stylised zoomorphic protrusion applied to vessels of the Želiezovce Group (Kuzma, 1996: fig. 83.1). The set of pottery is complemented by a sherd from the body of a thick-walled vessel with an eyelet (Kuzma, 1996: fig. 83.2) and a fragment of a pendant lamp from the succeeding cultural development. Based on the knowledge gained from prospections in the Upper Žitava Valley, it is possible that all three find locations belong to one larger settlement complex of the LBK and the Želiezovce Group.

Finally, in the southern part of the village (Dlhá 48 street), a ceramic inventory was obtained during earthworks, consisting of fragments of spherical vessels decorated with horizontally arranged indentations and circular lugs (Samuel, 2001b: figs. 104.2–5). Based on the bottom of the spherical vessel, which on its maximum extension bears engraved grooves arranged in semi-arches (Samuel, 2001b: fig. 104.1), the ensemble was assigned to an older stage of the LBK. The place of discovery is at a short distance from the site of ‘Za hlbokou cestou’, situated on the border between the cadastres of Vlkaš and Velká Maňa.

Michal nad Žitavou

At the south-western edge of the village of Michal nad Žitavou, near the location known as ‘Pri kmetovskom chotári’, objects of the LBK and the Želiezovce Group were uncovered during a small rescue excavation that also involved a geophysical survey (Cheben, I. and Cheben, M., 2014: fig. 1). The excavation probably captured the western edge of a settlement situated on the right bank terrace of the Žitava. Two human skeletons were assigned to the LBK and the Želiezovce Group based on the ceramic inventory (Cheben *et al.*, 2013; Cheben, I. and Cheben, M., 2014).

In the ceramic inventory, spherical and hemispherical shapes of thin-walled and thick-walled vessels are represented. There are also amphora-like vessels and vessels with necks. Unusual shapes are a bowl with hollow base and a conical bowl (Cheben, I. and Cheben, M., 2014: fig. 9.8). The engraved ornamentation of fine pottery consists mostly of pairs of straight, zigzag or semi-arched engraved lines. More rarely, a single engraved line, a triple line and an engraved wavy line appear. On spherical and hemispherical vessels, a circumferential line was applied, below which the main decoration motif is situated. Engraved ornamentations are complemented by indentations or notches. A separate group of ornamentations consists of eyelets and lugs. A fragment of an anthropomorphic figurine comes from Object 34, in which burnt daub and fragments of mollusc shells were found (Cheben, I. and Cheben, M., 2014: fig. 2.4). Plastic strips below the rim of a spherical vessel can also be considered as the stylised depiction of a human figure (Cheben, I. and Cheben, M., 2014: fig. 3.16).

Čifáre

Settlement finds from this cadastre have been previously documented at four locations. From the site of ‘Kapustníská’, one of the most striking is a sherd with engraved arc lines (Bátora, 1981: fig. 1.2). In the north-eastern part of the cadastre, at ‘Lúčky’, ceramic material of the Želiezovce Group, whose engraved ornamentations consist of pairs of lines and notches, was found.

In the ceramic inventory from a surface survey from the settlement area, situated south-east of the village, on a gentle slope above the brook Telinský potok, on the

parcel of land known as 'Farské', the rim of a spherical vessel decorated with bundles of double lines terminated and interrupted by a notch stands out (Ruttkayová and Ruttkay, 1991: fig. 2.4).

At a short distance from 'Farské', finds of fragments of vessels with engraved lines and music note-heads belong to a younger LBK phase (Ruttkayová and Ruttkay, 1991: 14, figs. 3.7, 9). The find inventory from the site 'Nad trstím' was enlarged by ceramic fragments assigned to the Želiezovce Group from our survey in 2018. A geophysical survey of the settlement was also carried out. The ensemble consists of fragments from bodies of medium-thick-walled, larger vessels. The decorative elements encompass a pair of engraved horizontal lines (Pl. 3.2.2, 15, 16), complemented by an indentation (Pl. 3.2.2, 16). There is also a notch located in the angle of a pair of engraved lines (Pl. 3.2.2, 18). A snowfall during the 2018 survey season precluded obtaining a more representative sample of ceramics.

It cannot be ruled out that both sites situated on the right bank of the Telinský potok – 'Farské' and 'Nad trstím' – which are today divided by a road, together form a single settlement.

Mochovce

LBK ceramics are mentioned from three sites in the Mochovce area, but only one is a sherd from the body of a vessel, decorated with bundles of pairs of horizontal lines divided by a long notch (Bátora, 1983a: fig. 16.7). This type of notch occurs in period III of the Želiezovce Group.

Tajná

Surface surveys on the parcel 'Klisovnice' focused on gently sloping terrain leading down to the Širočina stream. The site is situated on its right bank, and the south-eastern edge of the inhabited area follows the stream bed. Fragments of pottery and chipped stone were found distributed over an area of 150 × 250 m. From this site, finds belonging to the Želiezovce Group, the Lengyel and Baden cultures, the Kosiň-Čaka culture and the Middle Ages have previously been published (Bátora, 1976a).

The ceramic inventory of the LBK and the Želiezovce Group, as was the case in the previously investigated settlements, consists predominantly of smaller sherds, on which only hints of engraved ornamentations could be distinguished. The predominant element is a pair of engraved lines accompanied by notches. Fragments of the rims and bodies of thick-walled vessels were also collected, on which the preserved part of the decoration consists of notches or impressions. There is a greater proportion of applications of plastic protrusions on this type of ceramics. As for the shapes, mainly spherical vessels are represented (Pl. 3.2.1, 16), but a hemispherical bowl decorated with circumferential engraved lines is also represented (Pl. 3.2.1, 15). Of the decorated fragments, a sherd with engraved lines arranged in arches, which are accompanied by oval indentations, is worth mentioning (Pl. 3.2.1, 17). The composition of another ornamentation consists of pairs of engraved lines and converging lines (Pl. 3.2.1, 19). Under the circumferential engraved line below the rim of another piece, which is interrupted by a pronounced lug, are short, oblique grooves arranged in rows (Pl. 3.2.1.21). The finds are complemented by a fragment of a La Tène Age situla vessel (Pl. 3.2.1.18) and a sherd from the body of a pot-shaped vessel from the medieval period (Pl. 3.2.1.23).

Ceramic sherds of the LBK also came from the site of 'Nad lúkami', which is situated farther south.

Nevidzany

From among older registered finds, which are stored in the museum in Zlaté Moravce, ceramic fragments of the LBK and the Želiezovce Group are known from several sites. A fairly extensive assemblage comes from the site of 'Lúčne zeme', where music note-head impressions appear along with notches, indicating continuity in the development of the settlement, attested by fragments decorated with bundles of pairs of lines with notches (Ruttkayová and Ruttkay, 1991: figs. 21.4, 11; fig. 22.12; fig. 31.5, 8, 10). From the site of 'Konopiská'/'Dolné urbáre', situated on the right bank of the Širočina stream, a sherd is known with wider engraved lines with an indentation (Ruttkayová and Ruttkay, 1991: fig. 29.4). Finds of the Želiezovce Group found on the terrace above the right bank of the Podegarský potok stream (Ruttkayová and Ruttkay, 1991: figs. 24.3, 5) complete the inventory of Object 1/75. The pit, disturbed by construction work, contained a large number of pottery fragments, dominated by thin-walled spherical and hemispherical vessels decorated with pairs of engraved lines with notches. Red paint was also preserved on several fragments (Bátora, 1976b: fig. 4.6). Finds from this site include part of the body of an amphora-shaped vessel with an eyelet and an ornamentation of engraved lines terminated with an impression, which also documents the site's existence during the LBK (Ruttkayová and Ruttkay, 1991: fig. 21.13).

A Želiezovce Group settlement is documented on the parcel 'Za kostolom'. Our survey in 2017 yielded several small sherds. On one, a pair of engraved lines interrupted by a notch is preserved. Our surface collection in 2018, combined with geophysical measurements (Chapter 2.3), obtained a representative collection of ceramics from the parcel 'Dolné urbáre', in which, in addition to Želiezovce, younger periods are also represented (Pl. 3.2.3, 13, 18, 23; Pl. 3.2.4, 31). A very small number of sherds carries an engraved decoration complemented by indentations (Pl. 3.2.3, 19; Pl. 3.2.4, 2, 14) that would indicate a settlement of the site during the younger LBK. A fragment of a vessel decorated with wider engraved lines arranged in an arc can also be attributed to this stage (Pl. 3.2.3, 11, 14). The vast majority of vessel fragments belong to at least two chronological stages of the Želiezovce Group. The inventory is dominated by sherds from spherical and hemispherical vessels with pairs of engraved lines arranged circumferentially below the rim (Pl. 3.2.3, 9; Pl. 3.2.4, 3, 5, 10, 12, 21), and divided by a vertical notch. Below the circumferential line, the main decorative motif is placed, formed by another circumferential line, from which obliquely arranged pairs of lines emerge (Pl. 3.2.3, 9; Pl. 3.2.4, 6). Less frequent motifs are horizontal bundles of engraved lines (Pl. 3.2.4, 28), zigzag horizontal lines divided by a notch (Pl. 3.2.3, 15; Pl. 3.2.4, 20), and pairs of arched lines (Pl. 3.2.4, 10). A rare occurrence are multiple engraved wavy lines (Pl. 3.2.4, 4), the serrated rim of a hemispherical bowl (Pl. 3.2.4, 5), and the perforated handle on a small fragment of an amphora-shaped vessel (Pl. 3.2.4, 7). For medium-thick and thick-walled vessels, several types of extrusions were used as decorative elements (Pl. 3.2.3, 20, 27), plastic extruded strips (Pl. 3.2.4, 24, 32), rows of indentations (Pl. 3.2.3, 24) and eyelets (Pl. 3.2.3, 3, 22; Pl. 3.2.4, 16). From a typological point of view, a vessel with a neck was also represented in the evaluated inventory (Pl. 3.2.3, 6).

Malé Vozokany

On the right bank of the Širočina stream, finds of fragments LBK and Želiezovce Group vessels are reported from three sites. In the southern part of the village, a ceramic inventory belonging to the Želiezovce Group, represented by a sherd with an engraved double line interrupted by a notch and a horizontal eyelet with the possible representation of animal horns (Bátora, 1981: figs. 3.4, 7), was obtained from the

parcel 'Briežky'. Our survey in 2017 could only be carried out along the edges of an agricultural field on a gently sloping area. The ceramic inventory obtained consists of several undiagnostic sherds only.

From the space between the cemetery and the area of the peasant cooperative, called 'Lázky', sherds assigned to the LBK are published. Among these, the most striking are a sherd divided by two vertical notches and a sherd from the body of a vessel decorated with engraved lines (Bátora, 1981: figs. 3. 1, 2). North of this location, surface collection from a sector located just beyond the edge of the built-up area yielded sherds of the younger LBK (Bátora *et al.*, 1995). Both sites are situated on sloping terrain along the right bank of the Širočina stream, which forms a promontory in the southern part. The small distance between the finds suggests that they could belong to a single settlement area.

From a private collection comes the undocumented find of an anthropomorphic figurine decorated with two horizontal lines of grooves at the place of the stem, which holds in its outstretched hands a vessel resembling a bowl in shape (Bátora, 1983b: fig. 4.6). In south-western Slovakia, this kind of depiction of a human figure is unique to the end of the Želiezovce Group. A distant parallel can be found in the ceramic inventory of the period III settlement of the Želiezovce Group in Bajč, which includes anthropomorphically shaped vessels (Cheben, 2000: pl. 50, 20; pl. 98, 513.1).

Veľké Vozokany

In the profile of a trench in the parcel 'Stružkovské diely', some settlement objects were disturbed, from which pottery decorated with bundles of engraved lines complemented by music note-head impressions was obtained. Fragments of thick-walled vessels decorated with a row of indentations below the rim were also found. The character of the find set allows us to assume that these are disturbed objects of the younger LBK (Hrubec, 1986).

Čierne Kľačany

An LBK settlement is documented at the southern edge of the village, in the parcel 'Panské', which consists of gently sloping terrain on the right bank of the Širočina stream. Among the finds are lithic artefacts and a fragment from the body of a vessel decorated with wider engraved lines and indentations (Bátora and Bednár, 1982: fig. 9, 8). From this site, further LBK ceramics of both thin-walled and thick-walled shapes were obtained from a ditch dug for a water supply. Fineware ceramics are represented mainly by spherical shapes embellished with engraved ornamentations complemented by music note-heads. A unique find is the rim of a cylindrical or barrel-shaped container with a drinking hole below the rim. The inventory also includes what is most likely a fragment of an anthropomorphic figurine decorated on the back with a bundle of three engraved lines, supplemented on the sides by a zigzag line (Veliačik, 1975: fig. 95, 1, 3, 11).

A large set of ceramics comes from the site 'Pri mlyne', where several field activities were carried out. Based on a geophysical survey, carried out by Knut Rassmann and Michal Cheben, it was possible to identify the settlement extent and to recognise two types of floor plans of houses. During three excavation campaigns, two houses of the first type, dating to the younger part of the Lengyel culture, were examined (Cheben *et al.*, 2019). Both had a foundation ditch around the entire structure for mounting wooden stakes forming the house walls. The second type of house, belonging to the LBK and the Želiezovce Group, was identified on the geophysical plan on the basis of the characteristic pairs of long pits (Cheben, I. *et al.*, 2020). In addition to the houses, a domed oven belonging to the Želiezovce Group is worth mentioning. For the foundation

a



b



Figure 3.2.7. Čierne Kľačany 'Panské': a) hemispherical vessel and b) its find context.

of the floor, river pebbles and sherds of a tall hemispherical vessel with a polished surface and red painting were used. The ornamentation of the vessel consists of groups of three engraved lines surrounding the vessel below the rim, under which four horizontal rows of pairs of zigzag lines are interrupted by notches (Fig. 3.2.7).

At the south-western edge of the settlement area, 13 objects were uncovered in an excavation located along the access road, providing a ceramic inventory of the younger LBK (Ruttkay and Cheben, 2013). Based on the evaluation of the geophysical plan, a long house with postholes was selected for excavation, which was situated in the northern part of the surveyed area. Based on the ceramic inventory obtained, the house could be assigned to the Želiezovce Group. The fills of both long pits contained spherical, hemispherical and amphora-shaped vessels decorated with pairs of lines accompanied by notches. The find set is complemented by fragments of vessels bearing an engraved decoration characteristic of the Bükk culture (Cheben, I. *et al.*, 2020).

From the same cadastre, another LBK settlement is recorded at the site of 'Hrnčiarka' (Bátora and Bednár, 1982: 34).

Volkovce

Fragments of thin-walled and thick-walled vessels were collected from the parcel 'Konopniská', situated on the terrace of the Bočovka stream, located at the eastern edge of the village. The decoration, in the form of fine engraved lines complemented by music note-head impressions (Bednár, 1985: fig. 8), makes it likely that the site is a settlement of the younger LBK.

Prílepy

In the southern part of the village, on the right terrace of the Širočina stream, several sherds of LBK pottery were collected during a surface survey (Bednár, 1984: 38). On the border of the cadastres of Čierne Kľačany and Prílepy, there is probably a Neolithic settlement area, the extent of which has not been verified by further research. The existence of another site, situated in the northern part of the Prílepy cadastre, is indicated by finds of thin-walled ceramics of the Želiezovce Group, the decoration of which was made by engraved lines interrupted by notches (Ruttkayová and Ruttkay, 1991: 35, fig. 32.1).

Tesárske Mlyňany

During construction of a motorway, settlement objects belonging to the third phase of the Želiezovce Group were examined in the parcel 'Sihot'. From storage pit 33, a large set of chipped stone (3079 pieces) was obtained, in which limnosilicite was the dominant raw material. Among the artefacts, production waste and flakes from primary raw material processing dominated the inventory (Cheben, M. *et al.*, 2020).

During rescue research, three objects were examined at the site 'Kopanice nad šarinami', from which an inventory of LBK pottery was obtained. Spherical, hemispherical and amphora-shaped vessels are represented. The engraved ornamentations are formed either by separate lines or by pairs of lines. The main motif consists of circumferential lines below the rim, under which grooves are arranged in arcs or zigzag horizontal lines. The decoration is complemented by music note-head impressions. In one case, an engraved wavy line located in a triangle formed by a groove is also documented. Plastic decoration on larger vessels consists of extruded tape, rows of pressed dimples, and lugs (Bielich and Ruttkay, 2008: fig. 17).

Zlaté Moravce

From the cadastre of Zlaté Moravce, including the urban part of Chyzerovce, finds of LBK and Želiezovce Group pottery are documented from several locations. In the collection of the Municipal Museum are sherds decorated with engraved double lines and indentations from the public swimming pool, but there are also some fragments with engraved double lines with incisions typical of the Želiezovce Group (Ruttkayová and Ruttkay, 1991: fig. 56.1, 3; fig. 57.1). Sherds decorated with engraved lines and notches were recovered from objects disturbed during construction work in the south-western part of the cadastre, at the site 'Za potokom' (Hanuliak, 1983, fig. 51.1, 2). At the site known as 'Holdy', in the urban part of Žitavany, the trench for a water supply system disturbed 10 settlement objects. The bulk of the recovered assemblage consists of fragments of thin-walled vessels decorated with engraved lines and notched indentations. Two of the uncovered objects also contained pottery with Želiezovce notches on the vessels (Fottová, 2001, figs. 42.1–14, 18–26).

From the site 'Na fundušoch', in the township of Chyzerovce, comes a rare fragment of a vessel depicting a stylised human face. The wider grooves form three triangles, the two outermost of which are filled with oblique grooves. In the middle one, the eyes and nose are indicated by oval indentations (Ruttkayová and Ruttkay, 1991: fig. 66.5).

More extensive research was carried out in 2006, when, during the construction of a building in the industrial park in Zlaté Moravce, the ground plans of several long houses were registered. Their existence is confirmed by an aerial survey (Kuzma and Bartík, 2008: 104) carried out during the survey of the site. They are part of a larger LBK settlement, and the presence of Želiezovce Group pottery is also attested (Ruttkayová and Ruttkay, 2015: 129, figs. 243–247).

Horné Sláňany

At the site of 'Domovina', in addition to finds from other periods, a spherical vessel decorated with a zoomorphic eyelet and pairs of engraved lines arranged in semi-arches with music note-head impressions was obtained, as well as a sherd from the body of a spherical vessel with a pair of lines and a zoomorphic eyelet (Ruttkayová and Ruttkay, 1991: 35, fig. 35.7, fig. 38.7). From this site comes an amphora-like vessel of the Želiezovce Group, which has three vertical plastic strips around its body, terminated by bowl-shaped depressions (Ruttkayová and Ruttkay, 2015: fig. 173). On the excavation plan (Ruttkayová and Ruttkay, 2015: fig. 180), the objects of the LBK, the Želiezovce Group, and the Ludanice group of the Lengyel culture are not distinguished from each other. It thus remains unclear whether the vessels came from the building (Ruttkay, 1986; Ruttkay, 1987; Ruttkayová, 1988).

Topoľčianky

During surface collection, numerous finds of ceramics as well as chipped and ground stone were obtained from the parcel 'Žikavka', which is located in the cadastre of Topoľčianky, and not in that of Žikava. It is a gently sloping area extending to the south-east above the Jarky stream. The material of the LBK and the Želiezovce Group was located within an area of 400 × 150 m. The older stage is represented by fragments of spherical vessels and a vessel with a neck, ornamented by engraved lines complemented by music note-head impressions. The younger phase of the settlement is evidenced by a fragment from the body of a vessel decorated with engraved lines terminated by a long notch, but especially by a fragment of an amphora-like vessel with an applied zoomorphic eyelet (Kuzma and Illášová, 1996: fig. 84).

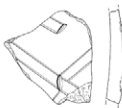
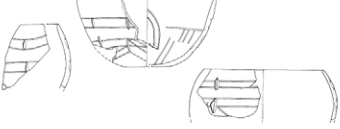
A small sherd with a pair of lines was recorded from the sewage plant area, which could belong to both the LBK and the Želiezovce Group (Ruttkay, 1999: 144, fig. 120.11).

Summary

The analysis of the ceramics of the LBK and the Želiezovce Group is based on decorative motifs on individual types of vessels. In general, an ornamentation is composed of basic elements. On thin-walled and medium-thick-walled ceramics, engraved lines are applied, mainly in pairs. In a younger phase of the LBK, the engraved ornamentation is complemented by music note-heads of a round or triangular shape. In contrast, notches that interrupt or terminate the engraved lines become typical with the Želiezovce Group, and especially in the younger period, they are applied in several designs. It should be noted that a combination of a music note-head and a notch occurs on vessels of an intermediate period. Especially for larger and thick-walled ceramics, plastic or applied ornamentations were used.

The aforementioned significant decorative elements and the shape of the engraved line was the decisive criterion for assigning a cultural period to the ceramics of the study

Figure 3.2.8. Characteristic sherds from the sites Úľany nad Žitavou 'Dolné diely' and Vlkaš 'Do hľuského chotára', with attribution to ornamentation styles.

Site	LBK	transition LBK/Želiezovce group	Želiezovce group
Úľany nad Žitavou Obj. 1			
Obj. 2			
Vlkaš Trench 12 Obj. 1			
Obj. 5			
Obj. 8			
Trench 15 Obj. 1			
Obj. 6			
Obj. 8			
Obj. 9			
Obj. 10			
B4			

Site	Parcel	LBK	LBK/Želiezovce	Želiezovce Group
Úfany nad Žitavou	Dolné diely	X	X	X
	Dolné Rakytiny			X
Hul		X		X
Vlkas	Do hľského chotára	X	X	X
Vlkas/Maňa	Za hľbokou cestou/Spodné pole	X		X
Maňa	Gedra	X		X
	Sandgrube	X		X
	Dlhá Str. 48	X		
Michal nad Žitavou	Pri kmetovskom chotári	X		X
Vráble	Veľké Lehemby/Farské	X	X	X
Čifáre	Kapustníská	X		
	Lúčky			X
	Farské			X
	Nad trstím	X		X
Mochovce				X
Tajná	Klisovnice	X		X
	Nad lúkami	X		
Nevidzany	Lúčne zeme	X		X
	Konopiská/Dolné urbáre	X		X
	right bank of Podegarský creek			X
	Za kostolom			X
Malé Vozokany	Briežky			X
	Lázky	X		
Veľké Vozokany	Stružkovské diely	X		
Čierne Kľačany	Panské	X		
	Pri mlyne	X		X
	Hrnčiarka	X		
Volkovce	Konopníská	X		
Prílepy	right bank of Širočina creek	X		
Tesárske Mlyňany	Kopanice nad Šarinami	X		
Zlaté Moravce	Za potokom	X		
Zlaté Moravce-Chyzerovce	Na fundušoch	X		X
Zlaté Moravce-Žitavany	Holdy	X		X
Topoľčianky	Žikavka	X		X
	Intravillan	X?		X?

Table 3.2.1. Early Neolithic sites in the Žitava Valley, with the ceramic styles found at each. The intermediate group 'LBK/Želiezovce' consists of ceramic sherds that bear both LBK- and Želiezovce-style decoration.

area (Fig. 3.2.8; Table 3.2.1). The frequency of finds is proportionate to the intensity of research in a given region, and this also applies to the region of the Upper Žitava Valley. Based on the information published so far about finds from individual sites of the LBK and the Želiezovce Group, even the occurrence of one decorated ceramic fragment must be considered as proof of the existence of the site. Such finds also help to narrow down the area to be subjected to systematic surface survey and modern prospection methods, not only to determine the size of the inhabited area, but also to identify settlement objects.

The occurrence of ceramics remains an indicator of population density, despite the fact that a substantial part of the registered inventory of the LBK and the Želiezovce Group comes from isolated finds and surface collections. Only a few of the sites have been subjected to excavation, and these yielded comprehensive find inventories. Compared with previous knowledge, the present project significantly broadened our knowledge of settlement agglomerations in the Upper Žitava Valley. The project's field activities have clearly proven that a network of settlements existed in the Žitava watershed, including along its numerous tributaries.

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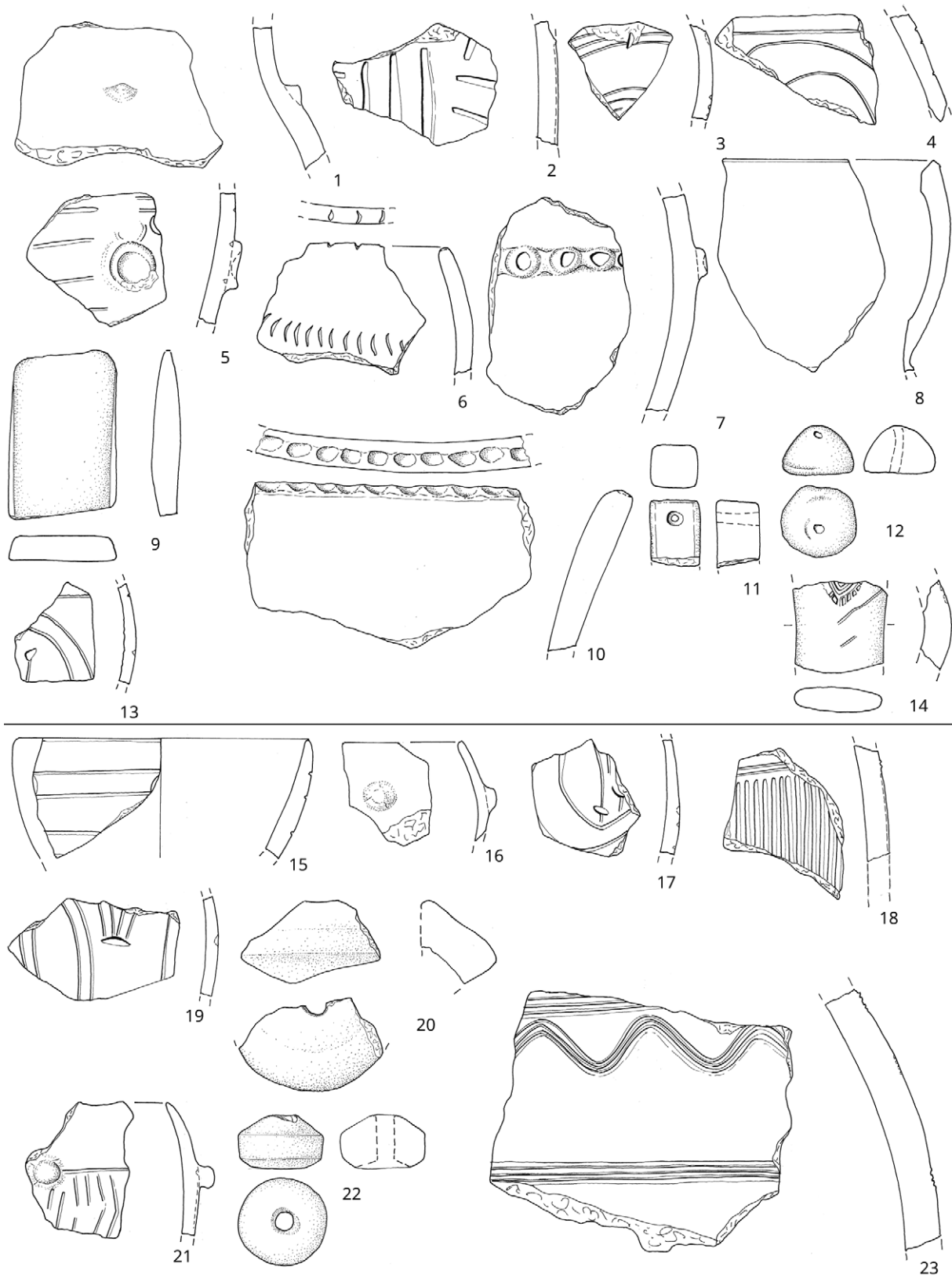


Plate 3.2.1. Surface finds: 1–14 Vlkaš 2017; 15–23 Tajná 2017. 1–8, 10, 13, 15–19, 21, 23 ceramics; 12, 20, 22 spindle whorls; 9, 11, 14 stone. Scale 1:2 (drawings: E. Bakytová).

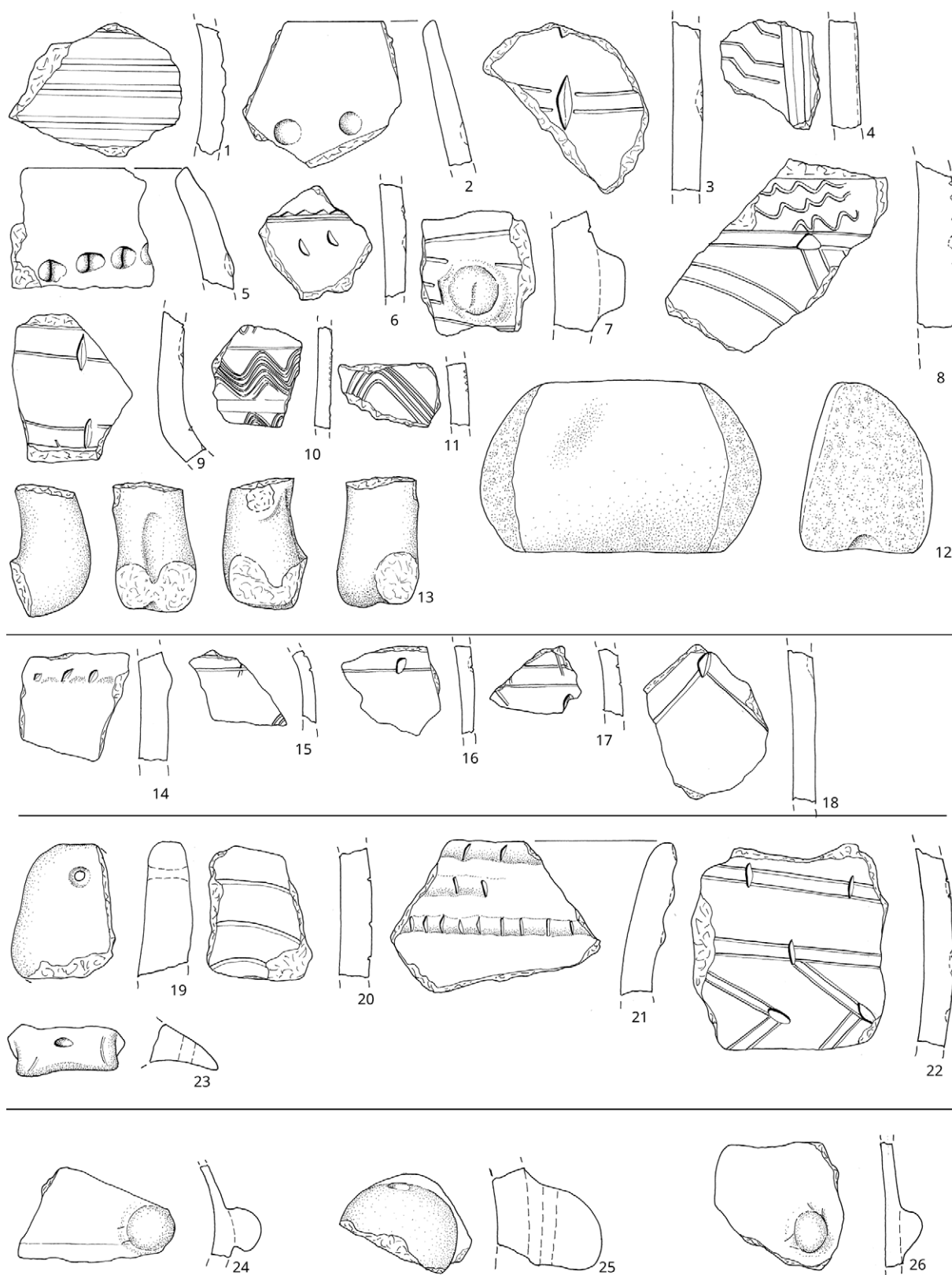


Plate 3.2.2. Surface finds: 1–4 Úľany nad Žitavou 2017; 14–18 Čířare 2018; 19–23 Vlkaš/Velká Maňa 2017; 24–26 Nevidzany 2017. 1–11, 14–26 ceramics; 12 stone; 13 figurine. Scale 1:2 (drawings: E. Bakytová).

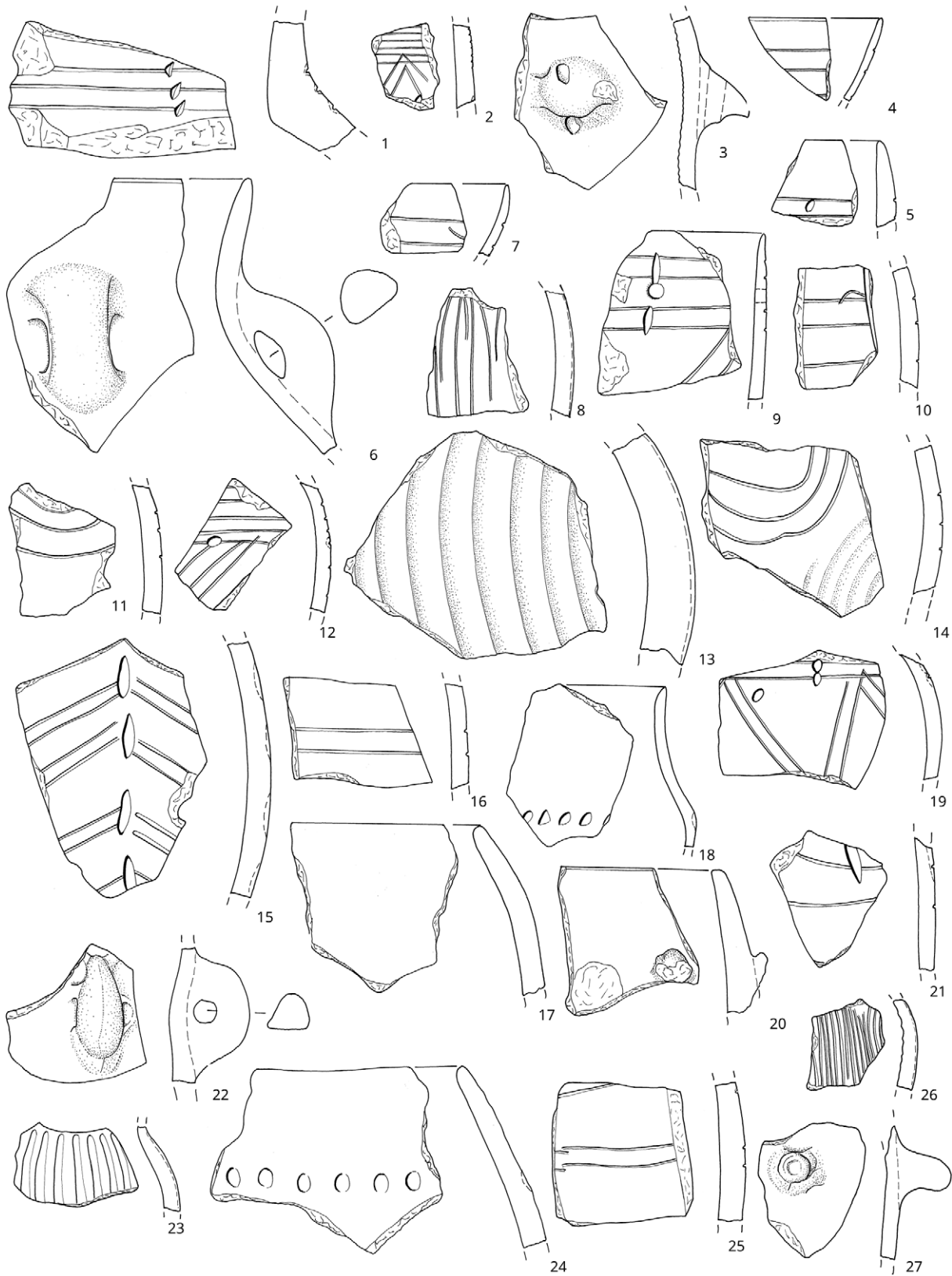


Plate 3.2.3. Ceramic surface finds from Nevidzany 2018. Scale 1:2 (drawings: E. Bakytová).

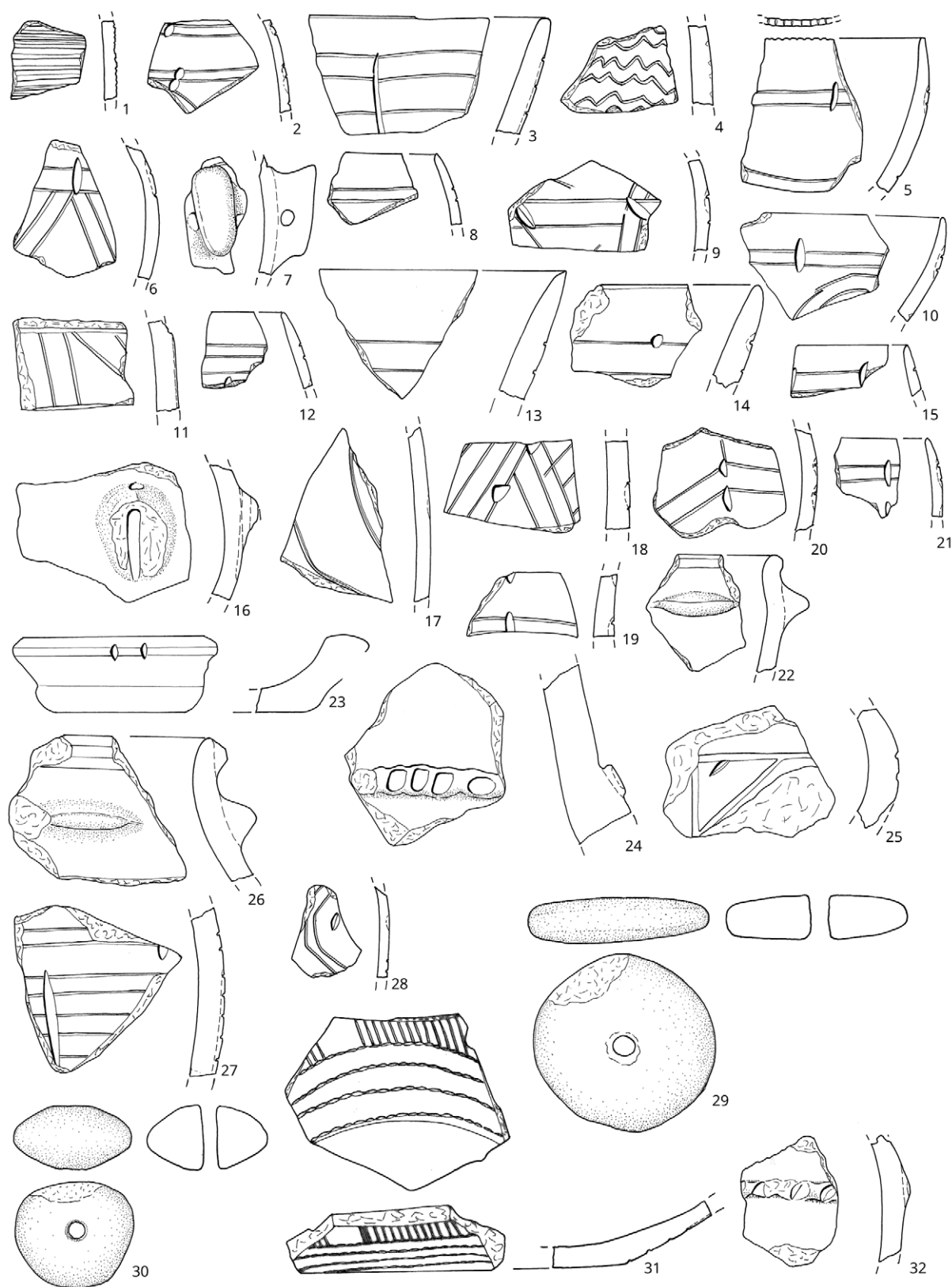


Plate 3.2.4. Surface finds from Nevidzany 2018. 1–28, 31–32 ceramics; 29–30 spindle whorls. Scale 1:2 (drawings: E. Bakytová).



Plate 3.2.5. Ceramic finds from Úľany nad Žitavou 2018. Scale 1:2 (drawings: E. Bakytová).

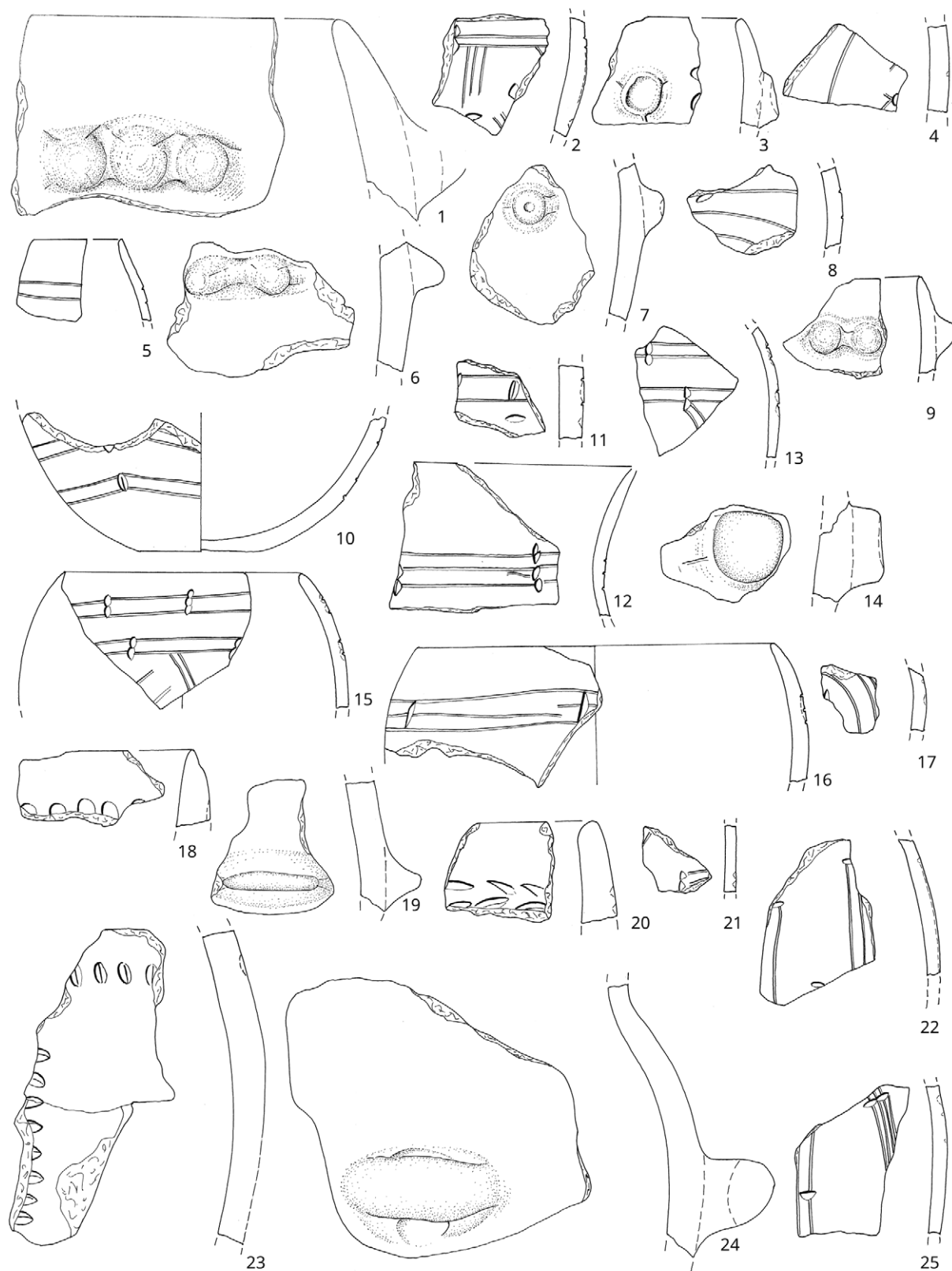


Plate 3.2.6. Ceramic finds from Úľany nad Žitavou 2018. Scale 1:2 (drawings: E. Bakytová).

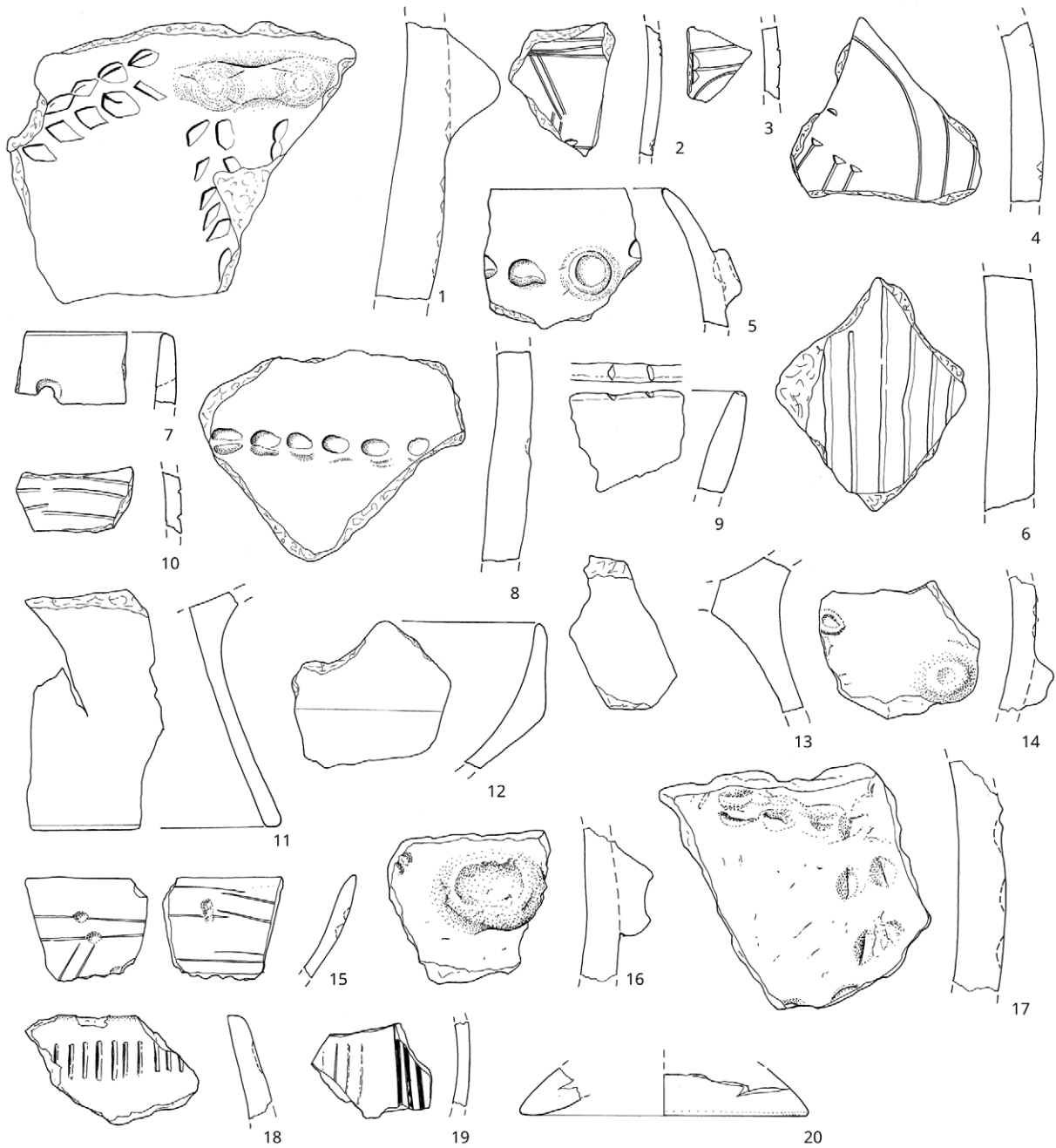


Plate 3.2.7. Ceramic finds from Úlany nad Žitavou 2018. Scale 1:2 (drawings: E. Bakytová).

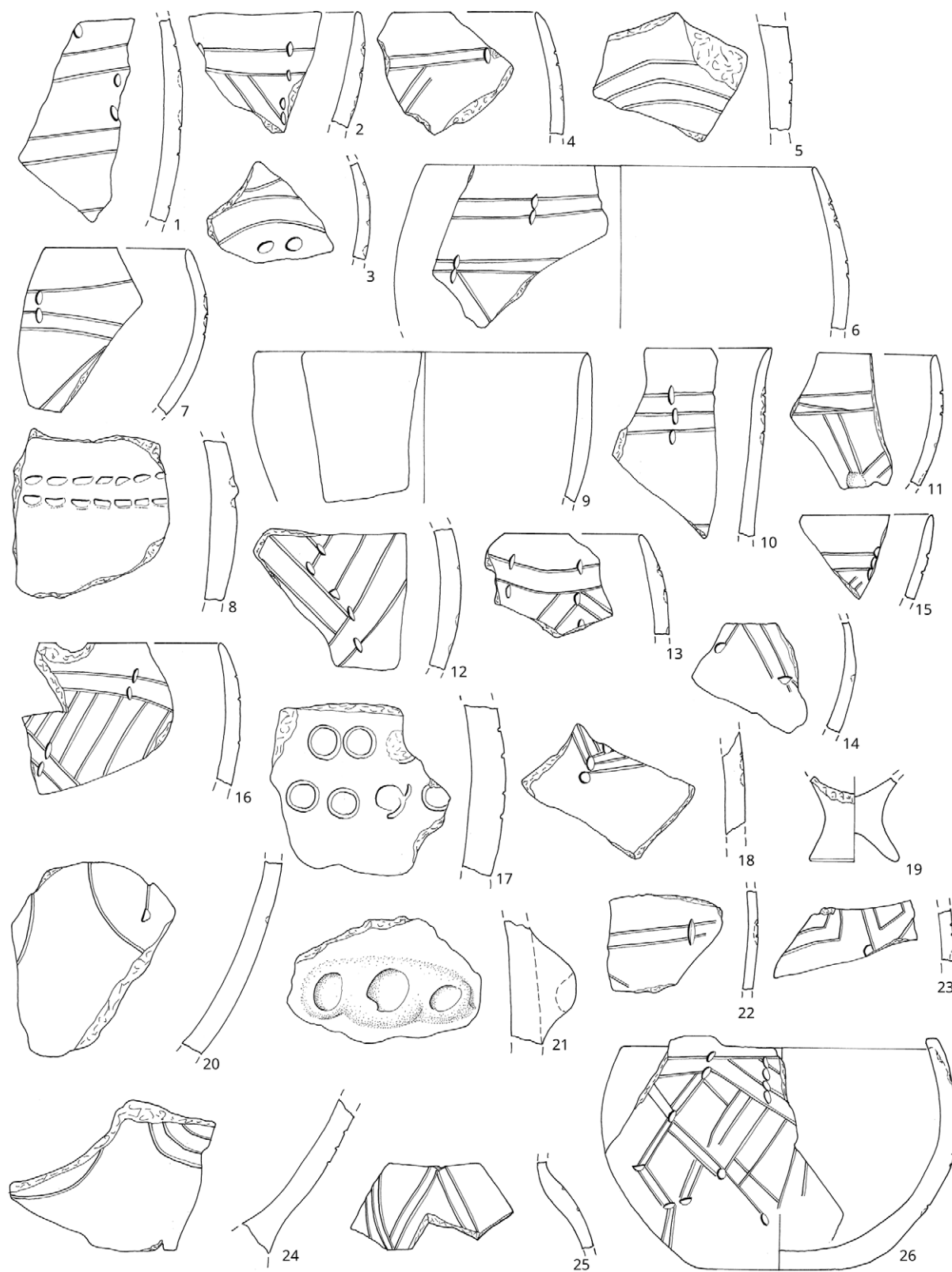


Plate 3.2.8. Ceramic finds from Vlkas 2018, trench 12. Scale 1:2 (drawings: E. Bakytová).



Plate 3.2.9. Ceramic finds from Vlkaš 2018, trench 12. Scale 1:2 (drawings: E. Bakytová).



Plate 3.2.10. Ceramic finds from Vlkaš 2018, trench 12. Scale 1:2 (drawings: E. Bakytová).

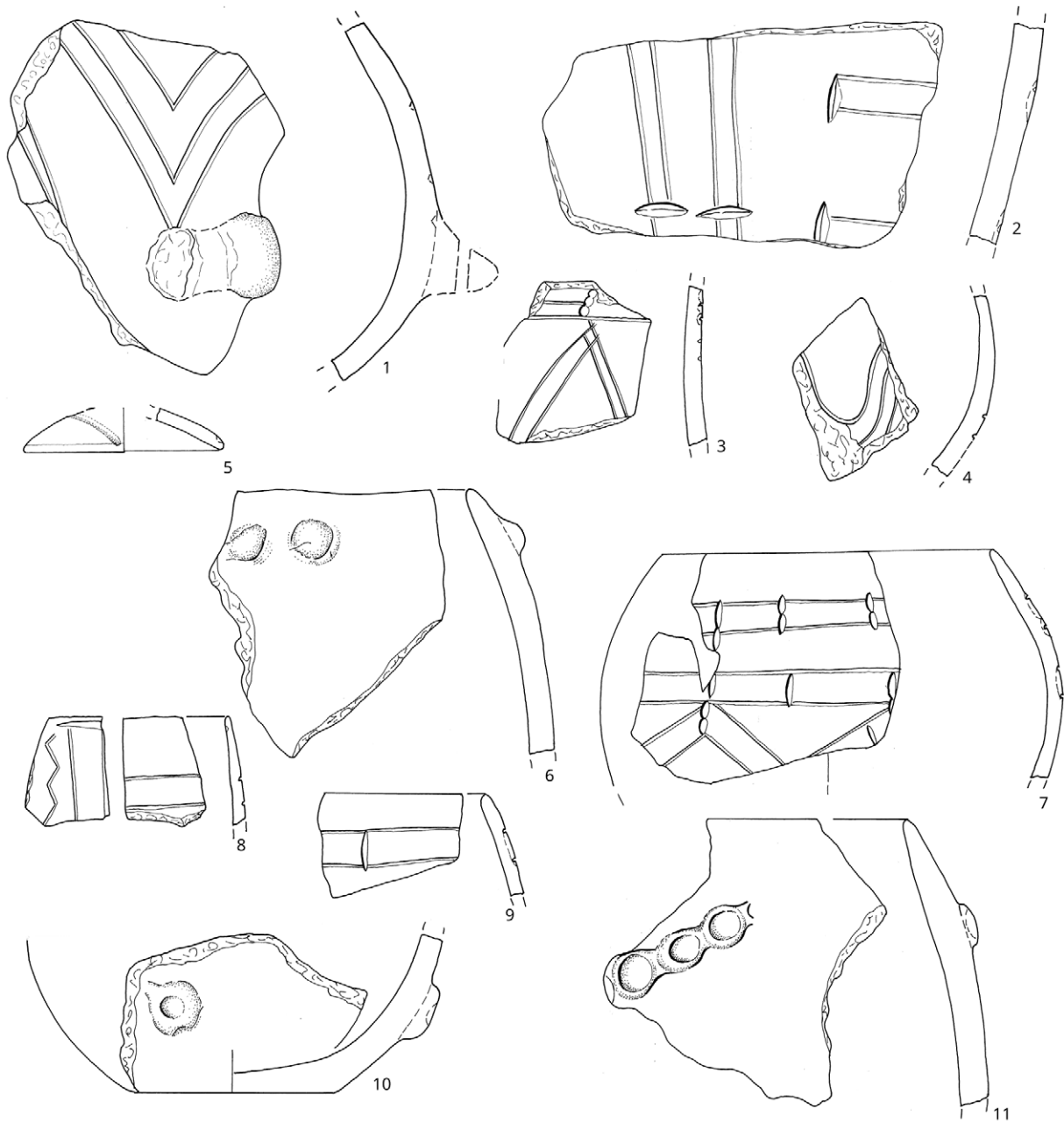


Plate 3.2.11. Ceramic finds from Vilas 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

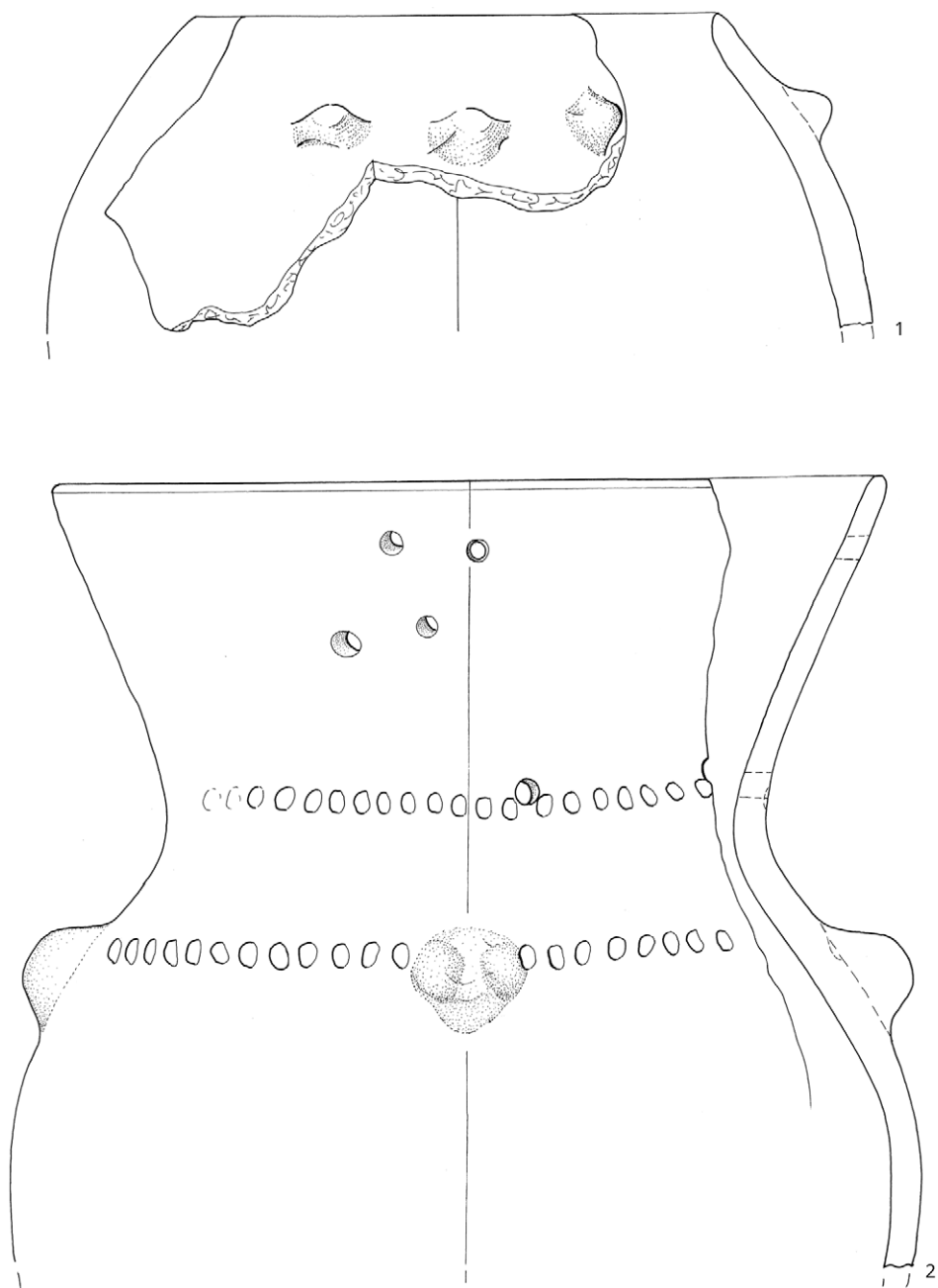


Plate 3.2.12. Ceramic finds from Vlkaš 2018, trench 15. 1 scale 1:2; 2 scale 1:4 (drawings: E. Bakytová).

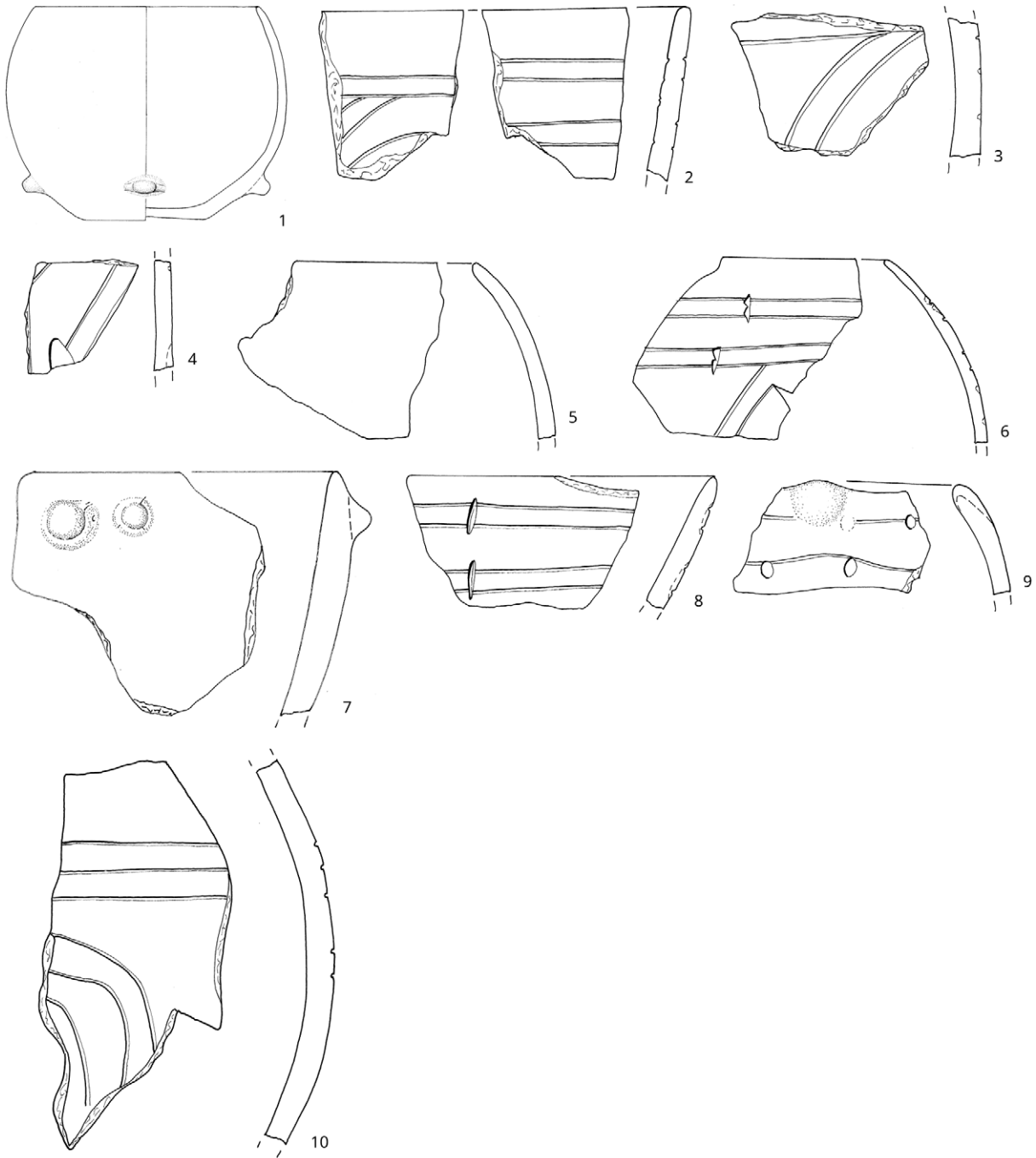


Plate 3.2.13. Ceramic finds from Vlkaš 2018, trench 15. 1–2 scale 1:4; 3–10 scale 1:2 (drawings: E. Bakytová).

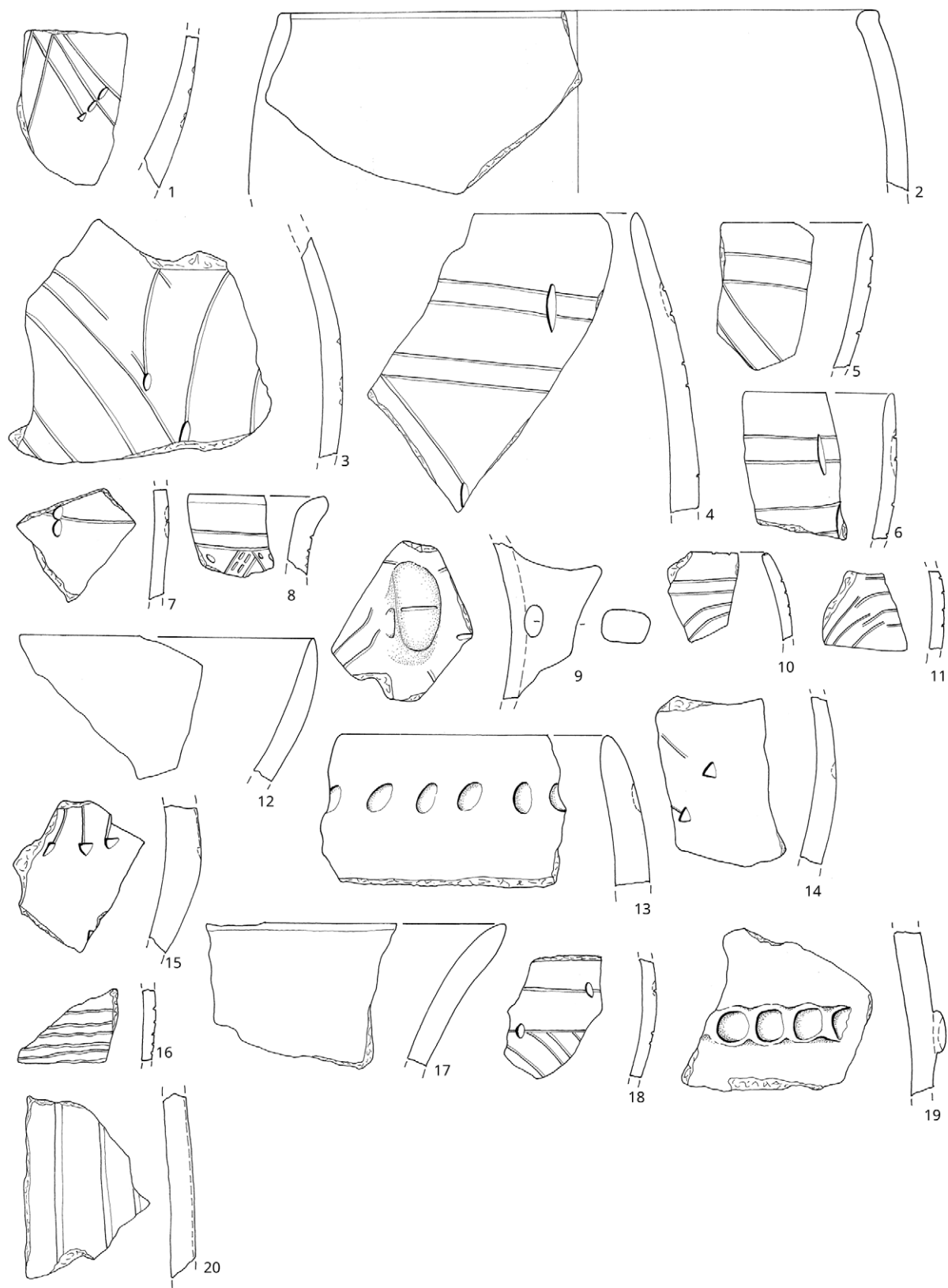


Plate 3.2.14. Ceramic finds from Vlkaš 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

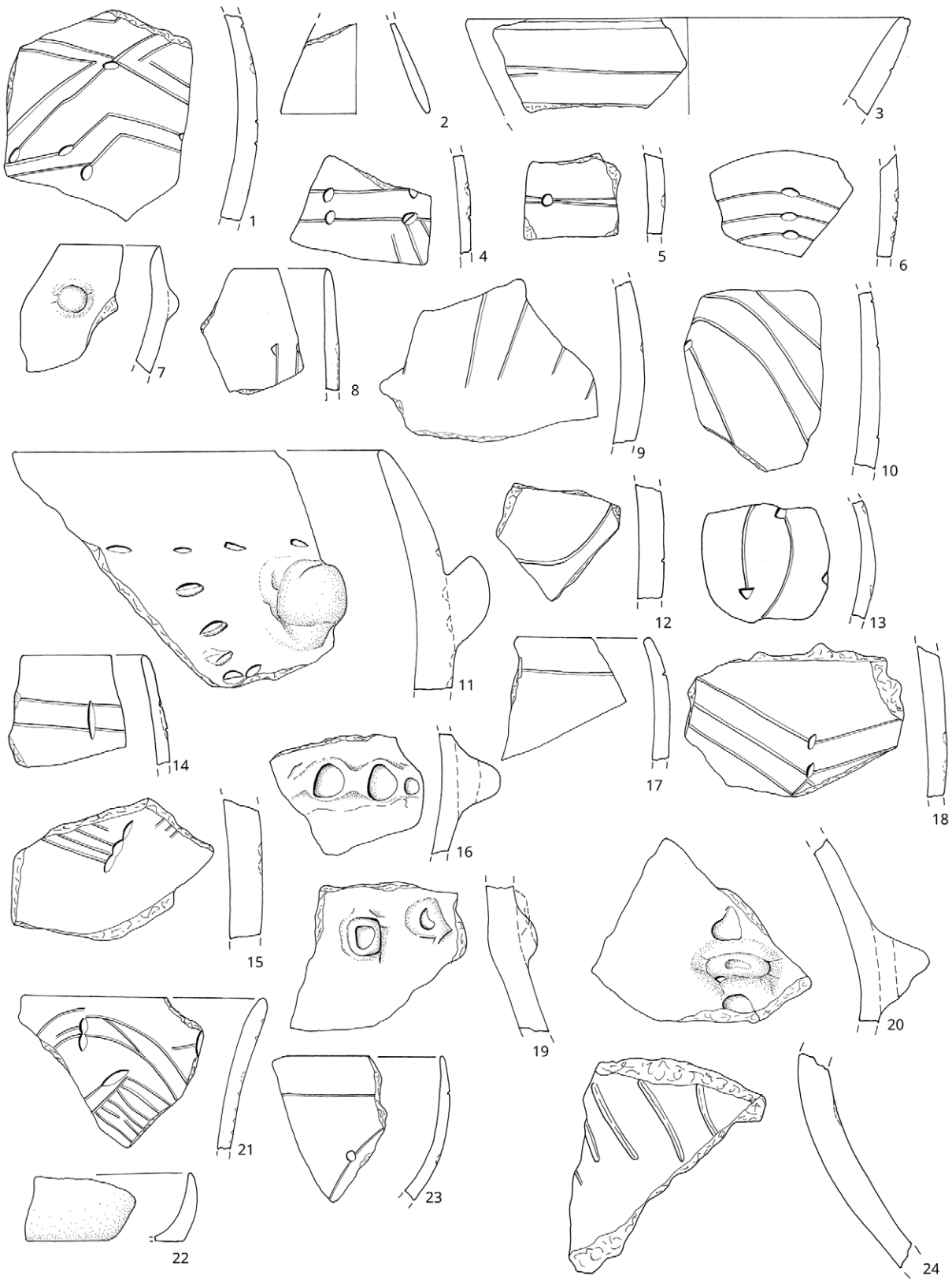


Plate 3.2.15. Ceramic finds from Vlkaš 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

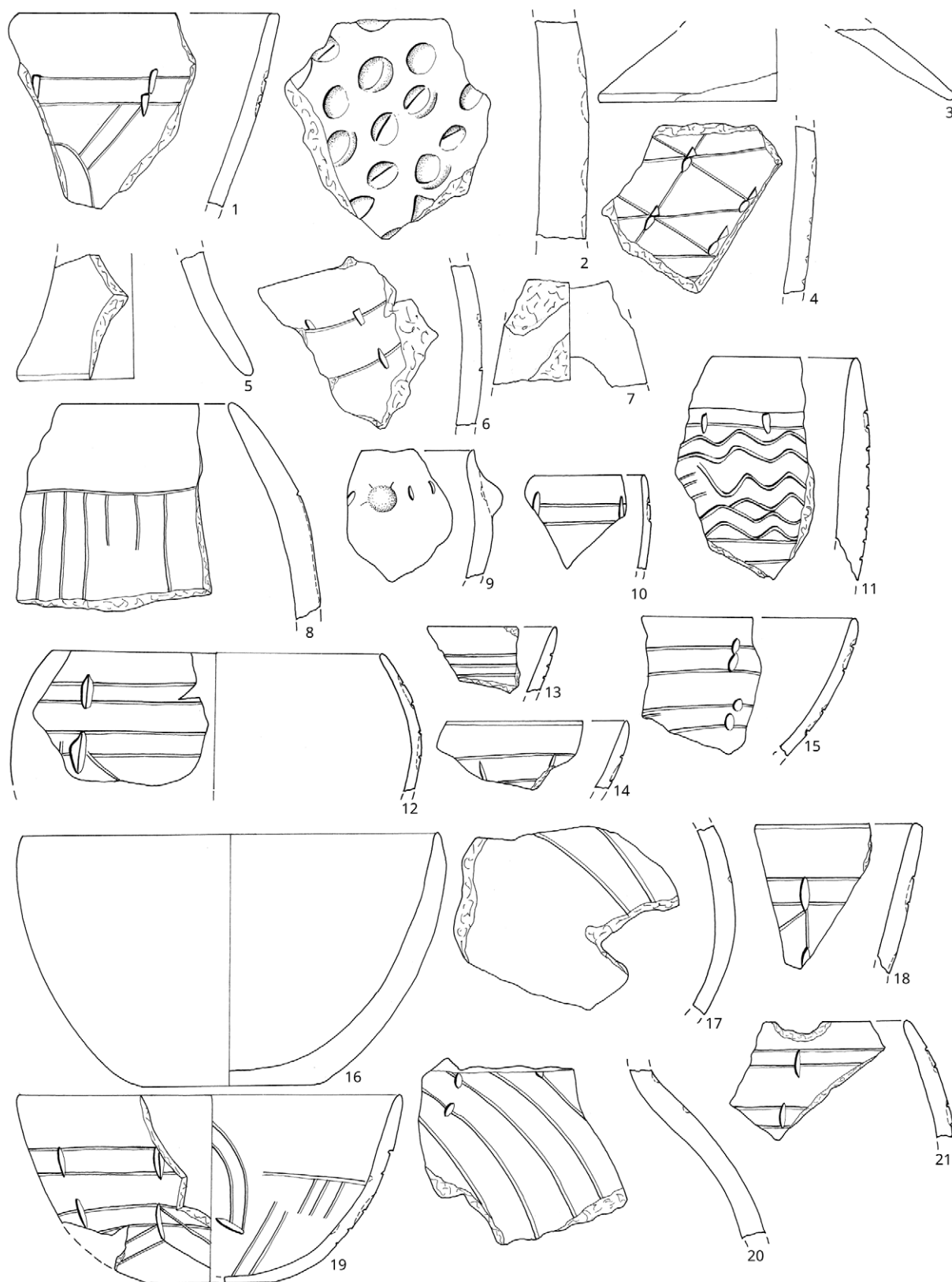


Plate 3.2.16. Ceramic finds from Vlkaš 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

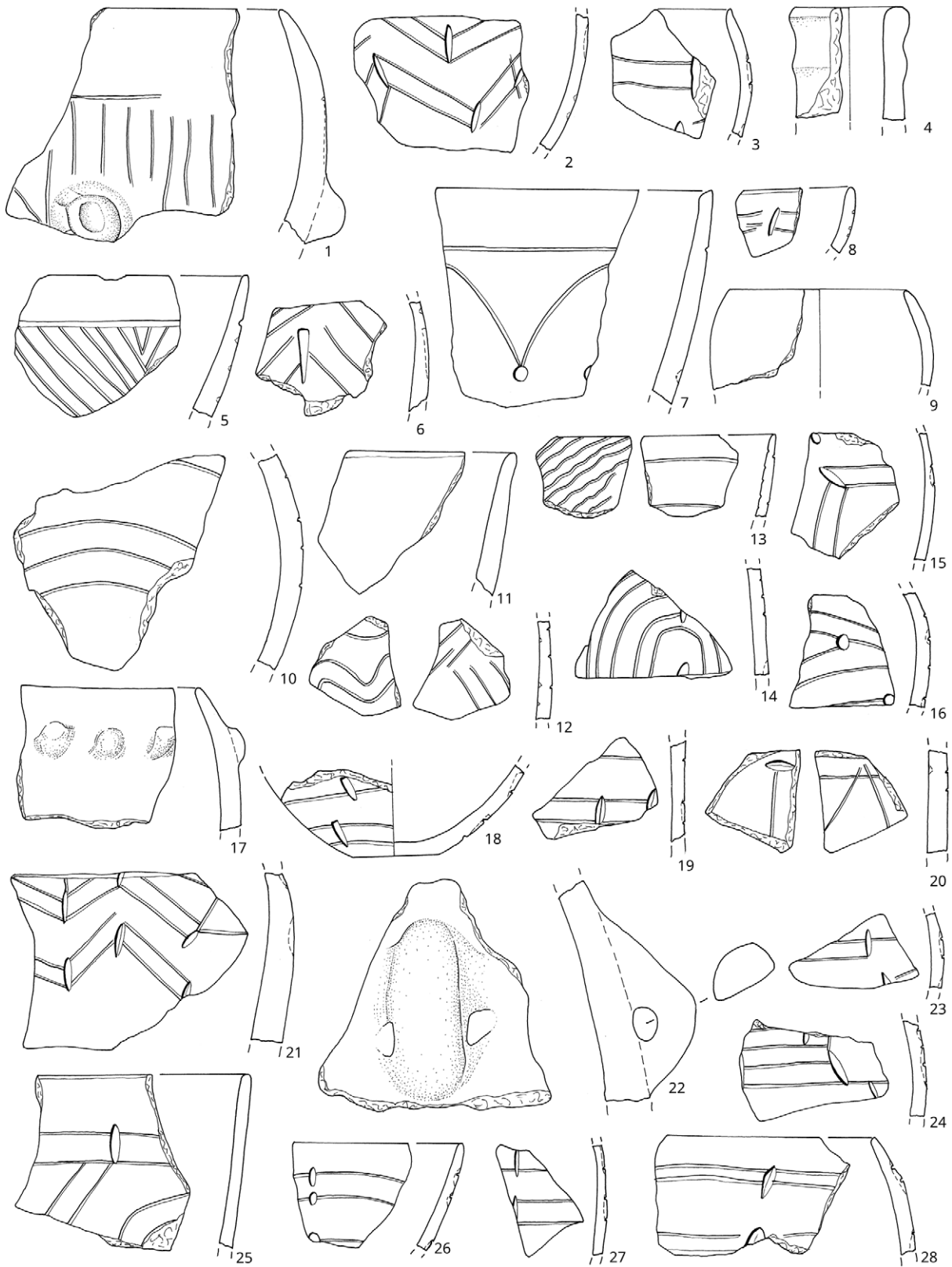


Plate 3.2.17. Ceramic finds from Vlkaš 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

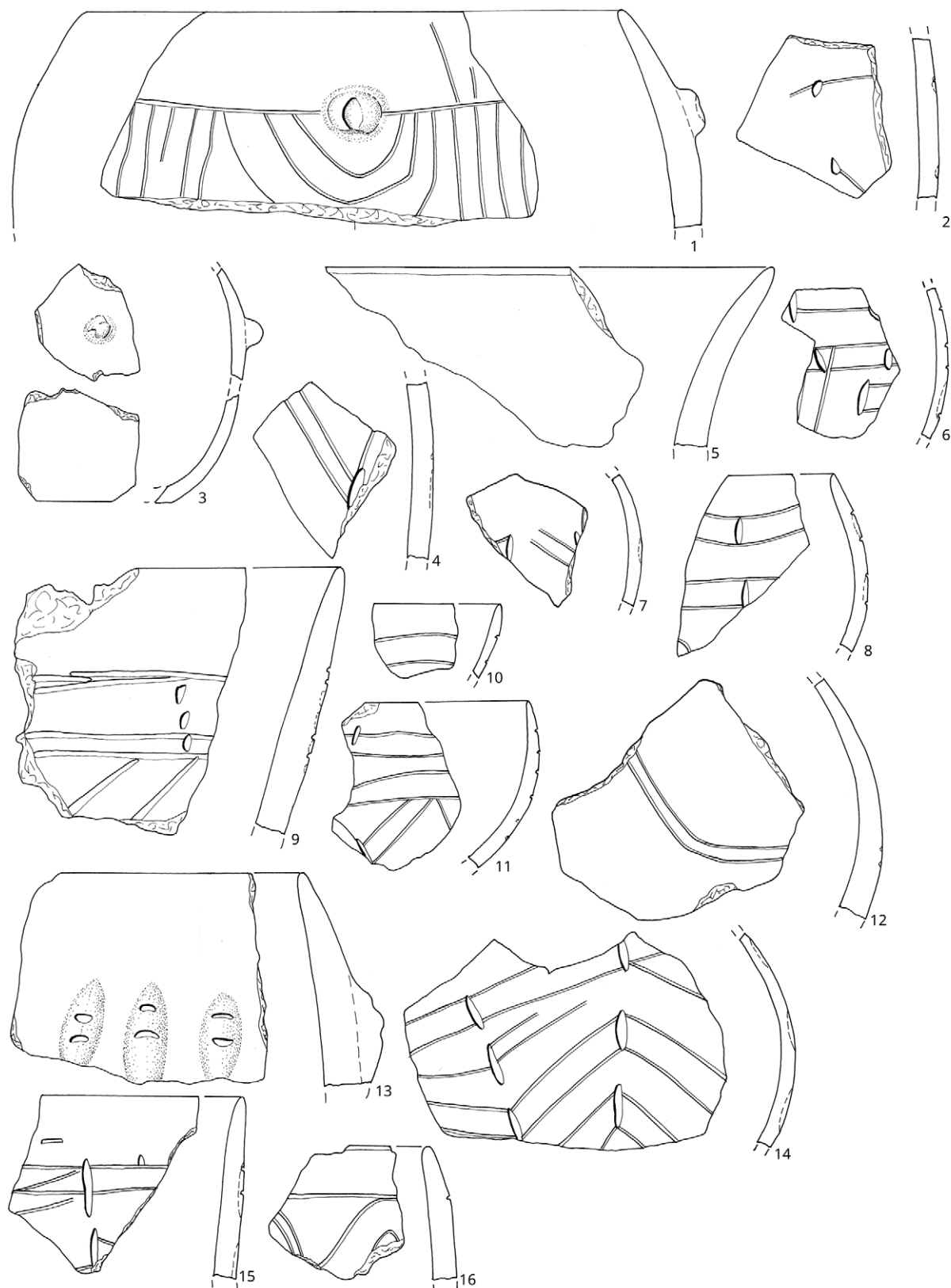


Plate 3.2.18. Ceramic finds from Vlkaš 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

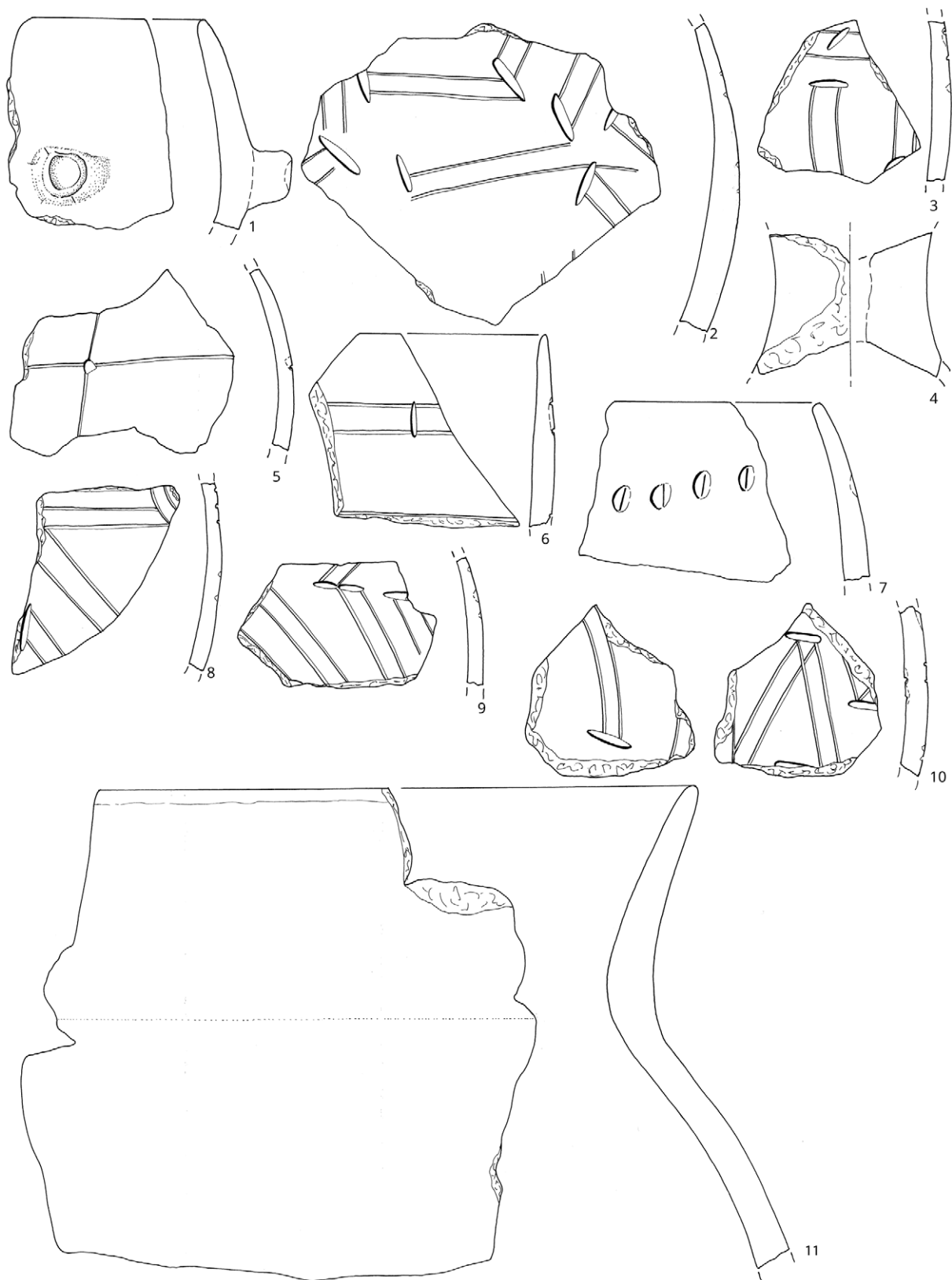


Plate 3.2.19. Ceramic finds from Vlkas 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

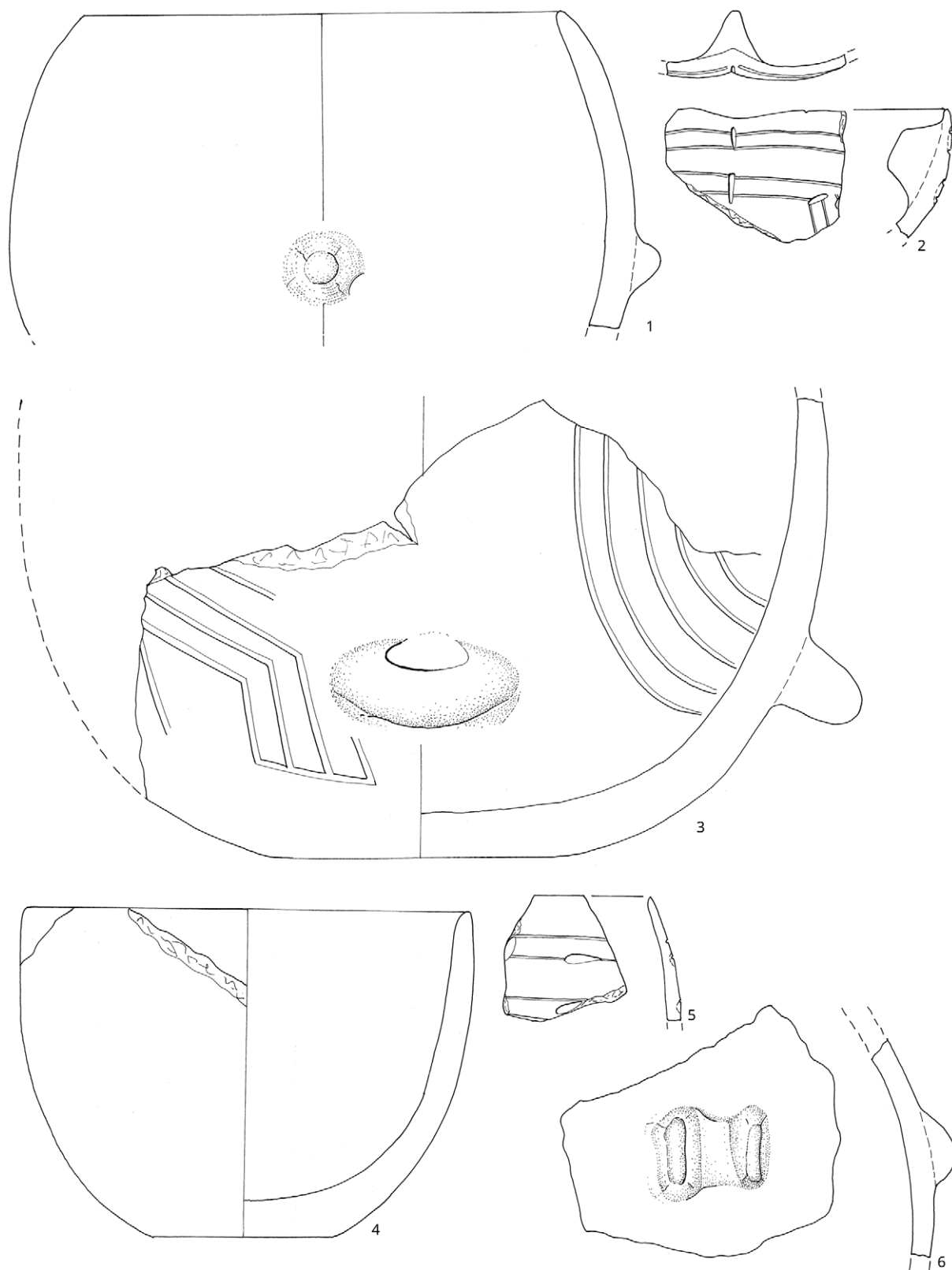


Plate 3.2.20. Ceramic finds from Vlkas 2018, trench 15. Scale 1:2 (drawings: E. Bakytová).

3.3 The animal remains from the LBK and Želiezovce Group settlement sites of Úľany nad Žitavou and Vlkas, Žitava Valley, south-western Slovakia

Rebekka Eckelmann, Nils Eberle

Abstract

A small number of faunal remains recovered at the Linearbandkeramik and Želiezovce sites of Úľany nad Žitavou and Vlkas in south-western Slovakia are compatible with the most widespread type of LBK animal exploitation. Both assemblages were part of a husbandry system built on cattle and smaller numbers of ovicaprids and pigs, with no significant contribution from hunting. The taxonomic distribution, interestingly, does not match that of the nearby settlement agglomeration of Vráble, where neighbourhood-specific preferences for different domestic species were found. These preferences were hypothesised to be expressions of differing group identities, and it is proposed that in smaller settlements, such as Úľany nad Žitavou and Vlkas, there may have been less need to emphasise diverging social identities.

Keywords: LBK, Early Neolithic, Slovakia, zooarchaeology, archaeozoology, subsistence

Introduction

Few developments have had as far-reaching consequences on human history as the Neolithic expansion. Practising a sedentary way of life based on plant agriculture and animal husbandry, *Linearbandkeramik* (LBK; Linear Pottery culture) groups were the first Neolithic culture to settle into central Europe, establishing multiple settlement sites on the Transdanubian plains from 5600/5500 to 5350 BCE onwards (Oross and Bánffy, 2009: table 1). Even though the LBK is one of the most widespread and most intensively studied archaeological complexes in Europe, recent years have seen a shift of focus from supra-regional analyses towards identification of more localised variations and of local differences in subsistence strategies, settlement patterns and cultural expressions (*e.g.* Tóth *et al.*, 2011; Furholt *et al.*, 2020b; Bickle *et al.*, 2014;

Oross and Bánffy, 2009). One extraordinary LBK site that was a part of this shift in focus is the settlement agglomeration of Vráble ‘Veľké Lehemby’, in the Upper Žitava Valley in Slovakia. Excavated over the past decade, this site, which consists of three distinct but contemporary neighbourhoods, has spurred a multitude of new insights into LBK social and economic organisation (cf. Furholt *et al.*, 2020a; 2020b). To further understand the role of inter-settlement connections and the development of such a unique structure, extensive prospections and geomagnetic surveys were undertaken. These revealed other previously unknown LBK sites in the microregion where Vráble is located. At two of these sites, Úľany nad Žitavou ‘Dolné diely’ (hereinafter Úľany) and Vlkaš ‘Do hľského chotára’ (hereinafter Vlkaš), excavations yielded a small number of animal bones.

Material and methods

Material

The faunal remains discussed in this study were recovered in 2018 during archaeological excavations in the vicinity of three LBK longhouses at Úľany and seven longhouses at Vlkaš. The focus of these excavations were the elongated pits running parallel to the houses’ long walls, which are signature features of the LBK and have been identified as both the main waste disposal units and the main source of archaeological finds in LBK settlements (e.g. Bickle, 2013: 155; Květina and Hrnčíř, 2013: 327; Gomart *et al.*, 2015: 231). Additional identified contexts include one *Schlitzgrube* (literally slotted pits, also referred to as V-shaped pits) at Úľany and a storage pit dating to the Bronze Age at Vlkaš (Chapter 3.1).

Even though a total of 300 bone specimens were recovered at Úľany and another 547 specimens at Vlkaš, only 225 and 223 specimens, respectively, were included in the final analysis. The reason for this is that the remaining finds stem from the so-called plough zone, a context close to the surface that has been heavily disturbed by historic and modern agriculture, and finds within this context cannot be reliably assigned to specific time periods of occupation (Chapter 3.1). While these finds are therefore still listed in the overall species distribution table for the sake of completeness, they were omitted from further analyses. Remains of Mollusca and microfauna, which were discovered in small numbers, were also not included in the analysis as they most likely represent later intrusions. A small number of bone artefacts were identified during the excavations and zooarchaeological investigations; they will not be discussed here.

During the excavation process, bones were recovered by hand-picking without additional sieving of the soil, because previous excavations in the area have shown that sieving does not result in a change in bone recovery rate or species distribution (Eckelmann, 2017). As is commonly the case with LBK sites situated on loess soils, the overall bone preservation was poor (Gordon and Buikstra, 1981: 469; Whittle, 2005: 321), with most specimens shattering during the recovery process. As was the case for the material from Vráble (Eckelmann *et al.*, 2020: 418), this shattering led to a prevalence of unidentifiable bone shards within the Neolithic assemblages at both Úľany and Vlkaš. The bones recovered from the non-Neolithic contexts showed better preservation.

Faunal analysis

All faunal remains were analysed by the authors using the comparative collection in the Zooarchaeological Laboratory at Kiel University. To optimise comparability

between assemblages, the analytical methods applied to the Újany and Vlkaš material were identical to those applied to the Vráble material (Eckelmann, 2017: 16–20; Eckelmann *et al.*, 2020: 418–419). These methods will only be summarised here.

Where possible, for each specimen, the skeletal element, taxon, body half, pathologies and other modifications were recorded. The specimens lacking characteristics that would allow identification below class were categorised by size: ‘large mammal’ for cattle- or red deer-sized; ‘medium mammal’ for sheep-, goat- or pig-sized; and ‘small mammal’ for rabbit- or fox-sized. Due to the overall poor preservation of morphological traits allowing the distinction between sheep and goat, these two taxa were combined into one analytical unit referred to as either ovicaprids or sheep and goat. Where possible, size measurements were taken on cattle bones according to van den Driesch (1976), to differentiate between domestic and wild cattle. This was done by calculating the logarithmic size index (LSI) using a female aurochs as the standard (Meadow, 1999; Stepan, 2001; remeasured data after Degerbøl and Fredskild, 1970, 10). Due to a lack of measurable specimens, differentiating between domestic and wild pigs was not an option.

For livestock species, the state of tooth eruption and tooth wear was recorded to estimate age at death, and the state of epiphyseal fusion was recorded to reconstruct animal survivorship. This was done with the goal of gaining insights into husbandry and production goals, of which animal age at death and survivorship are important indicators (Payne, 1973; Gillis *et al.*, 2017). Tooth wear was recorded using the system developed by Grant (1982) and converted into age classes according to the methods developed by Legge (1992: 23) for cattle, Lemoine *et al.* (2014: 118) for pig, and Payne (1973) for sheep and goat. Age at epiphyseal fusion follows Silver (1969: 252–253) for cattle and pig, and Zeder (2006: 89–92) for sheep and goat. Bone structures indicative of infant or foetal individuals were also noted and taken into account. However, the number of specimens to which ageing methods could be applied, or which bore other traits indicative of biological age, was very low.

To facilitate an analysis of both meat processing and deposition practices, modifications to the bones were recorded. These included cutting, chopping, scraping, and impact marks; signs of burning and calcification; marks associated with carnivore or rodent chewing. For additional indications, fracture patterns were recorded and analysed according to Outram’s fracture freshness index (FFI; Outram 2001: 406).

The FFI assigns points for the fracture angle, outline and edge texture of a bone fragment. An FFI score of 0 is indicative of a fracture pattern associated with the breakage of fresh bone and an FFI score of 6 is associated with a fracture pattern commonly found when dry bone breaks. The FFI, in combination with the size of fragments, is a powerful tool for examining the intensity of processing, as well as waste disposal practices.

The distribution of skeletal elements on a site or the presence or absence pattern of specific bones is related to both transportation and processing of meat and harvesting goals, as different body parts have different quantities of adhering meat, fat and skin. To investigate these distributions, the portion present of each skeletal element was attributed to morphological zones according to the system developed by Dobney and Rielly (1988). These zones were then used to calculate the minimum number of skeletal elements and sorted into body part groups. The following groups were established: the head and neck (skull, mandible, cervical vertebrae, axis, atlas), the axial skeleton below the neck (ribs, thoracic and lumbar vertebrae, sternum, sacrum and pelvis), the forelimb (scapula, humerus radius, ulna), the hindlimb (femur, patella tibia and fibula), and the distal extremities, including the metapodials, carpals, tarsals and phalanges. Isolated teeth were excluded from this grouping in order to limit bias in the calculation of body part distribution.

Results

Analysis of the Neolithic animal bone assemblage

Due to the poor preservation and high degree of fragmentation of the material, few specimens could be identified to the level of species: 27 Neolithic specimens were identified to taxon at Ůľany, a below-class identification rate of only 12%. At Vlkaš a slightly better rate of preservation, as well as generally higher amounts of material, led to 73 identified Neolithic specimens with, an identification rate of 45%. A further 77 and 65 specimens, respectively, at each site were assigned to animal size classes (Tables 3.3.1–2).

Among the identified taxa, cattle were the most common at both Ůľany and Vlkaš, followed by sheep/goat and then pig (Fig. 3.3.1). Even though there were only a few measurement points available, the body size distribution data for cattle indicate they were of smaller stature than the female aurochs used as a standard, and similar in

	<i>Bos</i> sp.	<i>Ovis aries/</i> <i>Capra hircus</i>	<i>Sus</i> sp.	<i>Canis</i> sp.	Large mammal	Medium mammal	Small mammal	Micro- fauna	Total
LBK House 16	14	8	1	1	8	67	1	0	184
LBK House 593	1	0	0	0	1	0	0	0	36
LBK House 594	1	0	0	0	0	0	0	0	2
LBK <i>Schlitzgrube</i>	0	1	0	0	0	0	0	0	3
Total non-Neolithic contexts	3	1	0	0	9	37	0	2	75
Total Neolithic contexts	16	9	1	1	9	67	1	0	225
Total	19	10	1	1	18	104	1	2	300

Table 3.3.1. Ůľany nad Žitavou. 'Dolné diely': Taxonomic distribution of animal bones excavated in 2018 (NISP).

	<i>Bos</i> sp.	<i>Ovis aries/</i> <i>Capra hircus</i>	<i>Sus</i> sp.	<i>Canis</i> sp.	<i>Cervus elaphus</i>	<i>Capreolus capreolus</i>	<i>Felis catus</i>	<i>Erinaceus</i> sp.	Large mammal	Medium mammal	Small mammal	Microfauna	Small bird	Indeterminate	Total
LBK House 212	9	10	3	0	0	0	0	0	4	5	1	0	0	5	37
LBK House 213	1	3	0	0	0	0	0	0	0	4	0	0	0	1	9
LBK House 201	9	1	0	1	1	0	0	1	1	3	0	0	0	1	18
LBK House 202	9	4	5	0	0	0	0	1	10	13	0	2	0	7	51
LBK House 205	1	0	1	0	0	0	0	0	1	4	0	0	0	1	8
LBK House 590	7	2	2	1	0	0	0	0	4	6	2	2	1	2	29
LBK House 591	1	0	0	0	0	0	0	0	0	2	0	0	0	2	5
LBK Mixed Context	15	10	7	0	0	0	0	0	3	15	1	0	0	7	58
Bronze Age pit	0	1	1	0	0	0	0	0	1	2	1	0	0	2	8
Other contexts	59	35	34	3	1	3	1	0	54	87	6	1	0	30	324
Total Neolithic contexts	52	30	18	2	1	0	0	2	23	52	4	4	1	26	215
Total	111	66	53	5	2	3	1	2	78	141	11	5	1	58	547

Table 3.3.2. Vlkaš 'Do hľského chotára': Taxonomic distribution of animal bones excavated in 2018 (NISP).

body size to those encountered at Vráble, and that two specimens at Vlkaš are very small (Fig. 3.3.2; Eckelmann *et al.*, 2020: 421, fig. 5.4.2). Accordingly, the remains are interpreted as domestic cattle rather than aurochs. For pigs, no valid measurements were obtainable from the excavated specimens, but the overall size of the bones is more indicative of domestic pigs than of wild boar. The presence of dogs was verified at both sites through the presence of one tibia at Úľany, two mandible fragments at Vlkaš and additional non-canine elements bearing marks of carnivore chewing. Due to an overall low number of identified specimens, the minimum number of individuals (MNI) for the domestic species is 3 or less per taxon at both sites (Table 3.3.3). Fragments belonging to medium-sized animals were generally more abundant than those belonging to large mammals, while evidence for the presence of small-sized species was low.

Finds indicative of non-domesticated species were scarce in the Neolithic contexts, with none at all identified at Úľany and only four at Vlkaš (Table 3.3.1). Of those four elements attributed to wild fauna at Vlkaš, one was identified as a piece of red deer antler, one as a tibiotarsus fragment of an unidentified small bird and two as fragments of hedgehog femurs, which may originate from the same specimen. The other specimens belonging to wild taxa, including roe deer and wild cat, cannot be securely attributed to the Neolithic occupation period as they came from the plough zone.

Nearly all animal remains were recovered from the elongated pits running parallel to the side walls of each house. Though it is unknown if the fills of these pits can be attributed to the occupants of the associated houses only (*e.g.* Bickle, 2013: 155; Květina and Hrnčíř, 2013: 327; Gomart *et al.*, 2015: 231), their content is often used

	Úľany	Vlkaš	Vráble
<i>Bos</i> sp.	1	3	4
<i>Ovis aries/Capra hircus</i>	2	3	5
<i>Sus</i> sp.	1	3	6
<i>Canis</i> sp.	1	1	1

Table 3.3.3. Minimum number of individuals (MNI) for domesticated species at Úľany, Vlkaš and Vráble (Vráble after Eckelmann *et al.*, 2020). Only Neolithic specimens are included.

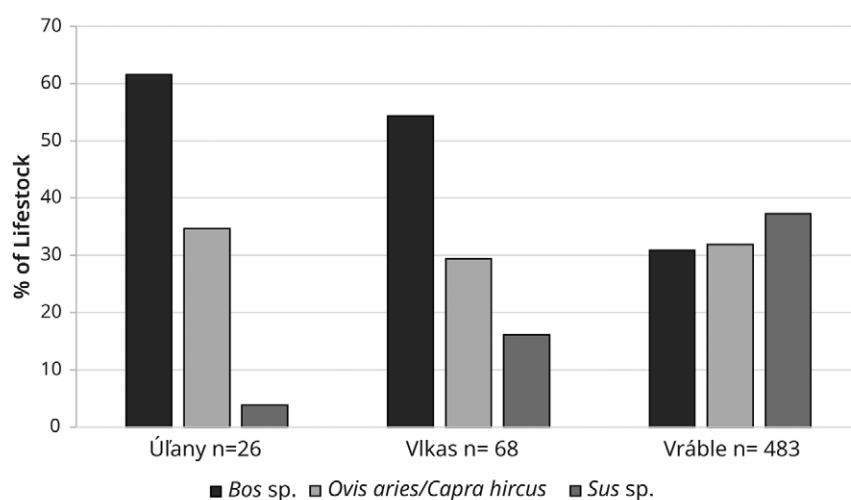
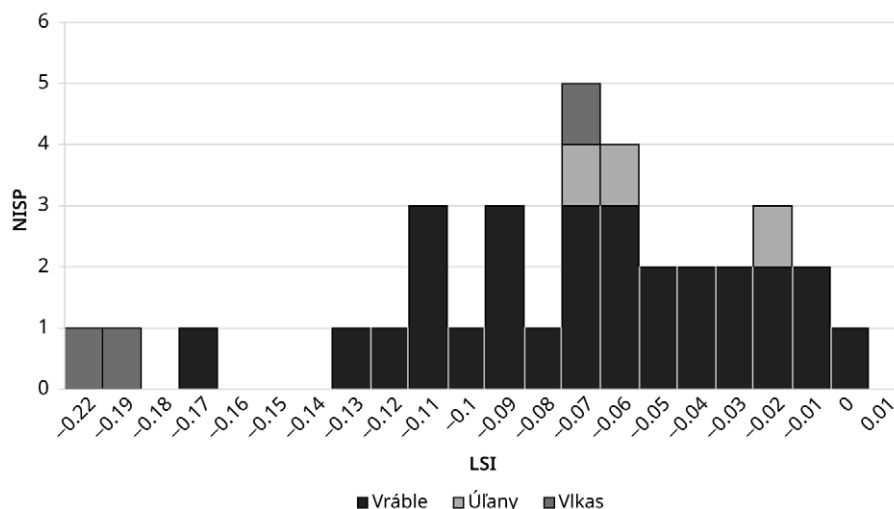


Figure 3.3.1. Cattle, pig and ovicaprids as a proportion of all livestock at Úľany, Vlkaš and Vráble (Vráble after Eckelmann *et al.*, 2020: 420, table 5.4.1).

Figure 3.3.2. Log Standard Index distribution for Neolithic cattle at Vrábě, Úlany and Vlkaš (using Steppan 2001 as a standard; Vrábě after Eckelmann et al., 2020: 421, fig. 5.4.2). Two specimens from Vlkaš come from subadult individuals.



to compare between households. In the present case it was, however, not possible to analyse differences in species distribution in this way due to the overall small number of finds. At Úlany, in addition to these pits, one additional Neolithic feature, identified as a *Schlitzgrube*, contained one ovicaprid scapula and an unidentified bone fragment. Both specimens most likely entered the context by accident rather than as a purposeful deposition.

It was not possible to create either site-specific mortality profiles or survivorship curves, as the number of specimens bearing morphological traits indicative of animal age at death was too low. For Úlany, tooth wear stages could be determined for only one ovicaprid, indicating an animal of about 3 years of age at death, and for one pig, indicating an animal around 1 year of age at death. In congruence with this, epiphyseal fusion data also indicated one sheep or goat below 4 years of age at death. At Vlkaš, cattle tooth data are restricted to two individuals, one of 6 to 8 years of age at death and one of 1 to 3 months age at death. Ovicaprids are represented by three individuals, one of 1 to 2 years of age at death, one of 4 to 6 years of age at death and one older than 8 years at death. For pigs it was only possible to identify one individual as juvenile. Epiphysial fusion indicated that one cattle individual died before the age of 10 months and another before 3 years of age, two very small LSI measurements further point to the presence of at least one juvenile animal. In ovicaprids, a tibia and calcaneum showed an age of death predating ca. 3 years of age. One unfused pig femur indicates death before 3 years of age, which fits with the available tooth wear data.

Analysis of elemental distribution was also problematic due the low number of finds, especially at Úlany, making a statistically sound analysis impossible. General observations do, however, not indicate an uneven distribution at either Úlany or Vlkaš, with skeletal areas naturally containing more bones (e.g. the skull in comparison to the hindlimbs; Fig. 3.3.3). The only unusual observation was a slightly higher than expected amount of elements belonging to the head and neck area and a low number of elements associated with the feet, a trend which was not seen at Vrábě.

Bone modifications indicative of processing and disposal processes were identified in small amounts at both sites. Of these, marks indicative of exposure to fire were the most common, but signs of chopping, impact and trampling were present as well. Impact and chop marks occurred on long bones and one talus bone; no specific positioning could be identified for any other type of modification. In contrast to Vrábě, no marks indicative of cutting or scraping were discovered on the Neolithic material from either Úlany or Vlkaš (Fig. 3.3.4).

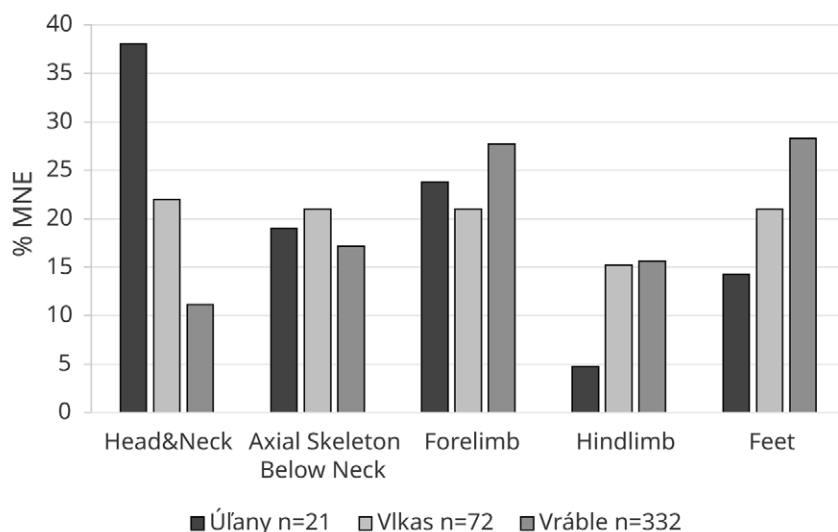


Figure 3.3.3. Proportion of minimum number of elements at Úľany, Vlkas and Vrábľe (Vrábľe after Eckelmann et al., 2020: 425, fig. 5.4.12). Isolated teeth and non-Neolithic specimens are not included.

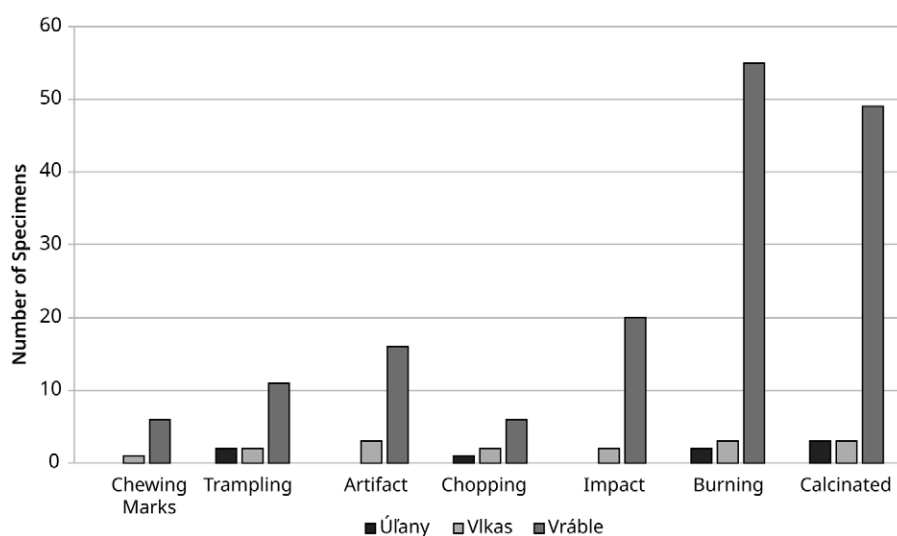


Figure 3.3.4. Number of Neolithic elements with modifications indicative of either processing or waste management at Úľany, Vlkas and Vrábľe (Vrábľe after Eckelmann et al., 2020: 424, fig. 5.4.9).

Regarding fragmentation patterns the overall size of fragments with ancient breakage (40% of all specimens in Úľany and 36% at Vlkas) at Vlkas is slightly larger than at Úľany, with both sites showing a tendency towards bigger fragments than were common at Vrábľe, where very small fragments (<2 cm) made up about 50% of all specimens (Fig. 3.3.5). The FFI shows that a similar proportion of fragments exhibit traits indicative of 'dry', or 'old' breakage (33% at Úľany and 27% at Vlkas with FFI of 6) and ambiguous characteristics (24% at Úľany and 25% at Vlkas with FFI of 3; Fig. 3.3.6). This stands in stark contrast to Vrábľe, where nearly 50% of all fragments were indicative of 'dry' breaks. Conversely, the percentages of fresh breakage are higher at both Úľany and Vlkas than they are at Vrábľe.

The non-Neolithic features

At Úľany, all of the archaeological features were identified as belonging to the Neolithic, but at Vlkas, one feature dating to the Bronze Age was identified which also contained faunal remains. Only eight bones were recovered from this Bronze Age pit and only two identified to species level, one belonging to an ovicaprid and

Figure 3.3.5. Fragment size distribution for Neolithic specimens at Úlfany, Vlkas and Vráble (Vráble after Eckelmann et al., 2020: 424, fig. 5.4.10). Fragments bearing only modern fractures were not included.

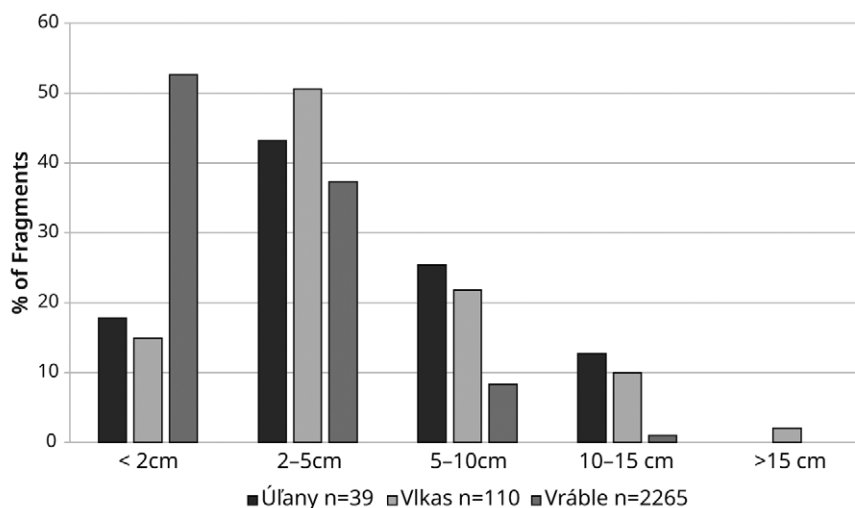
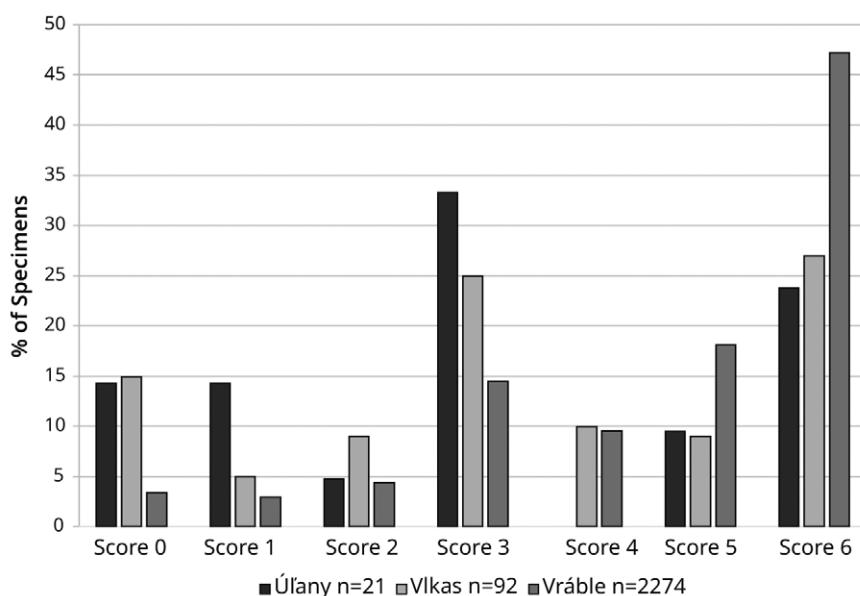


Figure 3.3.6. Distribution of Neolithic specimens according to Outram's fracture freshness index at Úlfany, Vlkas and Vráble (Vráble after Eckelmann et al., 2020: 425, fig. 5.4.11).



one to a pig (Table 3.3.1). This number of finds and their as-yet undetermined cultural context does not allow for an interpretation in regard to subsistence or cultural development. A more general assessment of Bronze Age faunal assemblages does, however, indicate an overall dominance of mature cattle as the main source of meat and secondary products and smaller numbers of ovicaprids and pigs, as seen elsewhere (e.g. Bartosiewicz, 2013: 56; Kulcsár, 2009: fig. 9). The specimens recovered at Vlkas do not contradict these findings.

In addition, Vlkas also yielded faunal remains from a context – the ploughzone – that cannot be securely attributed to a specific prehistoric or historic period and most likely constitutes a mixture of what were originally discrete horizons, as a result of agricultural use. This assumption of admixing is supported by the highly variable preservation and fragmentation patterns of the encountered specimens. The finds include a variety of animals, among them a few wild species not encountered within the Neolithic contexts, but which could also have been accumulated without human interference. The presence of at least three infant piglets is unusual under the assumption of meat-oriented husbandry production and could be an interesting subject of further research should radiocarbon dates for them become available.

Economic and social implications of the Neolithic faunal remains

The faunal assemblages at Úľany and Vlkas display a similar range of exploited animals to most other LBK sites in central Europe, namely cattle, sheep, goat and pig, as well as a small proportion of dog and wild fauna (Bickle and Whittle, 2013: fig. 1.5, 1.6).

The commonly reported contribution of wild fauna to LBK faunal assemblages averages about 3.5–5% in the middle Danubian region (Knipper, 2011: 36–38; Bickle and Whittle, 2013: fig. 1.6; Fehlmann, 2008: 90). The presence of only four specimens attributed to non-domesticated animals at Vlkas and none at Úľany does fit within this framework, especially considering the overall low number of finds, and also conforms with the previously recorded extremely low proportion of wild specimens at Vrábľe (4%; Eckelmann *et al.*, 2020: 419). It is, however, questionable whether these four specimens are even related to hunting: Two of them belong to hedgehogs, and although it cannot be ruled out that these animals were used to supplement the human diet, it is equally possible that they entered the archaeological record as vermin or carnivore prey. The same is true for the single bird bone recovered. The last specimen, a piece of roe deer antler, may be indicative of hunting, but antlers are also naturally shed each year and it may therefore have been collected without actually killing a deer (*e.g.* Fehlmann, 2008: 85; Kokabi *et al.*, 1994: 13). The concept of hunting was surely not unknown at Úľany or Vlkas, but the current state of evidence does not support even an occasional dietary contribution by wild fauna. Accordingly, it has to be assumed that, consistent with other LBK communities of the middle Danube region, the settlements of Úľany and Vlkas relied nearly exclusively on animal resources provided by the domesticated species present.

Bearing in mind the biological age of the few individuals for which age at death could be determined and the general trends known for LBK subsistence in the region, it seems most likely that meat production was the main husbandry goal at this site (see Payne, 1973; Bickle and Whittle, 2013: 13; Eckelmann *et al.*, 2020: 426–428). Additional research into milk production in the LBK areas does, however, also make it clear that extensive dairy production linked with meat production, specifically cattle meat, can most likely also be assumed (Gillis *et al.*, 2017: 7; Brychova, 2021: 97).

Considering the domesticated species found at Úľany and Vlkas, it is clear that with cattle, sheep and goat, pig and dog, the common LBK species spectrum is present. The clear dominance of cattle in the assemblages conforms with the general assessment that LBK communities overwhelmingly relied on cattle husbandry as their primary source of meat, milk and manure, supplemented by sheep and goats and only very small numbers of pigs (*e.g.* Lüning, 2000: 110–112; Knipper, 2011: 35; Bickle and Whittle, 2013: 13–16). The reasons for this species distribution have previously been attributed both to the social and cultural importance that cattle gained in the LBK and to the higher amount of meat they produce per individual compared with sheep and goat and the availability of secondary products, such as dairy, which cannot be obtained from pigs (*e.g.* Russell, 2011: 346–348; Gillis *et al.*, 2017: 7). Additionally, the greater suitability of cattle compared with sheep and goat to the more humid regional environments in central Europe as opposed to the more arid planes of eastern Europe, where the percentage of ovicaprids usually exceeds that of cattle, is often cited as a possible explanation (*e.g.* Bökönyi, 1984: 29–30; Bartosiewicz, 2005: 54).

While these finds are therefore as common in the regional expression of the LBK as is the lack of hunting evidence, they are unusual in comparison with those at the nearby site of Vrábľe. At Vrábľe, most identified specimens belonged to pigs, followed by ovicaprids and only then by cattle. While the difference in numbers between the taxa was not very big, the relatively equal presence of all three species at Vrábľe is considered remarkable, especially because the three distinct neighbourhoods revealed localised differences in species distribution, with a most likely culturally

induced preference for a different domesticated species in each neighbourhood (Eckelmann *et al.*, 2020: 427–428).

This scenario has become even more likely in the light of recent research on LBK settlements in the Aisne Valley, in northern France, where similar intra-settlement differences in species preference have been encountered at the site of Cuiry-lès-Chaudardes (Hachem, 2018: 11). Considering the data from Ůlany and Vlkaš, with both sites displaying the ‘classic’ LBK cattle-dominated faunal spectrum, it becomes increasingly reasonable to argue that the diverging intra-settlement species distribution is not a regional phenomenon of either south-western Slovakia or northern France but driven by other factors.

Previously, explanations for differences in LBK species distribution between sites included adaptations to local environments (see above), incorporation of Mesolithic traditions, such as an increased reliance on hunting (Döhle, 1993: 118; Lüning, 2000: 102, 115; Knipper, 2011: 36–38), or a chronological component, which postulates that cattle gained in cultural importance over time caused by an increase in social inequality (Russell, 2011: 342–343). All of these options have been refuted for Vráble, because incorporation of Mesolithic traditions, environment or chronology should have led to similar expressions within the three contemporary neighbourhoods. It has been concluded that the distributions at Vráble are most likely a result of cultural preference, possibly linked to a desire to visualise and affirm differences in group identity between the inhabitants of the three settlement units (Eckelmann *et al.*, 2020: 428). With recent studies from France also strongly suggesting a cultural component to species preference possibly linked to LBK lineages or clans, and with the additional species distribution data now available from Vlkaš and Ůlany, differences in group identity become an even more likely cause for the visible differences at Vráble (cf. Hachem, 2018: 11; Gomart, 2015: 235).

It is likely that in smaller settlements, such as Ůlany or Vlkaš, the local population may have shared a higher degree of cultural or familial homogeneity, whereas in larger or agglomerated settlements, such as Vráble, the population was more diverse or even comprised multiple lineages, as has been argued *e.g.* for Vaihingen an der Enz, one of the largest known LBK settlements, where the presence of five distinct ‘clans’, or lineages, has been proposed based on ceramic and artefact analysis (Bogaard *et al.*, 2011: 413). Therefore, in smaller settlements, with fewer lineages present, it may have been less important to broadcast and affirm a neighbourhood- or lineage-specific sense of shared or diverging identity – in this case with animals as one of the visible signs. Alternatively, a greater size of the settlement agglomeration may have allowed for a higher degree of separation of work than in smaller settlements, leading to some areas housing people specialised in the keeping of one of the livestock species, while another settlement part specialised in a different species. In this scenario, it is considered probable that cultural identification with specific species could emerge over time as a result.

Future work should investigate whether this spatial differentiation of species preferences is a systematic phenomenon in large or closely grouped LBK settlements or an incidental occurrence both in France and Slovakia. If it is encountered more often, it would be of interest to see if species preferences can be associated with *e.g.* ceramic types that have already been established as identifiers of specific LBK lineages (cf. Bogaard *et al.*, 2011: 413).

Processing of the faunal remains

Skinning, butchering, cooking and other practices aiming at the processing of animal carcasses are both culturally dependent and aimed towards specific production goals. An animal that was killed for its fur will be processed differently than one killed for its meat, and a society that is used to an abundance of animal protein will most

likely invest less time in bone grease extraction than a resource-stressed population. As a result, the presence of bone modifications, fragment sizes and skeletal element distributions are valuable evidence to reconstruct and understand ancient animal butchering, processing and disposal practices (e.g. Outram, 2001; Bartram, 1993; Marciniak, 2005a).

At Úľany and Vráble, the distribution of skeletal elements shows a potential underrepresentation of phalanges and other bones associated with the distal limbs, which could be an indication that the skinning of the animals was undertaken in another part of the settlement, as these bones are often removed from the long bones as part of the skinning process. Cut or scraping marks, which are likewise associated with skinning, are similarly mostly absent (e.g. Baxter and Hamilton-Dyer, 2003; Bartram, 1993). However, while skinning is a possibility, the overall number of elements is too small to make any definite statement. Similarly, the comparatively high percentage of skull fragments is most likely a result of taphonomy, rather than an indicator for the overabundance of the skeletal element.

In general, modifications on the bone specimens at Úľany and Vlkas are mostly consistent with those encountered at Vráble, though once again in much smaller quantities (Eckelmann *et al.*, 2020: 424, fig. 5.4.9). While few specimens bore chop and impact marks, the placement of these marks is comparable to the placement found at Vráble and, furthermore, is reminiscent of other studies which indicated they were usually a result of cutting the meat into more transportable portions of meat and to gain access the bone marrow (Lüning, 2000: 152; Marciniak, 2005a: 150; Oliver, 1993: 210). The relatively large size of the fragments and the bone portion representation is, however, not indicative of an intense exploitation of bone marrow, which is characterised by smaller fragments and small proportions of intact bone diaphysis (e.g. Marciniak, 2005a: 150; Binford, 1978: 154). There is also no evidence for bone fat extraction, which would be indicated only by even smaller bone shards, showing signs of fresh breakage (e.g. Church and Lyman, 2003: 1083; Janzen *et al.*, 2014: 522). This fits within the larger picture of LBK bone exploitation strategies, which have been shown to include moderate amounts of marrow exploitation but only very rarely bone grease exploitation (cf. Marciniak, 2005b: 260; Johnson, 2018: 68). It has to be concluded that the supply of food, and more specifically animal protein, at most settlements, including Úľany and Vlkas, was secure enough that time- and labour-intensive practices, such as bone fat extraction, did not need to be pursued (*ibid.*).

This assumption of a stable food supply is further supported by the presence of charred, partially charred and calcined bones. Specimens bearing these modifications can be indicative of roasting of meat, primary disposal of bones in fire pits, or even use of bones as fuel (e.g. Théry-Parisot, 2002: 1419; Binford, 1978: 153). However, bones make for poor fuel, and both the number of burnt specimens and finds at other LBK sites and the most likely relatively easy access to better fuel sources, e.g. wood (Schroedter, 2020: 460; Kreuz, 2008: 57), make it highly unlikely that bone was ever used for this purpose in this region and time frame. Similarly, considering the overall low numbers of burnt bones and the presence of most bones unburnt in the pits, disposal by fire is also an unlikely cause for these modifications. Roasting of meat, on the other hand, is a cooking technique that causes the partial burns some specimens show and has been detected at other LBK sites, including Vráble (Marciniak, 2005a: 150; Eckelmann *et al.*, 2020: 429). Because roasting is less effective in retaining nutrition and facilitating marrow extraction than cooking but may produce a more preferred taste, it would have been a choice of preference rather than necessity (Marciniak, 2005a: 150; Serjeantson, 2006: 124). Accordingly, it is considered a more valid reasoning for the presence of charred bones than waste disposal by burning. In general, this means that at Úľany and Vlkas, a moderate amount of bone marrow exploitation and meat roasting took place, as was the case at a lot of other LBK sites, e.g. in the Kuyavian Neolithic (Marciniak, 2005b: 156–157).

Instead of burning bones to discard them, the main means of depositing waste of all kinds are the longitudinal pits from which most of the bones were recovered (Bickle, 2013: 155; Květina and Hrnčíř, 2013: 327; Gomart *et al.*, 2015: 231). Previous studies have shown that waste was most likely not immediately disposed of in the longitudinal pits but, rather, collected at some point from temporary dumps in the interior and exterior of a house and then deposited in these pits (Allard *et al.*, 2013: 26). The pits themselves would have been left open for at least 4 to 5 years and used for bulk disposals repeatedly (Domboróczy, 2009: 105). At Úľany and Vlkaš, this scenario is corroborated zooarchaeologically by the presence of a small number of fragments bearing trampling marks and a larger number of specimens with dry breakage, including some showing both fresh and dry breaks. These traits indicate that waste was most likely primarily deposited on the surface areas of the settlement and thereby exposed to drying out and damage by humans and animals walking resulting in these marks (cf. Domboróczy, 2009: 90). At some point, the specimens were then deposited in the disposal pits and thereby removed from further damage by exposure, trampling or carnivore chewing.

Compared with the findings from Vráble, the relatively small number of elements with trampling marks and an increased percentage of larger fragments at Úľany and Vlkaš could indicate that the time between primary and final deposition may have been shorter than at Vráble, resulting in the specimens being subjected to damage by exposure for a shorter amount of time.

Summary and conclusions

The animal bone finds recovered from the LBK sites of Úľany and Vlkaš are indicative of a subsistence system that was focused on producing meat through exploitation of domestic animals, specifically cattle. This cattle-based economy conforms with the species spectrum associated with LBK husbandry systems that is the most widespread, as do the reconstructed cooking and waste disposal practices. No marked difference between the sites was visible, though this could be due to small sample sizes. The marked reliance on cattle is a stark contrast with the assemblage analysed from the nearby settlement of Vráble, where each neighbourhood showed a prevalence of one specific domestic species, which has been interpreted as a marker of social identity. Accordingly, it is proposed that in smaller settlements presentation of social identity may have been of lesser importance, due to greater social homogeneity.

However, to verify this thesis and to gain a better understanding of the similarities and differences in husbandry practices and overall human–animal relationships at Úľany and Vlkaš, much larger assemblages of faunal remains would be necessary than are currently available.

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3.4 Availability and choice of plant resources at the LBK and Želiezovce settlement sites Úľany nad Žitavou and Vlkas in the Žitava Valley, south-western Slovakia: Archaeobotanical and anthracological analyses

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Abstract

As the previous and more recent excavations by the German-Slovakian archaeological teams have revealed, the Žitava River basin was settled in different periods of prehistory, at least from the late 6th millennium BCE onwards. The recovery and analysis of plant macro-remains have thus far been employed at two neighbouring settlement sites in this region – the Neolithic Vráble-Velké Lehemby and the Bronze Age Vráble Fidvár. Now, two more settlement sites can be added to this list – the Neolithic Úľany nad Žitavou and the Neolithic–Bronze Age Vlkas. Both are situated south of the town of Vráble and in the immediate vicinity of two Danube tributaries, the Nitra and the Žitava rivers. Here we describe the procedure of extraction of macro-botanical remains in the field and laboratory and present the results of the analysis of carpological and wood charcoal remains. Einkorn and emmer, oak and ash are the most prominent species in the archaeobotanical and anthracological assemblages respectively. We compare the results with those from the Vráble sites, thus placing Úľany and Vlkas in a regional and diachronic context.

Keywords: South-western Slovakia, Žitava river basin, Neolithic, archaeobotany, anthracology.

Introduction

Excavations of settlement features at Úľany nad Žitavou and Vlkaš provided an opportunity to recover macro-plant remains and wood charcoal from two more prehistoric habitations in the Žitava River basin, in addition to the previously analysed large, tripartite LBK settlement Vráble-Velké Lehemby (Filipović *et al.*, 2020; Schroedter, 2020) and the enclosed Early Bronze Age settlement Vráble Fidvár (Schlütz and Bittmann, 2015), both located some 15 km north, near the town of Vráble. As will be shown below, the two sites yielded very small collections of generally badly preserved plant remains. This is unsurprising for the Neolithic cultural layers in the region, and a similar situation was encountered at LBK Vráble.

Nonetheless, the plant archives from both sites contain traces of several crops, crop weeds and trees. They allow insights, even if limited, into the range of plant species and materials produced or gathered by the prehistoric inhabitants, their plant-related activities, and the composition of the vegetation in the southernmost part of the Žitava River basin. In this chapter, we present the archaeobotanical (carpological) and anthracological (wood charcoal) analyses and results for Úľany and Vlkaš, compare the datasets with the evidence from Vráble, and place the observations in a broader regional context. We then discuss plant use strategies and the availability of plant resources in the sites' surroundings.

Methods and materials

The same sampling method developed for LBK Vráble was applied at Úľany and Vlkaš (Filipović *et al.*, 2020). From the archaeologically defined features and layers, up to 10 litres of sediment were taken where available. In the case of pits, archaeobotanical samples were collected from the middle and bottom sections of the matrix within the feature (the fill). Where the excavations proceeded within a square grid, the samples were taken from alternating squares and from arbitrary layers (ca. 10 cm-thick spits), excluding the layers near the modern ground surface.

The samples were processed manually using buckets, tap water, garden hose fitted with spray-gun and a 0.3 mm geological sieve (Fig. 3.4.1). Following flotation, the non-floating ('heavy') fraction was rapidly scanned for any obvious plant remains and



Figure 3.4.1. Bucket flotation at the dig house near the town of Nové Zámky, Slovakia (photos: G. Müller-Scheeßel).



Figure 3.4.2. Assorted carpological remains from Úl'any and Vlkas (scale-bar = 1 mm): 1 *Triticum monococcum*, grains from Úl'any; 2 *T. dicoccum*, grains from Vlkas; 3 *T. monococcum*, grain from Vlkas; 4a–c *T. monococcum*, two-grained, grains from Úl'any; 4d *T. monococcum*, two-grained, grain from Vlkas; 5 *Lens culinaris* from Vlkas; 6 *Stachys* sp. from Vlkas; 7 *Fallopia convolvulus* from Úl'any; 8 *Schoenoplectus tabernaemontani* from Vlkas; 9 *Solanum nigrum* from Úl'any; 10 *Galium spurium* from Vlkas; 11 *Chenopodium hybridum* from Vlkas; 12 *Chenopodium* sp. from Vlkas; 13 *T. monococcum*, spikelet fork from Vlkas; 14a *T. dicoccum* glume base from Úl'any; 14b–d *T. dicoccum* glume bases and spikelet fork from Vlkas (photo: Tanja Reiser, Dragana Filipović).

was subsequently discarded. The contents of the 0.3 mm sieve ('flots') were emptied into re-sealable plastic bags and, still damp, transported to the laboratory in Kiel, where they were rinsed and laid out indoors to dry. Dried samples were examined under a low-magnification stereo-microscope (10x–40x), facilitating the extraction of charred/archaeological plant parts (seed/fruit and wood); mollusc shells and bone fragments were also pulled. These materials were counted and molluscs and bone forwarded to the specialists.

The plant material was botanically determined (to the level of family, genus or species) based on the morphology (carpological remains) and anatomy (wood charcoal). Wood charcoal fragments larger than 2 mm were selected for the analysis in which the three fractures – radial, tangential and transversal – were observed under a reflected light microscope. In order to record as many different taxa as possible in spite of the small amounts of charcoal, we attempted to obtain 20 identifications per sample. Where samples contained fewer than 20 pieces of charcoal, all fragments were analysed. The non-wood and wood remains were counted. The 'indeterminate cereal grains' category includes fragments of cereal grains; the embryo and apical ends were counted and the greater score taken as the minimum number of whole grains (MNI), and recorded. All of the data, for each sample, were entered into the in-house archaeobotanical data repository (*Kiel ArboDat_central Europe*). A certain number of better-preserved cereal grains were submitted for radiocarbon dating and carbon and nitrogen stable isotope analysis (as noted in the Appendix). These and some other remains were photographed using a *Keyence* digital microscope (Fig. 3.4.2).

Results

A total of 13 sediment samples from Úľany, measuring altogether 100 litres, and 61 samples from Vlkaš, of the total volume of 627 litres, were processed. The samples from Vlkaš derived from layers dated to the Neolithic, Chalcolithic and Bronze Age, and from layers where archaeological materials from different periods were discovered, showing that post-depositional mixing took place in these locations. Further, a set of samples from Vlkaš came from what has in the post-excavation phase been reconstructed as the layer affected by modern-day agricultural activity; this layer is termed 'ploughing horizon' and also contained inclusions of different ages. We show the content of these samples in Appendix but we do not consider them here. The considered samples come from layers attributed to the Neolithic occupations, except for one sample from Vlkaš (sample 120182 from feature 106), which derived from a Bronze Age pit and contained only a fragment of charred elm (*Ulmus*) wood, and is not included in this report. Charring is the sole method of preservation noted in the plant assemblages. The overall number and frequency of both seed/fruit and wood charcoal remains are very low throughout. Therefore, there is little basis for quantitative assessments beyond looking at the item count and, in the case of charcoal, taxa frequency (*i.e.* percentage of samples in which a taxon occurs), and then using these parameters to gauge apparent differences in the representation of different taxonomic categories. Here we rely more on a qualitative approach, however, and focus on the botanical composition of the assemblages.

The assemblages show high level of fragmentation, probably as a result of a variety of post-depositional processes, such as the material being moved from its primary location of deposition. These may also explain the very small quantities of the remains per sample and overall at the sites. The character of the analysed deposits, which all are pit fills, and many of them of secondary or tertiary origin (see Chapter 3.1), confirms that the material was subject to relocation and re-deposition. That such disturbance occurred is also evident from the radiocarbon dates on plant materials.

Carpological remains

At Úľany, where a total of 148 grains or seeds were found, there were on average 0.5 remains present per litre of soil, though one of the samples (130027) stands out by containing little over 9 remains per litre. One of the samples (130104) did not contain any plant remains and one had only charcoal (130017). At Vlkas, 13 samples (20%) did not have any non-wood plant material, and the remaining 48 samples yielded ca. 270 plant remains; the average density is far below 1 (see the Appendix).

Table 3.4.1 gives counts of the different remains for the two sites. Einkorn and emmer grains dominate the datasets. Eroded grains of barley were documented, one at each site; the one at Vlkas was found in the ‘ploughing horizon’ and may not be prehistoric. Besides cereals, there are traces of legumes at Vlkas, indicating cultivation

	Úľany	Vlkas
No. of samples analysed	13	61
Volume of samples (l)	100	627
Taxon – plant part		
Crops		
<i>Triticum dicoccum</i> (emmer) – grain	21	51
<i>Triticum</i> cf. <i>dicoccum</i> – grain	15	6
<i>Triticum dicoccum</i> – glume base	1	4
<i>Triticum monococcum</i> (einkorn) – grain from one-grained spikelet	32	18
<i>T. monococcum</i> – grain from two-grained spikelet	11	
<i>Triticum</i> cf. <i>monococcum</i> – grain	6	3
<i>Triticum monococcum</i> – glume base		
<i>T. dicoccum</i> or <i>T. monococcum</i> – grain	23	27
<i>Triticum</i> sp., hulled – grain	18	
<i>Triticum</i> sp. – grain	2	21
cf. <i>Hordeum vulgare</i> (barley) – grain	1	1
indeterminate cereal grain – MNI from fragments	11	106
<i>Lens culinaris</i> (lentil) – seed		68
large pulse seed		7
Wild plants (seeds, unless otherwise stated)		
<i>Chenopodium hybridum</i>		
<i>Chenopodium</i> sp.		1
<i>Fallopia convolvulus</i>	1	1
<i>Galium spurium</i>		1
<i>Schoenoplectus tabernaemontani</i>		1
<i>Solanum nigrum</i>	3	
<i>Stachys</i> sp.		
Poaceae	1	1
indeterminate seed/fruit	2	3
fruit flesh fragment		1
‘food’/nutmeat/fruit flesh – indeterminate fragments		2
All items	148	274

Table 3.4.1. Taxa identified based on the carpological remains from Úľany and Vlkas.

of this other major group of crops. The assemblages also contain seeds of potential arable weeds, occurring in very small numbers. Softstem bulrush (*Schoenoplectus tabernaemontani*) was documented at Vlkaš and is of some interest as it grows in wet places; it could point to the use of riparian herbaceous vegetation (sedges, rushes, reeds), perhaps as raw material for crafts (e.g. basketry) or construction, and maybe also as fodder. Black bindweed (*Fallopia convolvulus*) and false cleavers (*Galium spurium*), both annuals, were typical weeds of arable land in the Neolithic in central Europe (e.g. Kreuz, 1990; Bogaard, 2004).

Emmer appears more common than einkorn at Vlkaš; the situation is opposite at Úľany. From both sites however, wheat grains were retrieved that could not be identified to either einkorn or emmer, and there are also fragmented cereal grains that remained unspecified. It is thus difficult to speak of possible differences in the representation and, based on that, importance of one or the other wheat species, but it is clear that both were the staple crops. The few finds of chaff (glume bases) signal keeping of non-fully-cleaned harvest in the settlements, perhaps in order to make use of both products and by-products of cereal processing.

Two forms of einkorn grains were registered at both sites: those from single-grained and from two-grained spikelets (Fig. 3.4.2). The former are larger, rounded in ventral view and symmetrical in lateral view. The latter appear as if the grain from single-grained spikelet was split in two longitudinally – they are flat in ventral view and smaller than the one-grained einkorn grains; the ridge on the dorsal side is somewhat lower and ‘pushed’ to the side, i.e. the grains appear lop-sided in dorsal view. Kreuz and Boenke (2002) describe and show the finds of two-grained einkorn from a number of LBK sites in central Germany (the state of Hesse) dated to the end of the 6th millennium BCE or later. By or at this time, this einkorn variety was present also at Neolithic sites in Hungary (Kreuz *et al.*, 2020) and further south in the Balkans (see overview in Kreuz and Boenke, 2002). In Slovakia, grains of two-grained einkorn (along with other wheat types) were discovered in a large deposit of over 34,000 grains extracted from an oven at the site of Bajč-Medzi kanálmi (Želiezovce group), located some 20 km south of Úľany, on a sand dune rising between old meanders of the Žitava river. That deposit was composed mostly of hulled wheat grains, mainly those coming from one- and two-grained einkorn (Hajnalová, 2007: 301). At Úľany, two-grained einkorn grains derived from the deposits from which some other grains were dated to the last centuries of the 6th millennium BCE (Sample 130027: Poz-109590, one-grained einkorn grain, 2σ 5359–5080 cal BCE; Sample 130187: Poz-109593, emmer grain, 2σ 5304–5066 cal BCE; see Chapter 4.1). It is of interest that Úľany sits on a small elevation in an otherwise flat area at the confluence of the Nitra and the Žitava—an environment perhaps similar to that of Bajč-Medzi kanálmi. Kreuz and Boenke (2002) noted that soil moisture might be a factor in the occurrence of two-grained einkorn (see below).

Wood charcoal

The charred wood remains give an insight, albeit fragmentary, into the structure of wooded landscape in the lower course of the Žitava Valley in prehistory. Table 3.4.2 lists the taxa identified and gives the quantities of the remains per site; the sample-by-sample data are available in the Appendix. All samples from the two sites were analysed, providing a total of 409 fragments. Figures 3.4.3–3.4.4 compare the relative quantities and frequencies of the remains per taxon and site. Despite being modest, the wood charcoal records offer first information towards the reconstruction of woodland exploited by the Neolithic inhabitants of Úľany and Vlkaš, and their firewood acquisition strategies.

	Úľany	Vlkas
No. of samples analysed	13	61
Volume of samples (l)	100	627
Taxon		
<i>Betula</i> sp. (birch)		3
<i>Corylus</i> sp. (hazel)		13
<i>Fraxinus</i> sp. (ash)	1	20
cf. <i>Hedera</i> sp. (cf. ivy)		
Maloideae (apple subfamily)	1	7
<i>Pinus</i> sp. (pine)	1	
<i>Prunus</i> sp. (plum)		1
<i>Quercus</i> sp. (oak)	45	263
<i>Ulmus</i> sp. (elm)	5	7
Indeterminate	1	40
All fragments	54	355

Table 3.4.2. Taxa recognised in the wood charcoal assemblages from Úľany and Vlkas.

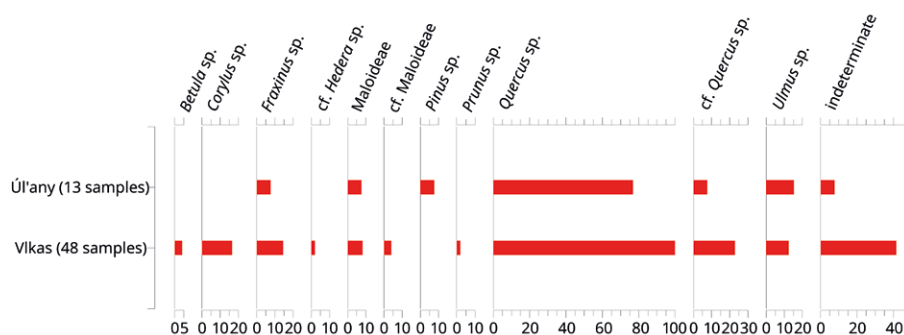


Figure 3.4.3. Proportional representation (% of total remains per site) of taxa in the wood charcoal assemblages from Úľany and Vlkas.

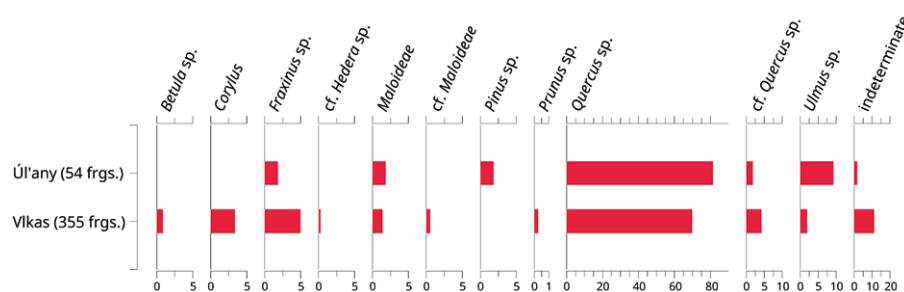


Figure 3.4.4. Frequency (% of samples per site) of taxa in the wood charcoal assemblages from Úľany and Vlkas.

Ten samples from Úľany contained 54 identifiable charcoal fragments and 48 samples from Vlkas offered 355 suitable charcoal specimens. In both cases, the size of fragments is very small (1–4 mm edge length) and this, along with the poor state of the material, has precluded identification of some of the pieces.

At Úľany oak is the dominant component of the assemblage (Table 3.4.2). Other taxa occur only as single finds, and in single samples. Still, their presence demonstrates that resources in addition to oak were exploited, such as ash, pine, elm and an apple-type tree(s).

At Vlkas, seven taxa have been documented in the Neolithic deposits, from which 315 fragments out of 355 could be taxonomically determined (Table 3.4.2). Similar to Úľany, the quantity of oak wood fragments is much higher than that of other taxa in the Neolithic assemblage.

Discussion

Availability and choice of plant resources at Neolithic Úľany and Vlkaš

Just like at Neolithic Vráble, plant assemblages from Neolithic layers at Úľany and Vlkaš are composed predominantly of the remains of einkorn, emmer, oak and ash (Table 3.4.3; Filipović *et al.*, 2020; Schroedter, 2020). No doubt were these resources preferred in the food and fuel economy of these communities. They also likely provided raw materials for crafts and construction, and fodder and bedding for the livestock. Combined, the charcoal evidence from these sites shows the presence of mixed oak forests of variable degree of openness, where oak may indicate relatively closed canopy, but light-demanding taxa such as birch, hazel, Maloideae and *Prunus* point to the parallel existence of less dense woodland and/or ample access to edges of woods and forests. The inhabitants used wood from all these different sources, while valued some also for their fruit, for instance hazel and Cornelian cherry and probably Maloideae. That the remains of Maloideae, a Rosaceae subfamily that includes apple (*Malus* sp.), pear (*Pyrus* sp.) and hawthorn (*Crataegus* sp.), occur in such small charcoal assemblages as these suggests a regular exploitation of these trees in the study region. This complies with the Europe-wide pattern; Neolithic anthracological and archaeobotanical records from the area stretching from northern Europe to the southern Balkans frequently offer evidence of Maloideae (e.g. Kreuz, 1990; Schroedter *et al.*, 2012; Jansen and Nelle, 2014; Valamoti, 2015; Marinova and Ntinou, 2018; Kirleis, 2019). Studies of other Neolithic/LBK settlements in central Europe also concluded that the woodland in the environs of these sites was relatively open and composed of a set of taxa similar to that registered in the Žitava Valley.

Based on the growing requirements or preferences of the tree taxa identified at Úľany and Vlkaš, different ecological niches were visited to collect wood for fire and timber – a situation previously observed at Vráble. Besides the oak-dominated woodland and its rich understorey, which would have characterised dry areas in the sites' surroundings, the presence of elm and ash reflects the use of resources found in moist areas, such as the riparian zone along the river. At Vráble, further taxa that would have occupied the river banks included alder and poplar. In addition to wood and edible fruit (e.g. Chinese lantern (*Physalis alkekengi*)), the riverine zone may have offered pasture, pannage and fodder for the animals. The location of Vlkaš in the upland zone, on a river terrace some distance away from the Žitava course (Chapters 2.3, 3.1, 3.2), perhaps suggest a (greater) orientation of its dwellers towards resources available in dry areas. In contrast, the occupants of Úľany may have focused on exploitation of food and raw materials found in the wet parts of the (shared) landscape. Our data are still too limited to allow investigation in this direction.

The different identified vegetation formations reflect what likely was a diverse soil cover, as expected in a landscape with dynamic hydrology, such as the valleys of the Žitava and Nitra rivers and other Danube tributaries of the western Carpathians. Here, alluvial loamy and clayey soils extend along the meandering rivers and are home to riverine forests. In the drier zones farther from the rivers, the thick layer of loess is sporadically covered by chernozem, brown soils, gley and pseudogley, whose distribution shapes the extent and composition of woodland and grassland (Nowaczinski *et al.*, 2015; Fehér, 2018; Vojtek and Vojteková, 2019; <https://geo.enviroportal.sk/atlassr/> [accessed: 2022/07/29]). Today, however, much of the area is open field landscape, with grain and root crops grown in the plains and vineyards in the foothills (Fehér, 2018: 5, 9; Filipović pers. ob., 2017). In agricultural sense, the

Taxon	Vráble		Úľany		Vlkas	
	wood	seed/fruit	wood	seed/fruit	wood	seed/fruit
<i>Quercus</i> sp. (oak)	xxx		xx		xxx	
<i>Fraxinus</i> sp. (ash)	xxx		x		xx	
<i>Betula</i> sp. (birch)					x	
<i>Corylus</i> sp. (hazel)	x	xx			x	
<i>Fagus</i> sp. (beech)	x					
<i>Prunus</i> sp. (plum [wild])	x				x	
<i>Ostrya</i> sp./ <i>Carpinus</i> sp. (hop-/hornbeam)	x					
<i>Cornus</i> sp.	x					
<i>Cornus mas</i> (Cornelian cherry)		x				
<i>Alnus</i> sp. (alder)	x					
Maloideae (apple subfamily)	x		x		x	
<i>Pinus</i> sp. (pine)	x		x			
<i>Populus</i> sp. (poplar)	x					
<i>Ulmus</i> sp. (elm)	x		x		x	
<i>Triticum monococcum</i> (einkorn)		xxx		xx		xx
<i>T. dicoccum</i> (emmer)		xxx		xx		xx
<i>Hordeum vulgare</i> (barley)		x				
<i>Lens culinaris</i> (lentil)		xx				
<i>Pisum sativum</i> (pea)		x				
<i>Linum usitatissimum</i> (flax)		x				
<i>Papaver somniferum</i> (opium poppy)		x				
<i>Physalis alkekengi</i> (Chinese lantern)		x				
<i>Fragaria vesca</i> (wild strawberry)		x				

Table 3.4.3. Combined records of the plants grown and gathered at Neolithic Vráble (after Filipović et al., 2020; Schroedter, 2020), Úľany and Vlkas as rough quantities: xxx = 100+; xx = 10+; x = <10.

region is classified as medium to very fertile. It must have had similar qualities in the Neolithic, suitable for the cultivation of cereal and pulse crops documented at Vráble, Úľany and Vlkas.

The finds of two-grained einkorn at Úľany and Vlkas may tentatively suggest that, here, the crop growing environment was quite favourable, perhaps particularly at Úľany, where more of these finds were encountered than at Vlkas. According to the insights provided in Kreuz and Boenke drawn from some modern growing experiments, two-grained einkorn grains tend to develop in better ecological conditions (e.g. sufficient moisture) or when more time for growing is available (i.e. in autumn sowing) (Kreuz and Boenke, 2002: 238). There can even be cases of single plants containing both types of grains. Another reason behind the presence of the two types of grains could simply be their origin from two different varieties of einkorn.

Acknowledging the limited size of the wood charcoal records, the impression is that, despite the apparently wide spectrum of woodland resources available in the Žitava Valley, the primary choice of wood of the Neolithic inhabitants of Úľany and Vlkas were oak and ash. Given the archaeological context of the finds – long-pits, presumably receiving residues from various uses of plants – and absence of

clear remains of construction wood, it is impossible to determine whether oak and ash wood served exclusively as fuel, or also as timber. Either way, they represented the staples of non-food plant economy, parallel to einkorn and emmer in the food economy. It would be worth to explore what, if any, kind of management of oak and ash stands may have been employed to ensure the supply of wood. Unfortunately, the size and preservation of wood charcoal from these sites do not permit this.

Conclusions

Remains of seed/fruit and wood charcoal were retrieved from Úľany and Vlkaš, two of the recently investigated prehistoric sites in the Žitava River basin, south-western Slovakia. The Neolithic deposits yielded mostly the remains of einkorn, emmer, oak and ash, suggesting that these two cereal crops and the two woodland species were regularly produced/acquired and used within the settlements. The plant food and fuel economies were here based on the same set of species as at another site in the Žitava Valley, the LBK Vráble. Furthermore, as a previous overview for Slovakia has shown, einkorn and emmer were the major Neolithic cultivars in the wider region. Future investigations within this project, yielding further archaeobotanical and anthracological assemblages, will undoubtedly enable us to address the questions arising from this initial work and will allow us to compare our observations with those for other parts of the Carpathian Basin.

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Appendix

Site		Úľany	Úľany	Úľany	Úľany	Úľany	
Archaeological period		Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	
Context							
Feature number		28	30	31	34	32	
Sample number		130017	130018	130020	130027	130035	
Sample volume (l)		8	6	7	10	11	
Total carpological remains		0	1	11	96	6	
Total charcoal remains		1	3	1	9	10	
Number of seed/fruit per litre (density)		0.0	0.2	1.6	9.6	0.5	
Taxon	Plant part						
CROPS							
<i>Triticum dicocum</i>	grain			2	12	2	
<i>Triticum cf. dicocum</i>	grain				12		
<i>Triticum dicocum</i>	glume base						
<i>Triticum monococum</i>	grain		1	2	22	2	
<i>Triticum cf. monococum</i>	grain				4		
<i>Triticum monococum</i> , 2-grained	grain				10		
<i>Triticum monococum</i>	glume base						
<i>Triticum monococum/dicocum</i>	grain			4	7	2	
<i>Triticum</i> sp., hulled	grain				18		
<i>Triticum</i> sp.	grain				1		
cf. <i>Hordeum vulgare</i>	grain				1		
Cerealia indeterminata	grain			2	5		
<i>Lens culinaris</i>	seed						
cf. <i>Lens culinaris</i>	seed						
Leguminosae sativae	seed						
cf. Leguminosae sativae	seed						
WILD PLANTS							
<i>Chenopodium hybridum</i>	seed						
<i>Chenopodium</i> sp.	seed						
<i>Corylus avellana</i>	nutshell fragment						
<i>Fallopia convolvulus</i>	seed				1		
<i>Galium spurium</i>	seed						
<i>Schoenoplectus tabernaemontani</i>	seed						
<i>Solanum luteum/nigrum</i>	seed				3		
<i>Stachys</i> sp.	seed						
Fabaceae	seed						
cf. Fabaceae	seed						
Poaceae	fruit						

	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic
	38	42	44	43	45	63	80	48
	130057	130070	130104	130106	130111	130187	130212	130280
	7	11	4	5	12	9	4	6
	4	11	0	2	5	5	1	6
	4	2	0	0	2	11	0	11
	0.6	1.0	0.0	0.4	0.4	0.6	0.3	1.0
	1	1		1		2		
		2						1
					1			
	2	1			1			1
		2						
						1		
		3			3	1		3
						1		
	1			1			1	1
		1						

Details of the archaeobotanical samples from Úl'any nad Žitavou and Vlkaš.

Site		Úľany	Úľany	Úľany	Úľany	Úľany	
Archaeological period		Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	
Context							
Feature number		28	30	31	34	32	
Sample number		130017	130018	130020	130027	130035	
Sample volume (l)		8	6	7	10	11	
Total carpological remains		0	1	11	96	6	
Total charcoal remains		1	3	1	9	10	
Number of seed/fruit per litre (density)		0.0	0.2	1.6	9.6	0.5	
Taxon	Plant part						
fruit flesh	fragment						
nutshell/fruit stone	fragment						
INDETERMINATE							
indeterminate seed/fruit				1			
"food"/nutmeat/fruit flesh	amorphous piece						
WOOD CHARCOAL							
<i>Betula</i> sp.	fragment						
<i>Corylus</i> sp.	fragment						
cf. <i>Corylus</i> sp.	fragment						
<i>Fraxinus</i> sp.	fragment				1		
cf. <i>Hedera</i> sp.	fragment						
Maloideae	fragment					1	
cf. Maloideae	fragment						
<i>Pinus</i> sp.	fragment						
<i>Prunus</i> sp.	fragment						
<i>Quercus</i> sp.	fragment	1	3	1	8	9	
cf. <i>Quercus</i> sp.	fragment						
<i>Ulmus</i> sp.	fragment						
indeterminate	fragment						
*removed for radiocarbon dating or stable isotope analysis			einkorn grain		einkorn and emmer grains		

Appendix 1 continued.

	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic	Úl'any Neolithic
	38	42	44	43	45	63	80	48
	130057	130070	130104	130106	130111	130187	130212	130280
	7	11	4	5	12	9	4	6
	4	11	0	2	5	5	1	6
	4	2	0	0	2	11	0	11
	0.6	1.0	0.0	0.4	0.4	0.6	0.3	1.0
		1						
								1
	3	2			1	11		5
	1							
					1			4
								1
		emmer grain				emmer grain		

Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas
Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic
longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, 2ndary fill	longpit, 2ndary fill	pit, 2ndary fill	longpit, fill	longpit, 2ndary fill	longpit, 2ndary fill
134	147	148	26	27	24	22	25	40	86	109	110	
120245	120260	120263	150104	150106	150108	150111	150113	150144	150337	150377	150415	
7	6	11	11	12	12	8	15	11	5	10	11	
1	1	1	0	4	3	4	8	29	0	6	11	
7	4	5	0	10	5	7	5	10	0	10	11	
0.1	0.2	0.1	0.0	0.3	0.3	0.5	0.5	2.6	0.0	0.6	1.0	
							1	3		1	4	
						1						
								2				
								3				
							1					
							1			1		
								3				
1	1	1		4	3	2	3	15		4	4	
							1					
								1				
						1					1	
							1					

Site		Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	
Archaeological period		Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	
Context		longpit, 2ndary fill	longpit, 2ndary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	longpit, primary fill	
Feature number		4	12	47	46	58	59	71	121	
Sample number		120029	120057	120129	120131	120142	120147	120164	120205	
Sample volume (l)		8	20	15	10	11	9	9	10	
Total carpological remains		2	2	1	0	1	5	3	35	
Total charcoal remains		3	10	3	2	0	3	0	0	
Number of seed/fruit per litre (density)		0.3	0.1	0.1	0.0	0.1	0.6	0.3	3.5	
Taxon	Plant part									
<i>Stachys</i> sp.	seed									
Fabaceae	seed									
cf. Fabaceae	seed									
Poaceae	fruit									
fruit flesh	fragment									
nutshell/fruit stone	fragment									
INDETERMINATE										
indeterminate seed/fruit						1				
"food"/nutmeat/fruit flesh	amorphous piece						1			
WOOD CHARCOAL										
<i>Betula</i> sp.	fragment									
<i>Corylus</i> sp.	fragment		1		1					
cf. <i>Corylus</i> sp.	fragment									
<i>Fraxinus</i> sp.	fragment									
cf. <i>Hedera</i> sp.	fragment									
Maloideae	fragment									
cf. Maloideae	fragment									
<i>Pinus</i> sp.	fragment									
<i>Prunus</i> sp.	fragment									
<i>Quercus</i> sp.	fragment	3	9	3	1		2			
cf. <i>Quercus</i> sp.	fragment									
<i>Ulmus</i> sp.	fragment									
indeterminate	fragment						1			
*removed for radiocarbon dating or stable isotope analysis				einkorn/ emmer grain					einkorn and emmer grains	

Site		Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	
Archaeological period		Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	
Context		longpit, 2ndary fill	longpit, primary fill	longpit, primary fill	longpit, 2ndary fill	longpit, 2ndary fill	longpit, primary fill	longpit, 2ndary fill	longpit, primary fill	
Feature number		136	102	102	137	139	140	161	191	
Sample number		150432	150434	150444	150446	150452	150454	150491	150493	
Sample volume (l)		10	9	6	7	10	7	15	9	
Total carpological remains		4	0	3	0	5	3	2	1	
Total charcoal remains		8	12	0	0	5	2	10	8	
Number of seed/fruit per litre (density)		0.4	0.0	0.5	0.0	0.5	0.4	0.1	0.1	
Taxon	Plant part									
CROPS										
<i>Triticum dicoccum</i>	grain			3						
<i>Triticum</i> cf. <i>dicoccum</i>	grain									
<i>Triticum dicoccum</i>	glume base									
<i>Triticum monococcum</i>	grain						1			
<i>Triticum</i> cf. <i>monococcum</i>	grain	1								
<i>Triticum monococcum</i> , 2-grained	grain									
<i>Triticum monococcum</i>	glume base									
<i>Triticum monococcum/dicoccum</i>	grain									
<i>Triticum</i> sp., hulled	grain									
<i>Triticum</i> sp.	grain					1				
cf. <i>Hordeum vulgare</i>	grain									
Cerealia indeterminata	grain	3				3	2	1	1	
<i>Lens culinaris</i>	seed									
cf. <i>Lens culinaris</i>	seed							1		
Leguminosae sativae	seed					1				
cf. Leguminosae sativae	seed									
WILD PLANTS										
<i>Chenopodium hybridum</i>	seed									
<i>Chenopodium</i> sp.	seed									
<i>Corylus avellana</i>	nutshell fragment									
<i>Fallopia convolvulus</i>	seed									
<i>Galium spurium</i>	seed									
<i>Schoenoplectus tabernaemontani</i>	seed									
<i>Solanum luteum/nigrum</i>	seed									
<i>Stachys</i> sp.	seed									
Fabaceae	seed									
cf. Fabaceae	seed									
Poaceae	fruit									

Appendix 1 continued.

Site		Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	
Archaeological period		Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	Neolithic	
Context		longpit, 2ndary fill	longpit, primary fill	longpit, primary fill	longpit, 2ndary fill	longpit, 2ndary fill	longpit, primary fill	longpit, 2ndary fill	longpit, primary fill	
Feature number		136	102	102	137	139	140	161	191	
Sample number		150432	150434	150444	150446	150452	150454	150491	150493	
Sample volume (l)		10	9	6	7	10	7	15	9	
Total carpological remains		4	0	3	0	5	3	2	1	
Total charcoal remains		8	12	0	0	5	2	10	8	
Number of seed/fruit per litre (density)		0.4	0.0	0.5	0.0	0.5	0.4	0.1	0.1	
Taxon	Plant part									
fruit flesh	fragment									
nutshell/fruit stone	fragment									
INDETERMINATE										
indeterminate seed/fruit										
"food"/nutmeat/fruit flesh	amorphous piece									
WOOD CHARCOAL										
<i>Betula</i> sp.	fragment							2		
<i>Corylus</i> sp.	fragment									
cf. <i>Corylus</i> sp.	fragment									
<i>Fraxinus</i> sp.	fragment									
cf. <i>Hedera</i> sp.	fragment									
Maloideae	fragment									
cf. Maloideae	fragment									
<i>Pinus</i> sp.	fragment									
<i>Prunus</i> sp.	fragment									
<i>Quercus</i> sp.	fragment	5	8			4	2	7	5	
cf. <i>Quercus</i> sp.	fragment	2	2							
<i>Ulmus</i> sp.	fragment								1	
indeterminate	fragment	1	2			1		1	2	
*removed for radiocarbon dating or stable isotope analysis		einkorn grain		emmer grains		large legume seed	einkorn grain			

Appendix 1 continued.

Site		Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	
Archaeological period		Chalco-lithic	Chalco-lithic	Br. Age	Br. Age	Br. Age	Br. Age	Br. Age	Br. Age	Br. Age	
Context		pit, prima-ry fill	pit, prima-ry fill	layer	layer	layer	layer	layer	layer	layer	
Feature number		42	44	5	6	7	8	10	51	106	
Sample number		150178	150311	120034	120035	120037	120048	120054	120134	120182	
Sample volume (l)		12	7	10	9	8	13	8	9	10	
Total carpological remains		0	2	1	4	0	14	16	5	0	
Total charcoal remains		2	2	3	1	0	5	8	4	2	
Number of seed/fruit per litre (density)		0.0	0.3	0.1	0.4	0.0	1.1	2.0	0.6	0.0	
Taxon	Plant part										
CROPS											
<i>Triticum dicoccum</i>	grain				3		2	8	1		
<i>Triticum cf. dicoccum</i>	grain				1						
<i>Triticum dicoccum</i>	glume base										
<i>Triticum monococcum</i>	grain						1		1		
<i>Triticum cf. monococcum</i>	grain						1				
<i>Triticum monococcum</i> , 2-grained	grain						1				
<i>Triticum monococcum</i>	glume base										
<i>Triticum monococcum/dicoccum</i>	grain						3	5			
<i>Triticum</i> sp., hulled	grain										
<i>Triticum</i> sp.	grain		1						1		
cf. <i>Hordeum vulgare</i>	grain										
Cerealia indeterminata	grain		1				4	3	2		
<i>Lens culinaris</i>	seed										
cf. <i>Lens culinaris</i>	seed										
Leguminosae sativae	seed										
cf. Leguminosae sativae	seed										
WILD PLANTS											
<i>Chenopodium hybridum</i>	seed						1				
<i>Chenopodium</i> sp.	seed										
<i>Corylus avellana</i>	nutshell fragment										
<i>Fallopia convolvulus</i>	seed										
<i>Galium spurium</i>	seed										
<i>Schoenoplectus tabernaemontani</i>	seed										
<i>Solanum luteum/nigrum</i>	seed										
<i>Stachys</i> sp.	seed						1				
Fabaceae	seed										
cf. Fabaceae	seed										
Poaceae	fruit										

Site		Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	Vlkas	
Archaeological period		Chalco-lithic	Chalco-lithic	Br. Age	Br. Age	Br. Age	Br. Age	Br. Age	Br. Age	Br. Age	
Context		pit, prima-ry fill	pit, prima-ry fill	layer	layer	layer	layer	layer	layer	layer	
Feature number		42	44	5	6	7	8	10	51	106	
Sample number		150178	150311	120034	120035	120037	120048	120054	120134	120182	
Sample volume (l)		12	7	10	9	8	13	8	9	10	
Total carpological remains		0	2	1	4	0	14	16	5	0	
Total charcoal remains		2	2	3	1	0	5	8	4	2	
Number of seed/fruit per litre (density)		0.0	0.3	0.1	0.4	0.0	1.1	2.0	0.6	0.0	
Taxon	Plant part										
fruit flesh	fragment										
nutshell/fruit stone	fragment										
INDETERMINATE											
indeterminate seed/fruit				1							
"food"/nutmeat/fruit flesh	amorphous piece										
WOOD CHARCOAL											
<i>Betula</i> sp.	fragment										
<i>Corylus</i> sp.	fragment		1	1				1			
cf. <i>Corylus</i> sp.	fragment										
<i>Fraxinus</i> sp.	fragment										
cf. <i>Hedera</i> sp.	fragment										
Maloideae	fragment										
cf. Maloideae	fragment										
<i>Pinus</i> sp.	fragment										
<i>Prunus</i> sp.	fragment										
<i>Quercus</i> sp.	fragment	2	1	1	1		5	7	1		
cf. <i>Quercus</i> sp.	fragment								2		
<i>Ulmus</i> sp.	fragment								1	1	
indeterminate	fragment			1						1	
*removed for radiocarbon dating or stable isotope analysis			wheat grain					emmer grain			

Appendix 1 continued.

3.5 Integrated plant and faunal stable isotopic analysis from the archaeozoological and archaeobotanical assemblages of the LBK and Želiezovce settlement sites Úľany nad Žitavou and Vlkas in the Žitava Valley, south-western Slovakia

Rosalind E. Gillis, Rebekka Eckelmann, Dragana Filipović

Abstract

Samples of animal and plant remains from the Neolithic and Bronze Age contexts at Úľany nad Žitavou and Vlkas were selected for a pilot stable isotope study. The initial results from both cereal grains and animal bones provide a glimpse of early animal husbandry and agricultural practices. Sheep and cattle provided manure for cereal cultivation while grazing on plant stubble at the end of harvest, a scenario that has previously been proposed for the nearby site of Vráble ‘Veľké Lehemby’. Einkorn appears to have been grown under an intensive manuring scheme. Stable isotope analysis of cattle and sheep/goat bone collagen from the Vlkas Bronze Age contexts suggests that manuring of cereals intensified overtime. Future analysis is recommended to provide a more nuanced picture of changes in plant and animal husbandry practices at the sites and within the local region.

Keywords: Stable carbon and nitrogen isotopes, domesticated and wild fauna, emmer and einkorn cereal grains, animal husbandry, agricultural practices

Introduction

The excavation and recovery of a small but important assemblage of animal and plant remains at Úľany nad Žitavou ‘Dolné diely’ (hereinafter Úľany) and Vlkas ‘Do hľuského chotára’ (hereinafter Vlkas) provide an opportunity to carry out a pilot stable isotope study. Stable carbon and nitrogen isotope analysis of archaeological

remains of plants and animals can provide an important insight into past human diet and activities, such as animal husbandry and agricultural practices. Carbon isotopes of plants and herbivores reflect the overall growing conditions of plants, for example humidity and light levels (Tieszen, 1991), as well as soil salinity (Guy *et al.*, 1980; Britton *et al.*, 2008). There is on average 5.1‰ fractionation between plants and primary consumers, such as herbivores, and there can also be an approximately 1‰ trophic increase between herbivores and omnivores/carnivores (DeNiro and Epstein, 1978). Nitrogen ($\delta^{15}\text{N}$) isotopes of plants provide an indication of soil conditions, such as humidity, as well as the levels of key nutrients, such as nitrates (Amundson *et al.*, 2003; Fraser *et al.*, 2011). The incorporation of manure into the soil N cycle can lead plant $\delta^{15}\text{N}$ values to increase by 4–9‰. This is because manure is enriched with ^{15}N due to the loss of ^{14}N by the animal during digestion and excretion (Robbins *et al.*, 2005). Analysis of cereal grains from experimental farms has provided ranges of $\delta^{15}\text{N}$ values for different levels of manuring schemes: without manure (c. 2.5‰); with low quantities of manure (2.5–6‰); and with a long, moderate to intensive manuring regime (>6‰) (Fraser *et al.*, 2011; Bogaard *et al.*, 2013). One way of ensuring fields are manured is allowing animals to graze on fields after the harvest, which also provides animals with a fodder supply, thereby reducing overgrazing on surrounding natural pastures. Stable isotopic analyses of animal remains can be used to reconstruct past pasturing and foddering practices (Balasse *et al.*, 2013a; Balasse *et al.*, 2013b; Balasse *et al.*, 2014; Makarewicz, 2015; Gillis and Zanon, 2021), as well as animal management, such as weaning and dairy husbandry (Gillis *et al.*, 2013).

Linearbandkeramik (LBK) animal and, to a lesser extent, plant remains have been subject to stable isotope analyses¹. These analyses have shown that species-specific management was practised, with sheep/goats grazing in open areas close to the settlements (Gillis *et al.*, 2020b; Gillis and Zanon, 2021), while cattle were being foddered on forest resources in certain regions, such as Alsace and the Paris Basin (Gillis and Zanon, 2021), probably during winter (Gillis *et al.*, in press). Results of sequential oxygen isotope sampling of cattle teeth have shown that a proportion of LBK cattle were born outside of the main birthing season (Balasse *et al.*, 2021). This would have increased the availability of milk outside the main lactation period. The body condition of cows may have been improved due to winter foddering, ensuring the survival of calves born out-of-season.

Where both plants and animals have been analysed, the overall picture emerges that during the Neolithic cereals were grown on plots under low quantities of manure (Fraser *et al.*, 2013) or under long-term moderate or intensive manuring regimes (Bogaard *et al.*, 2013; Gillis *et al.*, 2020b). The latter study, of stable isotopic results of fauna and cereal remains from Vráble ‘Veľké Lehemby’ (Slovakia), provided the first evidence in this region of integrated animal and plant husbandry, with animals, in particular sheep/goats, penned on fields to provide manure to fields after the harvest (Gillis *et al.*, 2020b).

Here we present an initial pilot study of the animal and plant remains from the Early Neolithic and Bronze Age contexts from Ůlany and Vlka. The findings are compared with previous results from the neighbouring site of Vráble.

1 Oelze *et al.*, 2011; Fraser *et al.*, 2013; Whittle and Bickle, 2013; Bogaard *et al.*, 2016; Styring *et al.*, 2017; Kendall *et al.*, 2019; Gillis *et al.*, 2020a; Gillis *et al.*, 2020b; Gillis and Makarewicz, 2020; Kamjan *et al.*, 2020; Balasse *et al.*, 2021; Gillis and Zanon, 2021; Gillis *et al.*, in press.

Material and Methods

Material

The faunal remains were recovered in 2018 during archaeological excavations in the vicinity of three distinct LBK longhouses at Úľany and a further seven at Vlkaš. These excavations focused on the elongated pits running lateral and parallel to the long house walls, which are a key feature of the LBK, sometimes referred to as household pits (Johnson *et al.*, 2022) or lateral long pits. The bone material was selected for its visual appearance, with low values for indicators of weathering or other taphonomic marks. Due to the small bone assemblage, we did not restrict the sampling to specific bones, nor did we control for minimum number of individuals; instead, we selected samples based on their preservation and taxonomic identification to ensure we had sampled in proportion to fragment counts by taxon (Table 3.5.1). A total number of 27 samples were selected with six discarded from Vlkaš as they came from the plough horizon. Therefore, this analysis is based on 21 samples (Úľany, $n = 9$; Vlkaš Early Neolithic, $n = 10$; and Vlkaš Bronze Age $n = 1$), with four domesticated species represented: cattle (*Bos taurus*), sheep/goat (*Ovis aries/Capra hircus*), pig (*Sus sp.*) and dog (*Canis familiaris*).

Emmer (*Triticum dicoccon*) and einkorn (*Triticum monococcum*) cereal grains were also chosen based on their preservation condition, and on the absence of exogenous carbonised material. Cereal grains from four Early Neolithic contexts from Vlkaš

Table 3.5.1. Úľany nad Žitavou 'Dolné diely' and Vlkaš 'Do hľského chotára'. List of zooarchaeological remains sampled for stable isotope analysis, with taxonomic identification and contextual information: For – Formation; Tr – Trench no.; Ob – Object; Cxt – Context; Qt – Quadrant; Sp – Spit; ds – distal; px – proximal; art. – articulation; EN – Early Neolithic.

ASIL N	For	Tr	Ob	Cxt	Qt	Sp	Context description		Species	Element	Symmetry/ location	Age
Úľany												
2000	100 345	13	1	132	8	6	EN long pit	House 16	<i>Bos taurus</i>	Radius	R: px shaft	adult
3000	100 345	13	1	48	8	5	EN long pit	House 16	<i>Bos taurus</i>	Ulna	L: px shaft	adult
3004	100 345	13	2	114	13	3	EN long pit	House 16	<i>Bos taurus</i>	Humerus	L: ds shaft	adult
3007	100 348	13	1	44	4	5	EN long pit	House 16	<i>Bos taurus</i>	Mandible	L	adult
2007	100 345	13	1	132	8	6	EN long pit	House 16	<i>Canis familiaris</i>	Tibia	L: px shaft	adult
2036	100 345	13	1	117	6	6	EN long pit	House 16	<i>Ovis/Capra</i>	Metacarpal	shaft frag.	
3006	100 345	13	1	113	6	5	EN long pit	House 16	<i>Ovis/Capra</i>	Femur	L: neck	adult
3006	100 345	13	1	113	6	5	EN long pit	House 16	<i>Ovis/Capra</i>	Calcaneus	R: ds art.	adult
3016	100 348	13	1	44	4	5	EN long pit	House 16	<i>Ovis/Capra</i>	Scapula	L: neck	adult
Vľkas												
2052	100 343	15	8	24	5	3	EN long pit	House 202	<i>Sus</i> sp.	Scapula	R: neck	adult
2059		12	1	6	5	3	EN pit		<i>Sus</i> sp.	Skull	L: maxilla	adult
2056	100 342	15	10	226	22	5	EN long pit	House 590	<i>Canis familiaris</i>	Mandible	L	adult
2057	100 339	15	10	209	22	4	EN long pit	House 201	<i>Canis familiaris</i>	Mandible	R	adult
2068	100 339	15	10	209	22	4	EN long pit	House 201	<i>Bos taurus</i>	Tibia	L: px shaft	adult
2069	100 339	15	10	209	22	4	EN long pit	House 201	<i>Bos taurus</i>	Tibia	L: px shaft	adult
2072	100 336	12	1	9	4	3	EN long pit	House 212	<i>Bos taurus</i>	Metatarsal	R: px shaft	adult
2065		12	1	106	14	4	EN pit		<i>Ovis/Capra</i>	Humerus	L: ds shaft	adult
2073		12	1	10	1	3	EN pit		<i>Bos taurus</i>	Humerus	R: ds shaft	adult
2067		15	8	44	4	5	EN pit		<i>Bos taurus</i>	Metatarsal	R: px shaft	adult
2061		12	8	140	15	6	Bronze Age pit		<i>Ovis/Capra</i>	Astragalus	L: ds art.	adult

(S15/6, H202/1, H590/1, H213/1) and a single context from Úľany (Feature 34) were chosen. The Vlkaš samples each comprised a single grain, while the Úľany sample comprised 9 grains for emmer and 10 for einkorn (Table 3.5.2). Bulk sampling of several grains is advantageous as it characterises the mean value and reduces the effect of a single high value (Nitsch *et al.*, 2015).

Carbonisation of cereal grains causes the loss and breakdown of proteins, lipids and carbohydrates (cellulose and starch) and leads to changes in the original bulk $\delta^{15}\text{N}$ and $\delta^{13}\text{C}$ values. Charring experiments have proposed several offset values for $\delta^{15}\text{N}$ values from 1.1‰ (± 0.4 ; Fraser *et al.*, 2011) to more recently, 0.3‰ (± 0.5 ; Nitsch *et al.*, 2015). The discrepancy in the offsets is due to the variation in temperature and charring time. Here we have used the most recent calculated offset value of 0.3‰ for $\delta^{15}\text{N}$ values and an offset value of 0.1‰ (± 0.1) for $\delta^{13}\text{C}$ values (Nitsch *et al.*, 2015).

Sample preparation methods

The bone collagen was extracted using 0.5HCl, rinsed in distilled water and then left in 1 M NaOH overnight to remove humics and rinsed again (Sealy *et al.*, 2014) and freeze-dried. The collagen samples were then weighed into tin cups (average: 0.88 mg) and sent to the Earth Science laboratories at Cardiff University. These samples were combusted under N₂ and CO₂ in an automated carbon and nitrogen analyser coupled to a continuous-flow isotope ratio mass spectrometer (Delta V Advantage/Flash EA). Samples were analysed in duplicate, and the two results averaged. The precision (1s) of repeated measurements of in-house laboratory standards (caffeine, Drogel gel) was less than 0.05‰ for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

Excess carbon was removed from the cereal grains using a weak acid-base preparation rinsed in distilled water repeatedly between preparations and air dried. The samples were then weighed at the stable isotope laboratory at the Department of Soil and Water at Katholieke Universiteit Leuven. Samples were measured on a Thermo EA1110 elemental analyser coupled to a Thermo Delta V Advantage (isotope ratio mass spectrometer) via a Conflo IV interface. Data were calibrated with multiple certified and in-house standards (tuna muscle tissue, Leucine, and IAEA-660 i.e. caffeine). Standard deviations on replicate standards were less than 0.15 per mil for both $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$.

Table 3.5.2. Úľany nad Žitavou ‘Dolné diely’ and Vlkaš ‘Dolné diely’. List of archaeobotanical remains sampled for stable isotope analysis, with taxonomic identification and contextual information.

Site	Sample no.	Species	N	Trench	Feature	Context
Úľany	9	Emmer	9	13	34	
	10	Einkorn	10	13	34	
Vlkaš	1	Emmer	10	12	121	H213/1, glateral long pit, primary fill
	2	Einkorn	3	12	121	H213/1, glateral long pit, primary fill
	3	Einkorn	1	15	40	S15/6, pit secondary fill
	4	Emmer	1	15	40	S15/6, pit secondary fill
	5	Emmer	1	15	102	H202/1, glateral long pit, primary fill
	6	Einkorn	1	15	140	H590/1, glateral long pit, primary fill
	7	Einkorn	1	15	292	H590/1, glateral long pit, primary fill
	8	Emmer	4	15	292	H590/1, glateral long pit, primary fill

Results

Fauna stable isotope results

The average percentage of bone collagen extracted from the samples was 6% (max.: 17.7%; min.: 0.8%), which is within the limits of preserved archaeological material. Following van Klinken (1999), the samples were assessed for their preservation based on the % Carbon (C), Nitrogen (N) and C:N ratio. The average % C value was $41 \pm 2.4\%$ and % N was $14.4 \pm 0.9\%$, while the C:N ratio varied between 3.3 and 3.4 (Table 3.5.3).

The Úľany carbon isotope values range from -21.2‰ to -20.5‰ with an average value of -20.7‰ . The cattle (N = 4) had an average value of $-20.6 \pm 0.4\text{‰}$, the sheep/goat (N = 4) $-20.8 \pm 0.4\text{‰}$ and the single dog sample of -20.7‰ . The average nitrogen isotope values were $6.9 \pm 0.3\text{‰}$ for cattle and $7.5 \pm 1.3\text{‰}$ for sheep. The single dog sample as expected for an animal consuming an omnivore diet had a higher $\delta^{15}\text{N}$ value than those from herbivores of 9.5‰ (Table 3.5.3. and 3.5.4; Fig. 3.5.1).

The $\delta^{13}\text{C}$ values for the Vlkaš Early Neolithic faunal samples ranged from -20.7‰ to -18.9‰ , with an average value of -20.1‰ . Cattle (N = 5) had an average of $-20.3 \pm 0.4\text{‰}$, while the mean of the samples of pig (*Sus* sp.) was $-20.2 \pm 0.6\text{‰}$ and dog (N = 2) had an average of $-20.1 \pm 0.1\text{‰}$. The single sheep sample had the highest value of -18.9‰ observed in the overall sample. The nitrogen isotope values ranged from 6.3‰ to 10.3‰ . Cattle had an average of $8.0 \pm 1.2\text{‰}$, while the single sheep sample as well as a cattle sample exhibited high values of 9.4‰ and 9.7‰ respectively. The dog had the highest average of $10.2 \pm 0.2\text{‰}$, as expected for an animal consuming an

ASIL sample no	Species	%Collagen	%C	%N	C:N	$\delta^{13}\text{C}$ (‰)	$\delta^{15}\text{N}$ (‰)
Úľany							
2000	<i>Bos</i>	5.6	14.4	40.9	3.3	-20.1	7.1
3000	<i>Bos</i>	11.3	14.8	41.9	3.3	-20.8	7.2
3004	<i>Bos</i>	2.5	14.3	41.9	3.4	-21.0	6.7
3007	<i>Bos</i>	3.5	13.9	40.3	3.4	-20.7	6.6
2007	<i>Canis</i>	10.0	14.5	41.3	3.3	-20.7	9.5
2036	O/C	17.7	14.1	39.8	3.3	-20.5	6.3
2040	O/C	9.0	15.1	42.8	3.3	-21.0	8.5
3006	O/C	7.6	13.4	38.3	3.3	-21.2	6.5
3016	O/C	10.6	13.6	39.3	3.4	-20.5	8.7
Vlkaš							
2052	<i>Sus</i>	6.1	15.3	43.2	3.3	-19.8	7.3
2056	<i>Canis</i>	5.8	13.8	39.3	3.3	-20.2	10.0
2057	<i>Canis</i>	3.9	14.0	40.3	3.4	-20.1	10.3
2068	<i>Bos</i>	2.5	14.6	41.5	3.3	-20.4	6.3
2069	<i>Bos</i>	8.1	15.3	42.7	3.3	-19.7	7.5
2072	<i>Bos</i>	5.2	15.0	42.6	3.3	-20.5	8.3
2059	<i>Sus</i>	3.6	14.4	41.6	3.4	-20.6	9.1
2061	O/C	1.4	15.1	43.0	3.3	-20.3	7.5
2065	O/C	1.9	15.4	44.0	3.3	-18.9	9.4
2073	<i>Bos</i>	3.1	15.0	43.0	3.3	-20.3	9.7
2067	<i>Bos</i>	0.8	11.6	33.2	3.3	-20.7	8.2

Table 3.5.3. Úľany nad Žitavou 'Dolné diely' and Vlkaš 'Do hľského chotára'. List of zooarchaeological remains sampled for stable isotope analysis, detailing percentage (%) collagen, %C, %N, C:N, $\delta^{13}\text{C}$ (‰) and $\delta^{15}\text{N}$ (‰). ASIL – Archaeological Stable Isotope Laboratory Kiel; O/C – Ovis aries/Capra hircus.

Table 3.5.4. Úľany nad Žitavou 'Dolné diely' and Vlkas 'Do hľuského chotára'. Descriptive statistics of the stable isotope results on zooarchaeological remains, per species.

Species	Vlkas					Úľany				
	n	$\delta^{13}\text{C}$	SD	$\delta^{15}\text{N}$	SD	n	$\delta^{13}\text{C}$	SD	$\delta^{15}\text{N}$	SD
Early Neolithic										
Cattle (<i>Bos taurus</i>)	5	-20.3	0.4	8.0	1.2	4	-20.6	0.4	6.9	0.3
Sheep/goat (<i>Ovis aries</i> / <i>Capra hircus</i>)	1	-18.9		9.4		4	-20.8	0.4	7.5	1.3
Pig (<i>Sus</i> sp.)	2	-20.2	0.6	8.2	1.3	NA				
Dog (<i>Canis familiaris</i>)	2	-20.1	0.1	10.2	0.2	1	-20.7		9.5	
Bronze Age										
Sheep/goat (<i>Ovis aries</i> / <i>Capra hircus</i>)	1	-20.3		9.1						

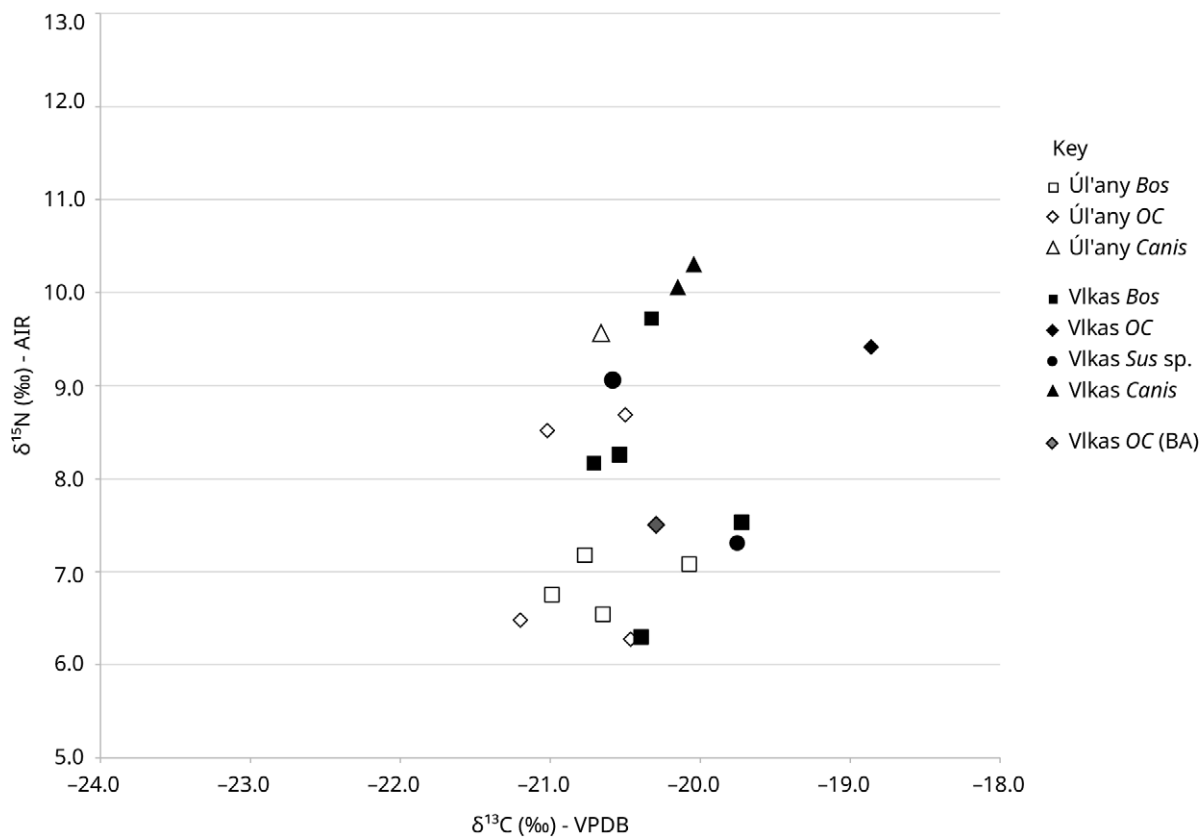


Figure 3.5.1. Úľany and Vlkas. Carbon and nitrogen stable isotope results for faunal samples.

omnivore diet, in comparison the pig samples had an average value of $8.2 \pm 1.3\text{‰}$, suggesting a more herbivorous diet.

In the Bronze Age material, the single sample of sheep/goat had a value of -20.3‰ . The $\delta^{15}\text{N}$ values for this sample was 7.5‰ , which was lower than that observed in the EN sheep sample.

Cereal stable isotope results

The corrected $\delta^{13}\text{C}$ values for cereal grain samples from Úľany were -21.1‰ for emmer wheat and -21.6‰ for einkorn (Table 3.5.5; Fig. 3.5.2). Four contexts from Vlkas were sampled, and the corrected $\delta^{13}\text{C}$ values for emmer ranged from -23.6‰

Sample No.	N	Species	Context	%C	%N	C/N	$\delta^{13}\text{C}$ (‰)	$\delta^{13}\text{C}_{\text{corr}}$ (+0.1‰)*	$\delta^{15}\text{N}$ (‰)	$\delta^{15}\text{N}_{\text{corr}}$ (-0.3‰)*
Úľany										
9	9	Emmer		56.4	3.3	17.0	-21.2	-21.1	7.3	7.0
10	10	Einkorn		51.1	3.3	15.5	-21.7	-21.6	10.5	10.2
Vľkas										
4	1	Emmer	S15/6	56.3	3.7	15.4	-21.7	-21.6	8.4	8.1
5	1	Emmer	H202/1	57.9	2.6	22.0	-23.7	-23.6	10.3	10.0
8	4	Emmer	H590/1	53.3	2.9	18.3	-22.7	-22.6	10.7	10.4
1	10	Emmer	H213/1	55.9	2.9	19.3	-22.8	-22.7	6.3	6.0
							-22.6	±0.8‰	10	±3.1‰
2	3	Einkorn	H213/1	55.3	3.0	18.7	-23.4	-23.3	5.9	5.6
3	1	Einkorn	S15/6	59.5	4.2	14.3	-22.4	-22.3	12.1	11.8
6	1	Einkorn	H590/1	58.5	4.0	14.5	-22.0	-21.9	12.9	12.6
7	1	Einkorn	H590/1	59.4	3.6	16.5	-24.1	-24.0	10.1	9.8
							-22.9	±0.9‰	8.6	±2‰

Table 3.5.5. Úľany nad Žitavou 'Dolné diely' and Vľkas 'Do hľského chotára'. Carbon and nitrogen stable isotope results for archaeobotanical samples (emmer and einkorn grains). *Offset values based on experimental studies (Nitsch et al., 2015).

to -21.6‰, while those for einkorn ranged from -24.0‰ to -21.9‰. At this site, there is a 0.3‰ difference between the average values for emmer (-22.6‰) and einkorn (-22.9‰), while at Úľany, there is 0.5‰ difference between einkorn and emmer. Overall, $\delta^{13}\text{C}$ values were lower for all cultivars at Vľkas in comparison to those from Úľany.

Turning to the corrected $\delta^{15}\text{N}$ values, the samples from Úľany for emmer and einkorn exhibit values of 7.3‰ and 10.2‰, respectively. The cereals from the Vľkas contexts range from 6.0‰ to 10.4‰ for emmer and from 5.6‰ to 12.6‰ for einkorn. House 213 had the lowest $\delta^{15}\text{N}$ values for both emmer and einkorn, while the highest value for both cereals was found in House 590. On average, einkorn (10‰ ±3.1‰) higher $\delta^{15}\text{N}$ values in comparison to emmer (8.6‰ ±2‰), which was also observed at Úľany. There is little difference between $\delta^{15}\text{N}$ values from einkorn samples between the two sites (0.2‰), while the emmer sample at Úľany is 1.6‰ lower than the average $\delta^{15}\text{N}$ values for this cultivar at Vľkas.

Discussion

Sample size

The size of the faunal samples was small, which restricts the statistical analysis of the results within the sites' regional context and comparison with Vráble. The total number of cattle sampled from Early Neolithic contexts was 4 for Úľany and 5 for Vľkas, in comparison to 20 at Vráble. Similarly, the sample size for sheep/goat was small with 4 at Úľany and 1 at Vľkas in comparison to Vráble. However, the samples are representative of the small assemblage of preserved archaeozoological remains recovered from these initial excavations (Chapter 3.3). For the cereal grain samples, there is also limited statistical analysis that can be carried out. However, the stable isotopic results from the cereal grain samples provide a potential indication of manuring activities at the sites. Furthermore, the small sample is representative of the cereal cultivars within the overall archaeobotanical assemblage.

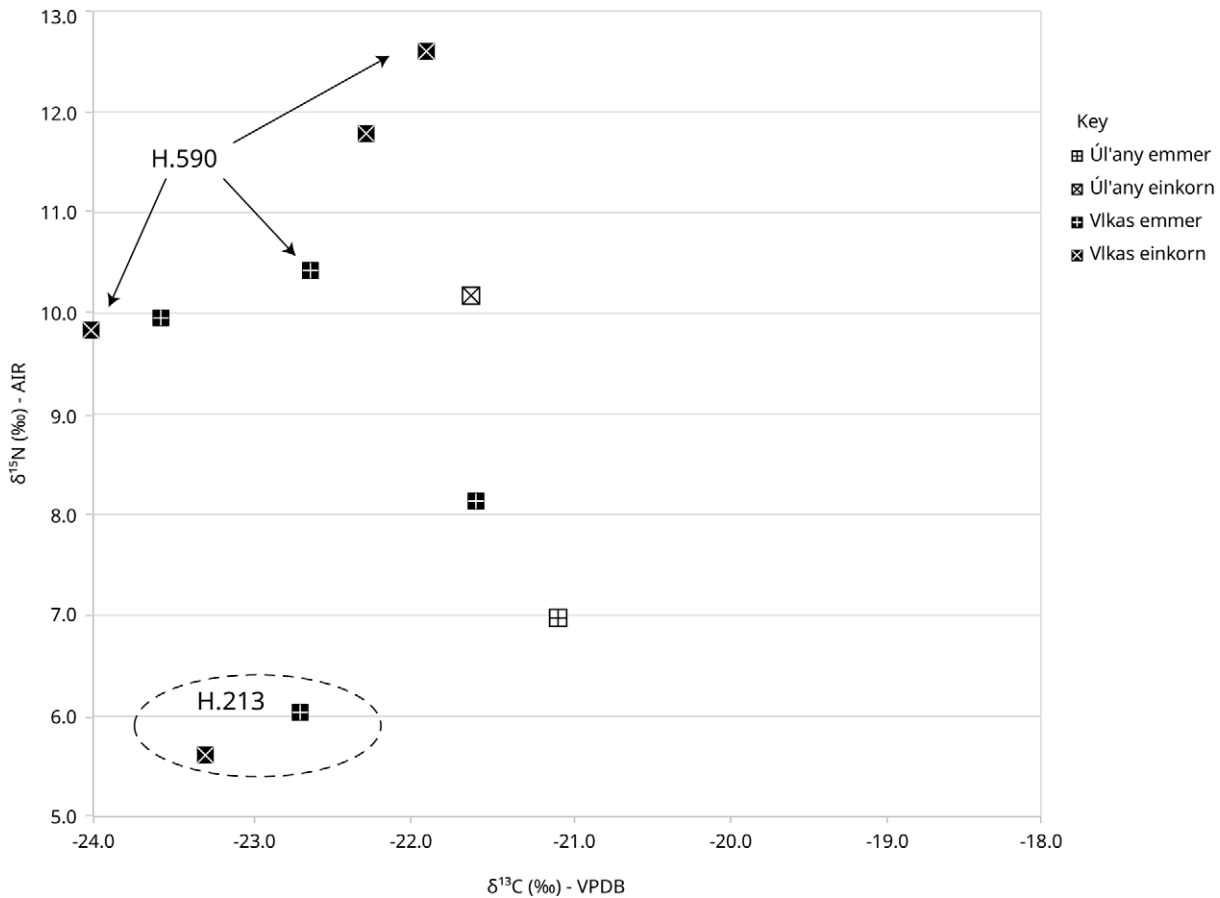


Figure 3.5.2. Úľany and Vlkas. Carbon and nitrogen stable isotope results for botanical samples (emmer and einkorn grains).

Site-specific observations on cereal cultivation

Carbon isotopes are sensitive to a plant's growing conditions. Discrimination toward ^{13}C in wetter and low light conditions can result in plants exhibiting low $\delta^{13}\text{C}$ values. The overall lower $\delta^{13}\text{C}$ values found in both cultivars at Vlkas, may indicate wetter conditions at the site. Einkorn samples at this site exhibited a larger variability as shown by the high standard deviation (3.1‰). This may be the result of single grain samples but it may also be a reflection of highly variable growing conditions for einkorn crops at the site. Further analyses are needed to see whether einkorn grains have on average lower carbon isotope values than emmer grains, which may be suggestive of damper soil conditions *i.e.* grown during spring or emmer grown in drier soils.

Nitrogen isotope values can provide us an insight into whether soils were enriched with manure. This fertilisation of the soils may have been a deliberate strategy or via grazing animals on crop stubble after harvest. Overall, at both the sites, the $\delta^{15}\text{N}$ values indicate a long moderate/intensive regime (>6‰) based on experimental analysis (Fraser *et al.*, 2011; Bogaard *et al.*, 2013). Moreover, einkorn samples had higher $\delta^{15}\text{N}$ values than emmer. Drilling down into specific contexts, einkorn and emmer samples from H.590 had an average of 11.2‰ and 10.4‰ respectively. This is in stark contrast to H.213, where the $\delta^{15}\text{N}_{\text{corr}}$ value for einkorn and emmer was 6‰ and 5.6‰ respectively (Fig. 3.5.2). H.213 samples were recovered from a context where there was scant other archaeobotanical remains with traces of an unmixed cereal deposit suggesting emmer and einkorn were sown as a maslin crop (see Chapter 3.4). Our initial results suggest that at H.590 and H.213, the crops were processed similarly however; the former's cereals were manured more than those

grown by H.213. This may be a reflection of differential access to resources, which may be expected in household-based economies. We need to further interrogate whether these houses are ‘archaeologically’ different, for example in terms of frequency and type of tools, pottery, as well as variations in the faunal species spectrum with the archaeozoological assemblage. Moreover, to investigate intensification of agricultural practices, it is necessary to expand the stable isotopic analysis to cereal remains from later periods as at present the samples are restricted to Early Neolithic contexts.

Site-specific animal husbandry observations

The overall sample size was small, with single species having a total sample size between 1 and 5. However, we can make some initial observations on similarities and differences between the two sites (Fig. 3.5.1). First, we consider the fodder of herbivore species, such as sheep, goat and cattle. Taking into account the 5.1‰ fractionation between bone collagen and diet carbon isotopes, the estimated fodder plant $\delta^{13}\text{C}$ values range for Úlany were -25.8‰ to -26.3‰ , and for Vlkaš, -24.0‰ to -25.8‰ , which is expected for an environment characterised by C_3 plants. Initial observation is that herbivores were grazing in more open environments at Vlkaš than at Úlany. The single sheep from Vlkaš had the highest value in the dataset (-24.0‰).

Dense forest canopies can cause low-light growing conditions and the respiration and recycling of ^{13}C depleted CO_2 (Tieszen, 1991). This results in plants and the lower branches of trees exhibiting low $\delta^{13}\text{C}$ values in comparison to those growing in open environments. Forest-dwelling herbivores, such as deer, have an average $\delta^{13}\text{C}$ value of $-22.6 \pm 1\text{‰}$ (based on deer samples ($N = 33$) from LBK contexts, Gillis and Zanon, 2021), which would provide a dietary value of c. -27.7‰ once corrected for fractionation. In comparison, the cattle diet estimates for Vlkaš and Úlany suggest little contribution to their diets from densely forested environments.

There is some variation in nitrogen isotopic values between the sites. During the Early Neolithic, Vlkaš cattle exhibited $\delta^{15}\text{N}$ values (8.0‰) that were c. 1‰ higher than those from Úlany (6.9‰), but similar to sheep/goat from this site (7.5‰). The sample from sheep/goat and a cattle humerus had a value (9.4‰ , 9.7‰ respectively) that were more similar to omnivorous animals. The high values observed at Vlkaš suggest that these animals consumed plants with high $\delta^{15}\text{N}$ values. This may be the result of animals being penned within long-standing pastures, or that animals were allowed to graze on manured crops as was postulated at Vráble.

Regional trends

The neighbouring site of Vráble is one of the largest LBK settlements at present identified in central Europe, with more than 313 house structures in an area of ca. 50 ha (Furholt *et al.*, 2014; 2020; Müller-Scheeßel *et al.*, 2020). A key finding at this site was the high $\delta^{15}\text{N}$ values measured in domesticated cereal grains and livestock, which suggested an integrated plant and animal management strategy. In comparison with the stable carbon results from Vráble, all animals from the sites investigated here appear to be foraging on plants growing within similar, open environments, with no evidence of woodland grazing (Fig. 3.5.3). For the faunal nitrogen stable isotopic values, the Vráble average for herbivores was 9.1‰ , which is higher than the values observed in Vlkaš and Úlany herbivore and pig samples. From this initial study, it would appear that the diet of domesticated herbivores at the sites studied here were not as enriched with ^{15}N as observed in the Vráble study. At Vráble, sheep and goats had particularly high $\delta^{15}\text{N}$ values. Similarly, at Úlany sheep/goat have higher values than cattle, and at Vlkaš, the single sheep/goat has higher values than both cattle and pig.

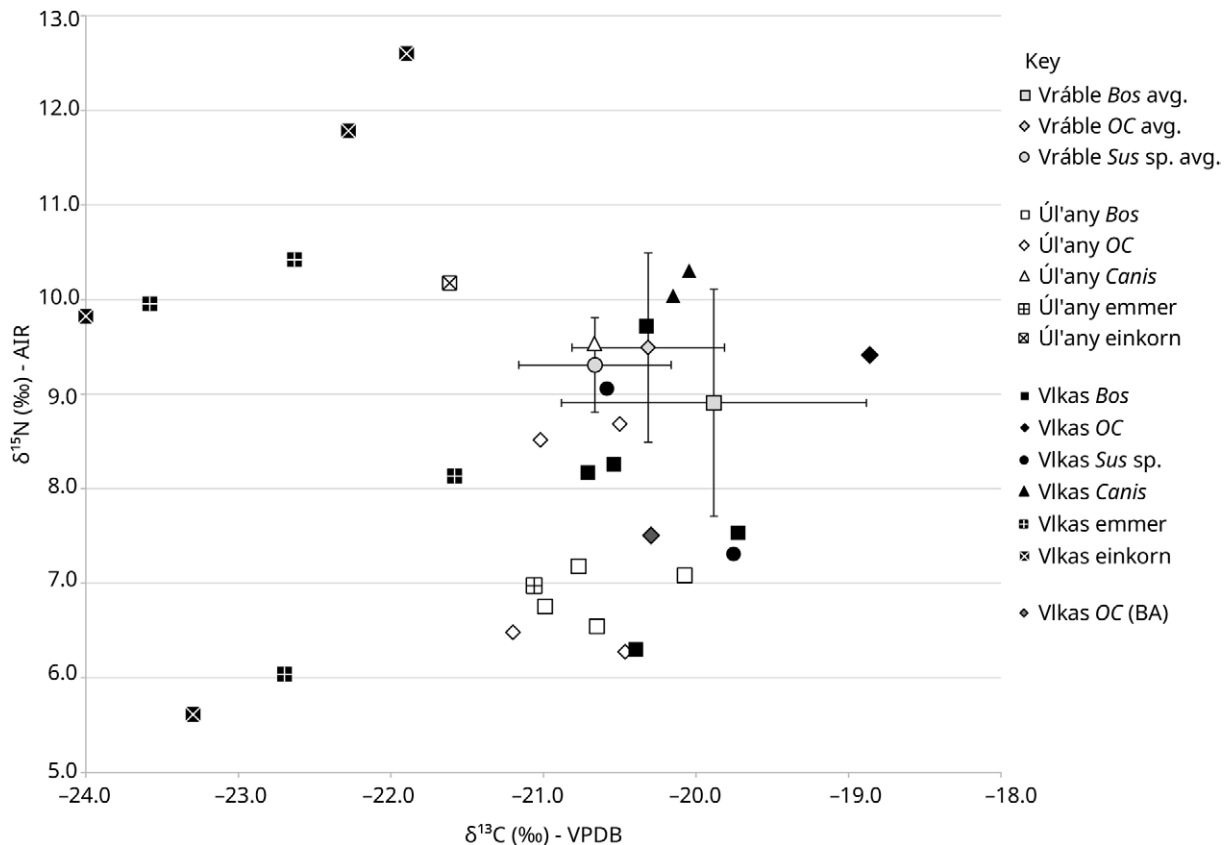


Figure 3.5.3. Comparison of all the $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ results from this study with those from the analysis at Vrable (Gillis *et al.*, 2020b).

We can only compare the $\delta^{15}\text{N}$ values from the cereals sampled at Vrable, as there were issues with the calibration of $\delta^{13}\text{C}$ values from Vrable (Gillis *et al.*, 2020b). The emmer and einkorn samples from Vrable have on average lower $\delta^{15}\text{N}$ value of 6.3‰ and 6.9‰ respectively, in comparison to samples from Úl'any (7‰, 10.2‰) and Vlkas (8.6‰, 10‰). There is a consistency in the results between the Early Neolithic phases at Úl'any, Vlkas and Vrable, when emmer has lower $\delta^{15}\text{N}$ values than einkorn. However, the reverse was observed in samples of emmer and einkorn from the Bronze Age contexts at Vrable (Schlütz and Bittmann, 2015). In light of the differences in sample size and sampling protocols between the Vrable study and the one reported here and in Gillis *et al.* (2020b) as well as the lack in Bronze Age samples, we cannot say whether this difference in the results is a reflection of changes in agricultural practices.

Recommendations for future research

The initial observations provide some interesting glimpses into cereal cultivation and animal husbandry at Úl'any and Vlkas. The variation between houses, may indicate differences in access to resources, which would be expected for household-based economies. This may have been the result of particular houses being focused toward one animal species i.e. cattle versus sheep/goat, as has been observed in LBK/Rubané villages in the Paris Basin (Hashem, 2011). Penning sheep/goat on cultivation plots and therefore directly providing manure for crop production in comparison to extensive management of cattle, may have resulted in varying rates of cereal production that may have impacted cereal production. To test this further, more detailed stable isotopic and archaeozoological analyses are required to explore the potential impact of household based-economies on the Early Neolithic societies at Úl'any and Vlkas.

Future sampling and analysis should collect samples from all sites and analyse them at the same laboratory to ensure comparability of results. Furthermore, more comprehensive cross-correlation of the frequencies of artefacts (stone and bone tools and pottery) and ecofacts (seeds, charcoal and faunal remains) is needed to fully understand the nature of the sampled contexts. Overall, the initial results from this pilot study provide a first insight into Early Neolithic animal husbandry and plant cultivation at the sites of Úlany and Vlkaš, as well as later Chalcolithic/Bronze Age phases at Vlkaš. Future stable isotope studies of cereals and fauna integrated with artefactual analysis such as type and distribution, will provide further information that will deepen our understanding of early farming practices and changes in these practices over time within Slovenia.

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Section 4: Temporal scales

4.1 Radiocarbon dates from the Early Neolithic settlement sites of Úľany nad Žitavou and Vlkas, in the Žitava Valley, south-western Slovakia

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Abstract

During the excavation of the settlements of Úľany nad Žitavou ‘Dolné diely’ and Vlkas ‘Do hľského chotára’ in 2018, altogether 18 botanical samples were taken for ^{14}C dating. All yielded interpretable results: 15 dates fall within the Early Neolithic, while 3 dates are post-Neolithic. While the excavated features at Úľany predate the majority of those at Vráble, the features at Vlkas are contemporaneous with most of the features excavated at Vráble so far. The few younger dates also show that at least Vlkas was also frequented in the Eneolithic and the Early Bronze Age. In general, the dates indicated by the ^{14}C analysis, the ceramics and house orientation are not inconsistent with each other. This, however, is also due to the fact that especially ^{14}C and ceramics offer only very broad date ranges. Where narrower date ranges exist, some are in good accordance with each other, but others are not. In the classification according to the orientation of houses as shown on the magnetic maps, the settlement of Vlkas would end about 5050 cal BCE. However, some of the ^{14}C dates seem to be younger than that, and also in the excavated area, a case can be made that there are houses of an orientation indicating a very late date. This shows that apparently the youngest houses are not clearly visible in the magnetic picture, either because they are not filled with magnetic material or because they were erected in areas – like that of Trench 15 – with a dense pattern and magnetic signal of older houses.

Keywords: Absolute chronology, Younger LBK, Želiezovce Group, radiocarbon dating, Bayesian modelling

Introduction

Investigations into the temporal depth of early agricultural activities in the Žitava Valley have so far focused on spatio-temporal modelling of large agglomerations (Meadows *et al.*, 2019), studying the relationships between architectural structures and human perception (Müller-Scheeßel *et al.*, 2020a), and assessing the potential of inferring demographic developments through time (Müller *et al.*, 2020). The excavations of 2018 therefore focused more on two smaller settlements within the Žitava Valley, Úľany nad Žitavou ‘Dolné diely’ (hereinafter Úľany) and Vlkaš ‘Do hľuského chotára’ (hereinafter Vlkaš). The excavations uncovered several lateral long pits that are typical of LBK houses, as well as pits of different shapes. Especially the situation in Trench 15 of Vlkaš turned out to be quite complex due to numerous intercutting features (see Chapter 3.1). Apart from indispensable absolute dating of the features encountered during excavation, ^{14}C dating was commissioned to help understand the complex stratigraphy of Trench 15.

Sampling strategy

Because we had previously encountered very low collagen values in some of the animal and human bones from Vráble (Meadows *et al.*, 2019; Müller-Scheeßel *et al.*, 2020b), for the dating of the features of the excavations of 2018 in Vlkaš and Úľany, we relied solely on short-lived botanical specimens. This puts some limits on the features which could be dated, as not all botanical samples yielded useable material. The material was only sent to the ^{14}C laboratory after it had been investigated and identified taxonomically by a botanical specialist (D. Filipović, Kiel).

All in all, 18 samples were sent to the ^{14}C laboratory in Poznań, 4 from Úľany and 14 from Vlkaš. Of the latter, 3 come from Trench 12, while the remaining 11 come from Trench 15.

Results of the radiocarbon dating

All 18 samples provided useable results, supporting the decision to concentrate solely on botanical samples (Table 4.1.1). Of the 18, 15 fall within the Early Neolithic, while 3 dates are post-Neolithic.

The kernel density modelling (Fig. 4.1.1) shows very clearly that, taken as a whole, the Neolithic samples from Úľany date before those from Vlkaš. It even seems to suggest that Vlkaš runs well into the 50th century cal BCE.

Discussion

Stratigraphic considerations

For Úľany, the stratigraphic analysis suggests that the *Schlitzgrube* was actually dug into Object S13/1 (Fig. 4.1.2; Table 4.1.2). The ^{14}C dates seem to confirm this interpretation, as the two raw ^{14}C dates from the *Schlitzgrube* (ULA18_130070-1/Poz-109591; ULA18_130187-1/Poz-109593) are much younger than the two raw dates from Object S13/1 (ULA18_130018-1/Poz-109589; ULA18_130027-1/Poz-109590). Accordingly, a model that perceives the *Schlitzgrube* as older is penalised by a warning of ‘Poor agreement’ for ULA18_130070-1 (Poz-109591). The non-penalised model puts the long pit S13/1 before 5200 cal BCE and the *Schlitzgrube* either shortly before 5200 cal BCE or around 5150 cal BCE.

Settle-ment	House	Laboratory code	Type	Sample code	Contextual details	Quadrant	Spit	Species	¹⁴ C age (cal BCE)
Úľany	593	Poz-109589	1 grain	ULA18 S013 – Probe 018-1	Trench 13, Object H539/1, context 34	9	3	Einkorn	6270±40
Úľany	593	Poz-109590	2 g rains	ULA18 S013 – Probe 027-1	Trench 13, Object H593/1, context 30	5	3	Einkorn	6280±40
Úľany		Poz-109591	1 grain	ULA18 S013 – Probe 070-1	Trench 13, Object S13/1 context 42	1	5	Emmer	6190±40
Úľany		Poz-109593	2 grains	ULA18 S013 – Probe 187-1	Trench 13, Object S13/1, context 63	1	11	Emmer	6230±35
Vlkas		Poz-109283	3 grains	VLK18 S012 – Probe 054-1	Trench 12, context 10	1	3	Emmer	6090±40
Vlkas	212	Poz-109587	1 grain	VLK18 S012 – Probe 129-1	Trench 12, Object H212, context 47	9	5	Emmer	6170±40
Vlkas		Poz-109588	charcoal	VLK18 S012 – Probe 260-2	Trench 12, Object S12/8, context 147	15	8	Fraxinus	3370±30
Vlkas	202	Poz-109594	1 grain	VLK18 S015 – Probe 111-1	Trench 15, Object H202, context 22	4	3	Emmer	6085±35
Vlkas		Poz-109595	1 grain	VLK18 S015 – Probe 113-1	Trench 15, Object S15/1, context 25	-	3	Emmer	6180±40
Vlkas		Poz-109527	2 grains	VLK18 S015 – Probe 173-1	Trench 15, context 41	8	4	indeterminate cereal	3535±35
Vlkas		Poz-109574	2 grains	VLK18 S015 – Probe 311-1	Trench 15, Object S15/8, context 44	4	5	<i>Triticum</i> sp.	4330±35
Vlkas	590	Poz-109576	1 grain	VLK18 S015 – Probe 377-1	Trench 15, Object H590, context 109	19	3	Emmer	6160±35
Vlkas	590	Poz-109410	3 grains	VLK18 S015 – Probe 415-1	Trench 15, Object H590, context 110	19	3	Emmer	6170±40
Vlkas		Poz-109573	1 grain	VLK18 S015 – Probe 432-1	Trench 15, context 136	19	4	Einkorn	6160±35
Vlkas	202	Poz-109575	1 grain	VLK18 S015 – Probe 444-1	Trench 15, Object H202, context 102	17	3	Emmer	6105±35
Vlkas	590	Poz-109523	1 seed	VLK18 S015 – Probe 452-1	Trench 15, Object H590, context 139	19	5	indeterminate legume	6110±35
Vlkas		Poz-109525	charcoal	VLK18 S015 – Probe 458-1	Trench 15, Object S15, context 141	8	5	Hazel	6075±35
Vlkas	202	Poz-109526	1 seed	VLK18 S015 – Probe 573-1	Trench 15, Object H202, context 239	17	5	indeterminate legume	6050±35

In Trench 12 of Vlkas (Fig. 4.1.3; Table 4.1.3), Object S12/1 is dated by two samples (VLK18_120054-1/Poz-109283; VLK18_120129-1/Poz-109587). The second covers a very broad time span, between approximately 5200 and 5000 cal BCE, while the first could date very early (5200 cal BCE, only 95.4 %) or very late, around 5000 cal BCE.

Four of the samples, VLK18_150377-1 (Poz-109576), VLK18_150415-1 (Poz-109410), VLK18_150432-1 (Poz-109573) and VLK18_150452-1 (Poz-109523), derive from different levels of quadrant 19 of Object S15/10 from Vlkas. The first three seem to come from the same layer (Fig. 4.1.4) and consequently yielded almost identical raw dates (6160 and 6170 bp). The fourth was found in a position that is stratigraphically below the other dates but much younger in uncalibrated terms (6110 bp). Because of the wiggle around 5200 cal BCE which the fourth date encompasses, there are two possibilities: the first is that the lowest layer dates exactly to this event and the layer above with the three other dates is from any interval between 5200 and 5020 cal BCE, and the second is that they all date between 5120 and 5020 cal BCE.

Table 4.1.1. Úľany nad Žitavou 'Dolné diely' and Vlkas 'Do hulského chotára'. List of radiocarbon samples, with raw dates. H = House.

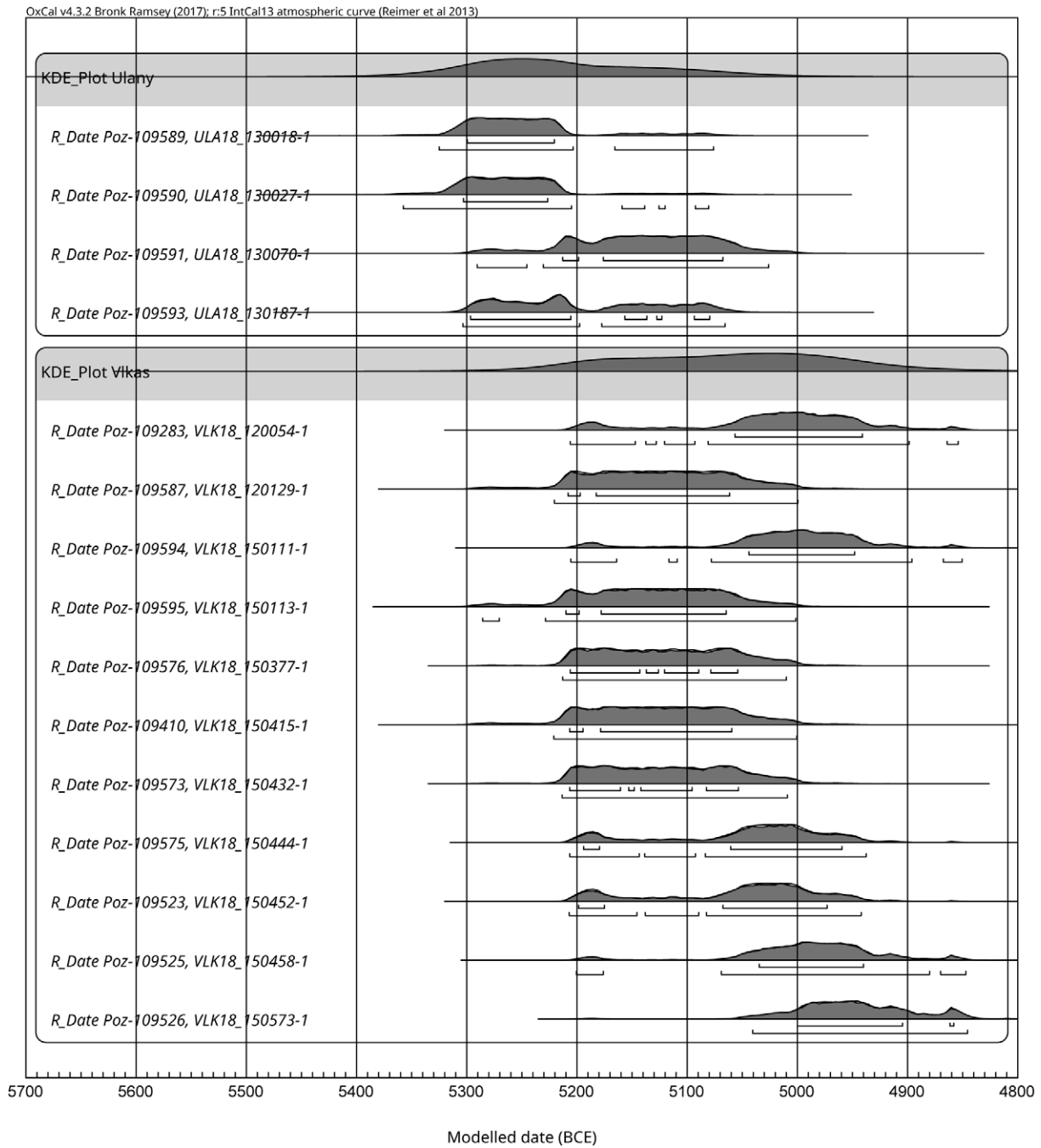


Figure 4.1.1. Kernel density estimation of the available Neolithic ^{14}C dates from Úlány and Vlkaš (cf. Table 4.1.1), with OxCal 4.4 (Bronk Ramsey, 2009).

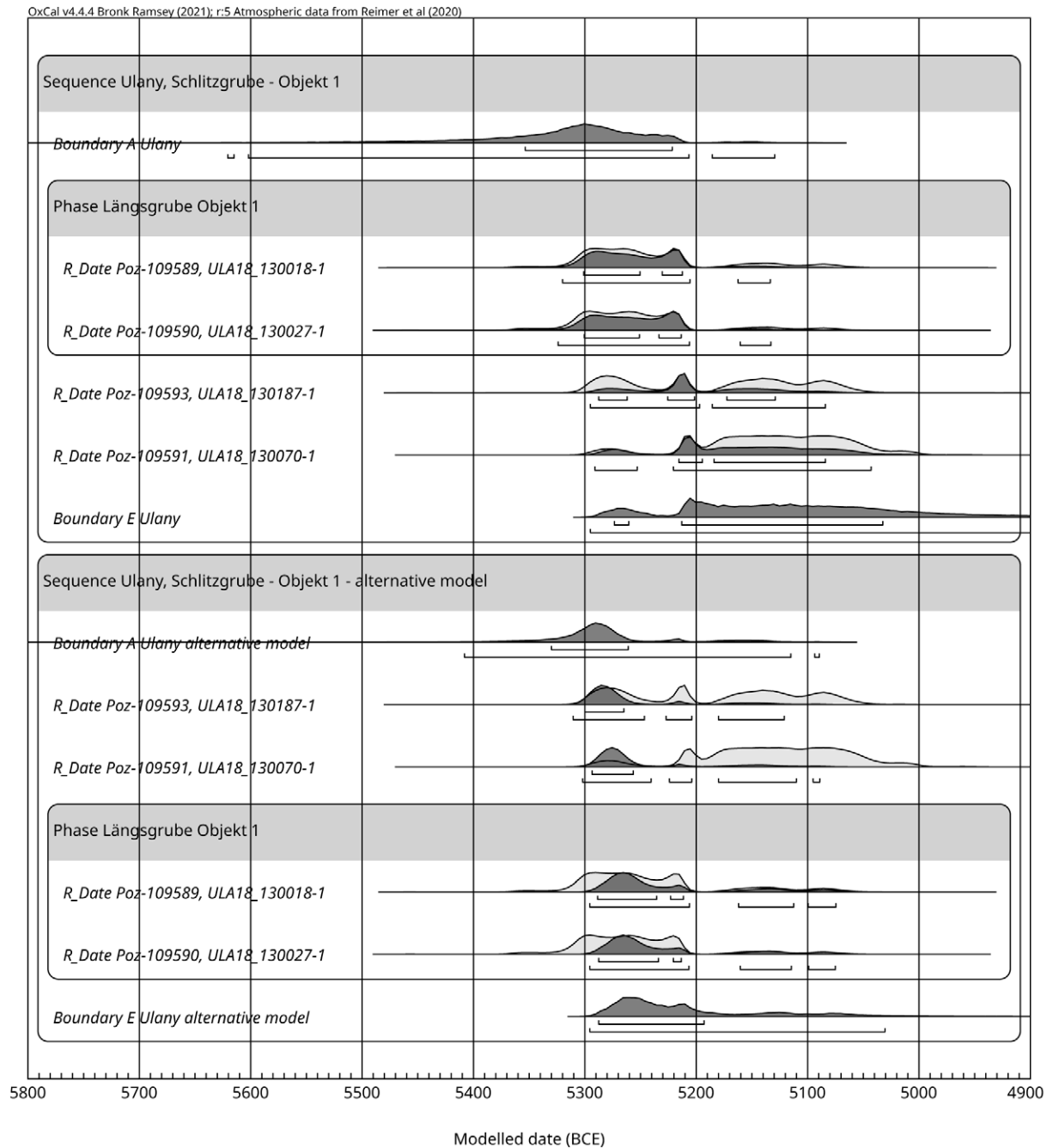


Figure 4.1.2. Bayesian model of the available Neolithic ^{14}C dates from Úlany (cf. Table 4.1.1), constrained by stratigraphic information, with OxCal 4.4 (Bronk Ramsey, 2009).

Name	Unmodelled (BCE/AD)				Modelled (BCE/AD)				Indices Amodel 71.1 Aoverall 77	
	from_68_3	to_68_3	from_95_4	to_95_4	from_68_3	to_68_3	from_95_4	to_95_4	A	C
Sequence Uľany, Schlitzgrube – Object 1										
Boundary A Uľany					-5354	-5222	-5621	-5130		95.8
Phase Long pit Object 1										
R_Date Poz-109589, ULA18_130018-1	-5307	-5213	-5323	-5071	-5302	-5213	-5321	-5134	113.4	99.2
R_Date Poz-109590, ULA18_130027-1	-5307	-5216	-5359	-5076	-5301	-5214	-5325	-5134	109.6	99.4
R_Date Poz-109593, ULA18_130187-1	-5297	-5076	-5306	-5056	-5288	-5130	-5296	-5085	107.1	99.6
R_Date Poz-109591, ULA18_130070-1	-5211	-5065	-5294	-5011	-5216	-5085	-5292	-5044	96.6	99
Boundary E Uľany					-5274	-5033	-5296	-4805		95.7
Sequence Uľany, Schlitzgrube – Object 1 – alterna- tive model										
Boundary A Uľany alternative model					-5331	-5262	-5409	-5090		95.7
R_Date Poz-109593, ULA18_130187-1	-5297	-5076	-5306	-5056	-5301	-5266	-5311	-5122	117.5	99.3
R_Date Poz-109591, ULA18_130070-1	-5211	-5065	-5294	-5011	-5294	-5257	-5303	-5090	47.9	99.6
Phase Long pit Object 1										
R_Date Poz-109589, ULA18_130018-1	-5307	-5213	-5323	-5071	-5289	-5212	-5296	-5075	105.8	99
R_Date Poz-109590, ULA18_130027-1	-5307	-5216	-5359	-5076	-5288	-5214	-5296	-5076	99.7	99.2
Boundary E Uľany alternative model					-5288	-5194	-5296	-5031		95.9

Table 4.1.2. Úľany nad Žitavou 'Dolné diely': Output of Bayesian modelling with the stratigraphic information (cf. Fig. 4.1.2), with OxCal 4.4 (Bronk Ramsey, 2009).

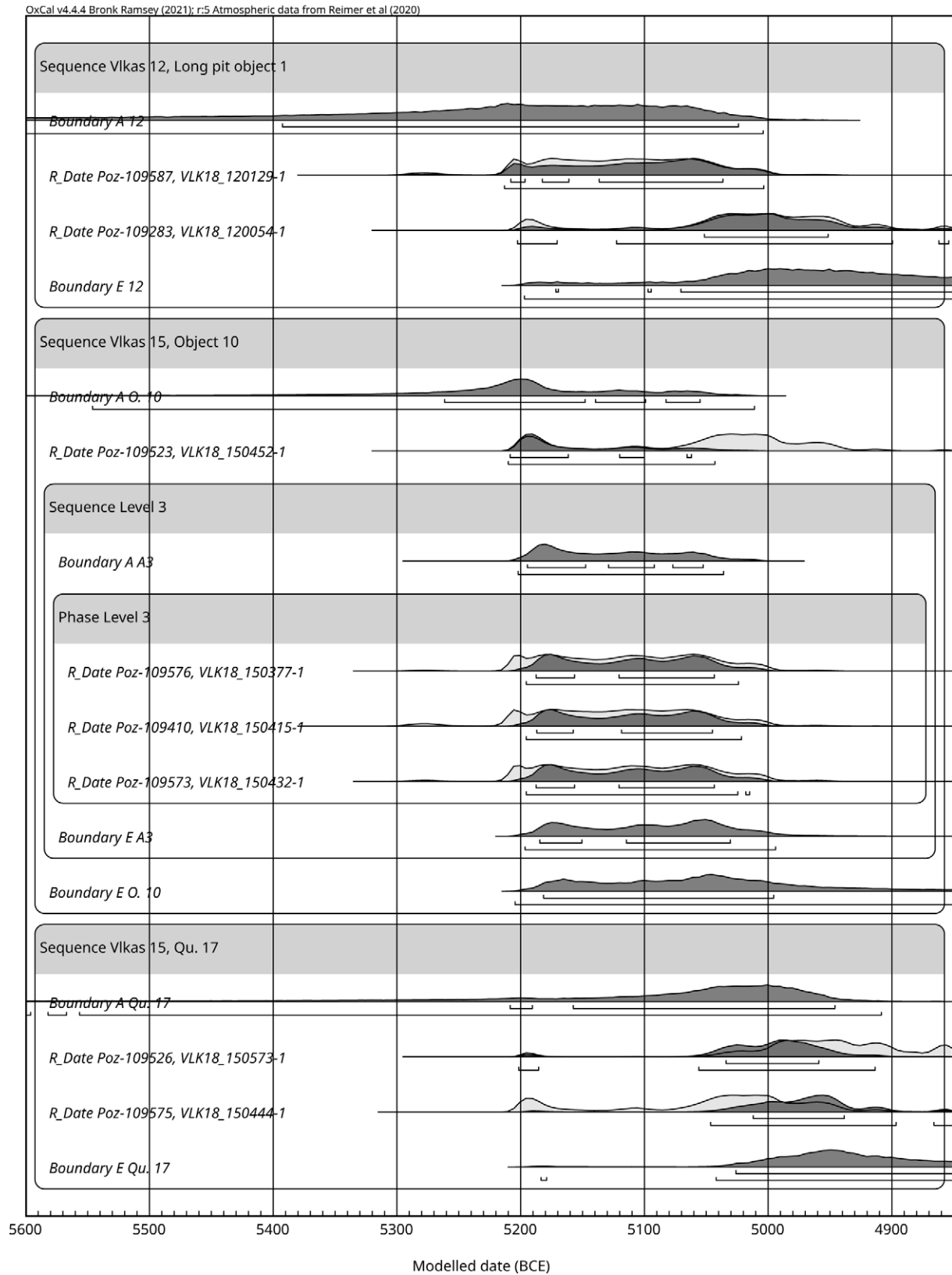


Figure 4.1.3. Vlkaš 'Do hľského chotára'. Bayesian model of the available Neolithic ^{14}C dates (cf. Table 4.1.1), constrained by stratigraphic information, with OxCal 4.4 (Bronk Ramsey, 2009).

Name	Unmodelled (BCE/AD)				Modelled (BCE/AD)				Indices Amodel 74.2 Aoverall 83	
	from_68_3	to_68_3	from_95_4	to_95_4	from_68_3	to_68_3	from_95_4	to_95_4	A	C
Sequence Vlkas 12, Long pit Object 1										
Boundary A 12					-5393	-5025	-6059	-5005		96.7
R_Date Poz-109587, VLK18_120129-1	-5208	-5054	-5217	-4997	-5209	-5037	-5214	-5004	99.7	99.5
R_Date Poz-109283, VLK18_120054-1	-5200	-4941	-5208	-4849	-5052	-4952	-5203	-4855	105.8	99.5
Boundary E 12					-5172	-4673	-5198	-4029		96.5
Sequence Vlkas 15, Object 10										
Boundary A O. 10					-5262	-5056	-5547	-5012		97.2
R_Date Poz-109523, VLK18_150452-1	-5204	-4954	-5209	-4937	-5209	-5063	-5211	-5044	78.7	99.6
Sequence Level 3										
Boundary A A3					-5195	-5053	-5203	-5037		99.2
Phase Level 3										
R_Date Poz-109576, VLK18_150377-1	-5208	-5045	-5211	-5006	-5188	-5044	-5196	-5025	106.2	99
R_Date Poz-109410, VLK18_150415-1	-5208	-5054	-5217	-4997	-5188	-5046	-5196	-5022	107.1	99.1
R_Date Poz-109573, VLK18_150432-1	-5208	-5045	-5211	-5006	-5188	-5044	-5196	-5016	106.2	99
Boundary E A3					-5185	-5031	-5197	-4995		98.7
Boundary E O. 10					-5182	-4996	-5205	-4647		95.9
Sequence Vlkas 15, Qu. 17										
Boundary A Qu. 17					-5209	-4947	-5871	-4909		97.9
R_Date Poz-109526, VLK18_150573-1	-4998	-4856	-5045	-4842	-5035	-4960	-5202	-4914	89.6	99.5
R_Date Poz-109575, VLK18_150444-1	-5202	-4952	-5209	-4909	-5013	-4939	-5047	-4850	85.7	99.5
Boundary E Qu. 17					-5027	-4808	-5184	-4147		96.4

Table 4.1.3. Vlkas 'Do hľského chotára'. Output of Bayesian modelling with the stratigraphic information (cf. Fig. 4.1.3), with OxCal 4.4 (Bronk Ramsey, 2009).

Samples VLK18_150444-1 (Poz-109575) and VLK18_150573-1 (Poz-109526) both come from quadrant 17 in Object S15/10 at Vlkas – the first from context 102, level 3, and the second from context 239, level 5. However, in terms of calibrated dates, there seems to be an inversion, as the first raw date is clearly older than the second. The Bayesian model caters for this fact by positioning both dates very late, around 5000 cal BCE.

Comparison with associated ceramics

Of particular importance for the absolute dating of LBK pottery in south-western Slovakia is the cemetery of Nitra, which puts the change from 'music note head' ceramics (German: *Notenkopfkeramik*) to the Želiezovce Group at about 5200 cal BCE (Griffiths, 2013). Úľany and Vlkas each yielded examples of both of these ornamental styles (see Chapter 3.2).

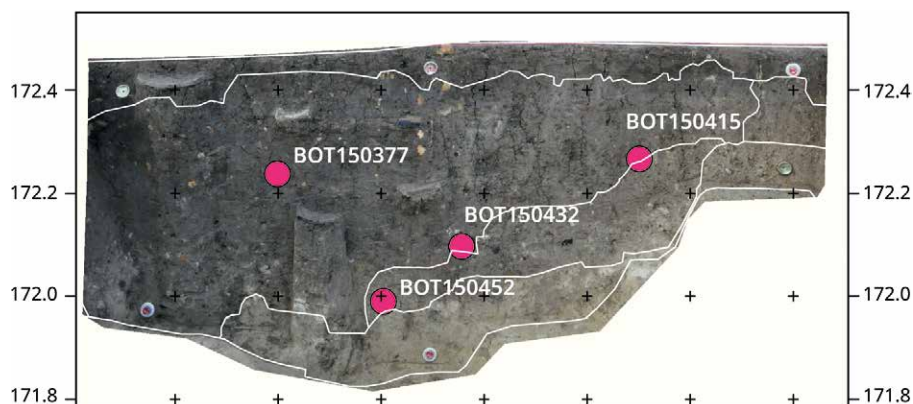


Figure 4.1.4. Vlkaš 'Do hľského chotára', Trench 15. South profile of quadrant 19, with the approximate location of botanical samples used for ^{14}C dating plotted into the profile.

For Úlany, the two dates from the area of the *Schlitzgrube* (ULA18_130187-1/Poz-109593; ULA18_130070-1/Poz-109591) are not associated with any ceramics, unlike is the case for the other two dates from Úlany (ULA18_130027-1/Poz-109590; ULA18_130018-1/Poz-109589), which stem from spit 3 in quadrant 5 and quadrant 9, respectively. Quite a number of ceramic fragments come from quadrant 5 of Object 1 (Fig. 3.2.3). The stratigraphic position links this sample to House 16/593. Regardless of the model (see above), this sample should date well before 5200 cal BCE, which is at odds with the ceramic sherds associated with it, as these bear mainly marks of an older stage of the Želiezovce group (see Chapter 3.2).

The two samples (VLK18_120054-1/Poz-109283; VLK18_120129-1/Poz-109587) from quadrants 1 and 9 from Vlkaš Object S12/1 are associated with music note head ceramics (Chapter 3.2; Fig. 3.2.4). In view of this association, the earlier range for these dates should probably be given precedence. Especially sample Poz-109283 is touching the wiggle at around 5200 cal BCE by only a small margin, which would fix this date quite firmly between 5200 and 5170 cal BCE.

Sample VLK18_150113-1 (Poz-109595) comes from Object S15/1, where ceramic sherds ornamented in the music note head style were found (Chapter 3.2; Fig. 3.2.5). This does fit with the ^{14}C date, which falls into a range between about 5200 and 5050 cal BCE.

Samples VLK18_150111-1 (Poz-109594) and VLK18_150458-1 (Poz-109525) both stem from Object S15/8. However, since they come from quadrants 4 and 8, which are in non-adjointing parts of the object, the samples were collected some distance apart (in this case 3.7 m). For both, the most likely dating range falls around 5000 cal BCE (c. 5040–4950 and 5040–4930 cal BCE, respectively, 68.3%). The ceramics (Chapter 3.2; Fig. 3.2.5), however, are of the music note head style.

For the northern part of Trench 15, samples VLK18_150444-1 (Poz-109575) and VLK18_150573-1 (Poz-109526), both from quadrant 17, are associated with a large fragment of a coarse vessel with lugs and ornamentation in the form of arched lines (Chapter 3.2; Fig. 3.2.6). The latter was found at roughly the same height as sample VLK18_150444-1 and may belong to the older phase of the LBK. The date of VLK18_150444-1 touches the wiggle at 5200 cal BCE but would still seem to be too young.

The remaining four samples, VLK18_150377-1 (Poz-109576), VLK18_150415-1 (Poz-109410), VLK18_150432-1 (Poz-109573) and VLK18_150452-1 (Poz-109523), come from quadrant 19 of Object S15/10, of which especially the upper levels were very rich in ceramics, as was already apparent in the profile (Fig. 4.1.3). These ceramics are of early Želiezovce type, which fits with the model outlined above (Chapter 3.2; Fig. 3.2.6).

Comparison with the orientation of houses

The overlapping Houses 16 and 593 from Úlany have an orientation of 16.1° and 11.5°, respectively. According to the correlation between orientation and chronology

Feature	Date(s)	cal BCE (1 SD)	Ceramic	House orientation
S13/1	Poz-109590, Poz-109589	5307–5216 5307–5213	older stage of the Želiezovce style	House 16: 16.1°; h. 593: 11.5° = 5110–5060 cal BCE
S12/1	Poz-109283, Poz-109587	5200–4941 5208–5054	music note head style	House 212: 22.1° = 5190–5150 cal BCE
S15/1	Poz-109595	5211–5066	music note head style	House 205: 27° = 5200 cal BCE
S15/8	Poz-109594, Poz-109525	5044–4947 5036–4941	music note head style	4° = 5000 cal BCE
S15/quadrant 17	Poz-109575, Poz-109526	5202–4952 4998–4856	older LBK	20° = 5150 cal BCE
S15/quadrant 19	Poz-109576, Poz- 109410, Poz-109573, Poz-109523	5208–5045 5208–5054 5028–5045 5204–4954	older stage of the Želiezovce style	House 201: 20.1° = 5150 cal BCE

Table 4.1.4. Úľany nad Žitavou 'Dolné diely' and Vlkaš 'Do hľuského chotára'. Comparison of dating by ¹⁴C, ceramics and house orientation.

(Müller *et al.*, 2020: 494, fig. 6.1.1; Müller-Scheeßel *et al.*, 2020a), this would suggest a dating between 5110 and 5060 cal BCE, which is in accordance with the ceramics but not with the radiocarbon dates.

House 212, in Trench 12 from Vlkaš, showed an orientation of 22.1° (Chapter 3.1). This can be equated with a date range between 5190 and 5150 cal BCE (Müller *et al.*, 2020: 494, fig. 6.1.1). If we accept the older date range of the two samples from Object S12/1, this would fit nicely with both the ceramics and the absolute dating.

Sample VLK18_150113-1 (Poz-109595) comes from Object S15/1 and is thus associated with House 205 (Chapter 3.1). Its orientation, of 27°, would indicate a dating around 5200 cal BCE. This range is covered by both the ¹⁴C date and the ceramics (music note head style).

The northern part of Object S15/8 from Vlkaš seems to be a lateral long pit of a house that would be oriented at an angle of about 4°. This translates to an absolute chronological age shortly after 5000 cal BCE (Müller *et al.*, 2020: 494, fig. 6.1.1). Samples VLK18_150111-1 (Poz-109594) and VLK18_150458-1 (Poz-109525), with their dates around 5000 cal BCE as well as their Želiezovce-type ceramic sherds, would be in accordance with this notion.

Samples VLK18_150444-1 (Poz-109575) and VLK18_150573-1 (Poz-109526) both come from quadrant 17 in Object S15/10, which in a lower part revealed the end of a probable lateral long pit. Because of the limited amount of exposure of this long pit, its exact orientation is difficult to determine. It seems to be in the range of 20°, which would argue for a date of about 5150 cal BCE. Similar to the situation in Trench 12, the upper limit of 5200 cal BCE is covered by sample VLK18_150444-1 but certainly not by sample VLK18_150573-1, which would be too young.

The four samples, VLK18_150377-1 (Poz-109576), VLK18_150415-1 (Poz-109410), VLK18_150432-1 (Poz-109573) and VLK18_150452-1 (Poz-109523), from quadrant 19 are associated with the western lateral long pit of House 201, whose orientation was determined to be 20.1°. This would support a dating around 5150 cal BCE, which could accommodate both the Želiezovce ceramic finds and the ¹⁴C dates.

The comparison of dating by ¹⁴C, ceramics and house orientation (Table 4.1.4) gives the impression that, generally, the three can be brought in accordance with each other. This, however, is also due to the fact that especially ¹⁴C and ceramics offer only very broad dating ranges. At least in the case of S12/1, the ceramics support the earlier dating range of the ¹⁴C dates, which would fit very well with the determined orientation of the house. Also, in the case of quadrant 19 and Object 1 from Trench 15, the three ageing methods do not contradict each other. In contrast, for Object S13/1, the ¹⁴C dates give a date for the feature that is older than the orientation of the long pits and the ceramics would suggest. For Object S15/8, the ceramics seem much too

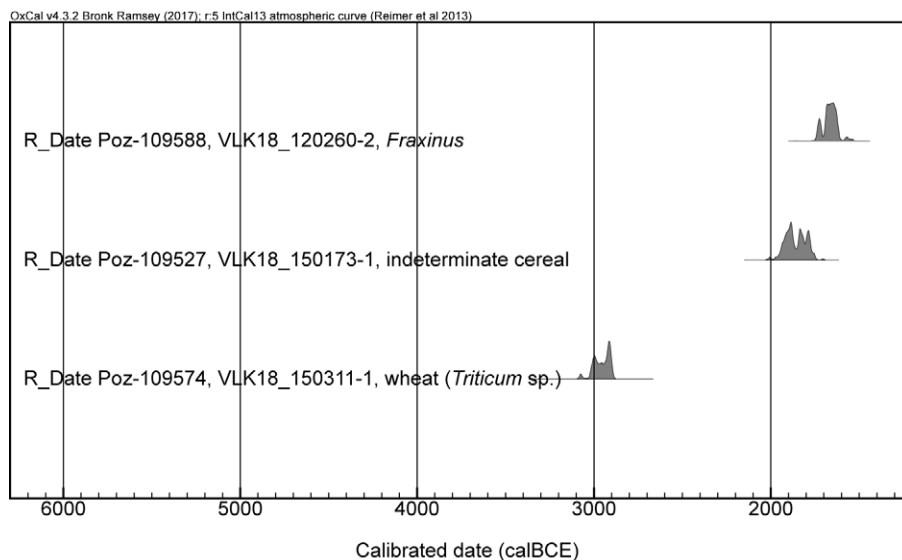


Figure 4.1.5. Vlkaš 'Do hľského chotára'. Post-Neolithic ^{14}C dates (cf. Table 4.1.1), calibrated with OxCal 4.4 (Bronk Ramsey, 2009).

old for both the ^{14}C dating and the orientation, and for quadrant 17 of Trench 15, the results from the three methods are not in accordance at all.

Post-Neolithic dates

Of the dated samples, only three are clearly post-LBK, even post-Neolithic. One falls into the Eneolithic, and the other two fall in the Early Bronze Age (Fig. 4.1.5).

Sample VLK18_150311-1 (Poz-109574) is of Eneolithic age. The sampled material should probably be considered as contamination due to bioturbation, as there was no sign of a later pit. This interpretation is supported by the results from sample VLK18_150111-1, which was taken from a higher level, at a horizontal distance of only 0.5 m, and yielded a clear LBK date.

Sample VLK18_120260-2 (Poz-109588) comes from a pit that was already recognised as post-LBK during excavation and contained pottery assigned to the Baden culture (Chapter 3.2). The date, however, falls in the Early Bronze Age.

Sample VLK18_150173-1 (Poz-109527) also returned an Early Bronze Age date. It can be associated with a small pit that was dug into Object S15/8.

Conclusions

While the excavated features at Úlany predate the majority of those in Vráble, the features at Vlkaš are contemporaneous with most of the features excavated in Vráble so far. The few younger dates also show that at least Vlkaš was also frequented in the Eneolithic and the Early Bronze Age.

The older dating of Úlany fits nicely with the chronology of the ceramics, among which decorative elements of the younger LBK (*Notenkopfkeramik*) and the older Želiezovce group were observed (Chapter 3.2). However, the question remains why such older dates are missing for Vlkaš, as the ceramic investigation at Vlkaš also identified typological traits tied to both the younger LBK and the Želiezovce group.

In the classification according to the orientation of houses in the magnetic maps, the settlement of Vlkaš would end about 5050 cal BCE. However, some of the ^{14}C samples seem to date younger than that, and also in the excavated area, a case can be made that there are houses of an orientation indicating a very late date. This shows that, apparently, the youngest houses are not very visible in the magnetic

picture, either because they are not filled with magnetic material or because they were erected in areas – such as that of Trench 15 – where a dense location of houses existed previously.

In general, the dating by ^{14}C , ceramics and house orientation can be brought in accordance with each other. This, however, is also due to the fact that especially ^{14}C and ceramics offer only very broad dating ranges. Where narrower age ranges exist, some are in good accordance with each other, but others are not. This certainly merits closer scrutiny in the future. As the number of ^{14}C dates is too low to check for internal consistency, it might be useful to obtain more dates from problematic contexts. Additionally, the ceramics could be checked for refitting sherds as a proxy to rate the quality of the typological dating of contexts, so that contexts with at least some refitted sherds with diagnostic ornamentation would get a higher rating in terms of the certainty of the dating.

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4.2 The absolute dating of the Late LBK

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Abstract

In order to investigate the absolute chronological limits of the Late *Linearbandkeramik* (LBK), the ornamentation of ^{14}C dated pottery sherds were subjected to correspondence analyses. Since the spatial dimension emerged as a decisive factor in the pan-European analyses, the western and eastern regions of the LBK were treated separately. In both cases, one of the axes was identified as the temporal dimension and used as additional information in subsequent Bayesian calculations on ^{14}C dates using OxCal. Both models produced plausible results. The analysis showed an earlier beginning of the western Late LBK than the eastern one and a later end, which should be further investigated and substantiated or corrected by more detailed analysis. On a more general level, it turned out to be very difficult to link published ^{14}C dates securely with certain pottery sherds. Therefore, in the future excavation reports should strive to make their results more transparent with more thorough interlinkages to enable meta-research as the one presented here easier or even possible.

Keywords: C14, correspondence analysis, depth model, ceramic ornamentation

Aims and rationale

For a long time, because of the lack of reliable ^{14}C dates for the *Linearbandkeramik* (LBK) culture, estimates relied on typochronological considerations of the eponymous, often richly decorated pottery (Modderman, 1977: 123–128; Pavúk and Husák, 1994: 64–66). Especially work on the LBK in the Rhineland, in Germany, employed a highly sophisticated typochronological methodology to come to a fine-grained subphasing of the LBK (Stehli, 1989). Scholars following this methodology claimed that the ensuing chronology achieved a resolution of ‘house generations’, each equalling circa 25 years. Considering this orthodoxy, it comes as no surprise that a recent survey on early dates of the LBK (Jakucs *et al.*, 2016) that shed some doubts on this taken-for-granted chronology stirred considerable interest and ensued in a heated debate (Bánffy *et al.*, 2018; Strien, 2017; 2019).

In view of the large number of ^{14}C dates generated for the LBK settlements in the Žitava Valley (Meadows *et al.*, 2019; see also Chapter 4.1), it seemed also timely to

Category	Quality	Sample and context	Sample and ceramics
1	very good	Closed context with rapid backfilling	Dating or organic material directly on/ in the pottery (organic deposition/leanness)
2	good	Graves, quickly filled context, postholes	Human bones from burials, food grains in ceramics, charcoal of short-lived materials
3	reasonable	Quickly backfilled pits or wells with stratigraphic information	Grain, joined bones, charcoals from short-lived materials
4	barely acceptable	Pit without information about the backfilling process or stratigraphic information	Unknown charcoal, single bones, pit contexts with clearly heterogeneous contains pottery

Table 4.2.1: Sample quality regarding the connection between archaeological context and ^{14}C dates.

consider the ^{14}C dates for the Late LBK and compare these with their typochronological position based on associated pottery. This is made possible by the formal statistical method of Bayesian modelling (see among others Tasić *et al.*, 2015; Bayliss *et al.*, 2015; Raczky and Siklósi, 2013; Czerniak *et al.*, 2016). Based on a correspondence analysis (CA) carried out with the R-package FactoMineR (Lê *et al.*, 2008), a depth model is calculated with the help of the program OxCal, version 4.4.4 (IntCal20-Curve; Bronk Ramsey, 2008; Bronk Ramsey, 2017; Bronk Ramsey and Lee, 2013; Reimer *et al.*, 2013), which summarises the temporal development of the LBK with regard to its eastern and western area.

The aim is to come to reliable and comprehensive absolute time measures of the Late LBK by coupling pottery typology and radiocarbon dating. The database along with R- and Oxcal-code are available online (DOI: 10.57892/100-309).

Sample quality

To answer the research question outlined above, it is necessary to date the artefacts as precisely as possible, which requires a particularly critical examination of both the archaeological context as well as the materials used for dating. Table 4.2.1 shows the categorisation of the data, by which the quality of the information can be assessed. This assessment is based on two criteria: 1. the relationship between the sample and the archaeological context to be dated, and 2. the sample material itself.

Sites included

The homogeneity of the find spectrum between LBK sites facilitates the comparison of the absolute dating with the typochronological classification (*e.g.* Pavúk and Husák, 1994: 262–263). The sites included in this analysis will be briefly presented from east to west in order to lay a general foundation for later discussion (Fig. 4.2.1). It must be taken into account that some of the sites enjoy a long tradition of research, while others were only discovered a few years ago. The description of the sites also serves to briefly present the contexts and the ^{14}C dating used.

Poland

The two easternmost sites included are the settlements of Tominy and Olszanica.

Tominy

In 2006, the first rescue excavations were carried out in Tominy as part of construction work. By 2009, about one hectare had been excavated, revealing features from the Palaeolithic (Szeliga and Zakoscielna, 2009) to the modern time with intensive settlement activity during the LBK phase. The range of Neolithic finds includes LBK sherds as well as units with typical Želiezovce motifs and a few fragments with

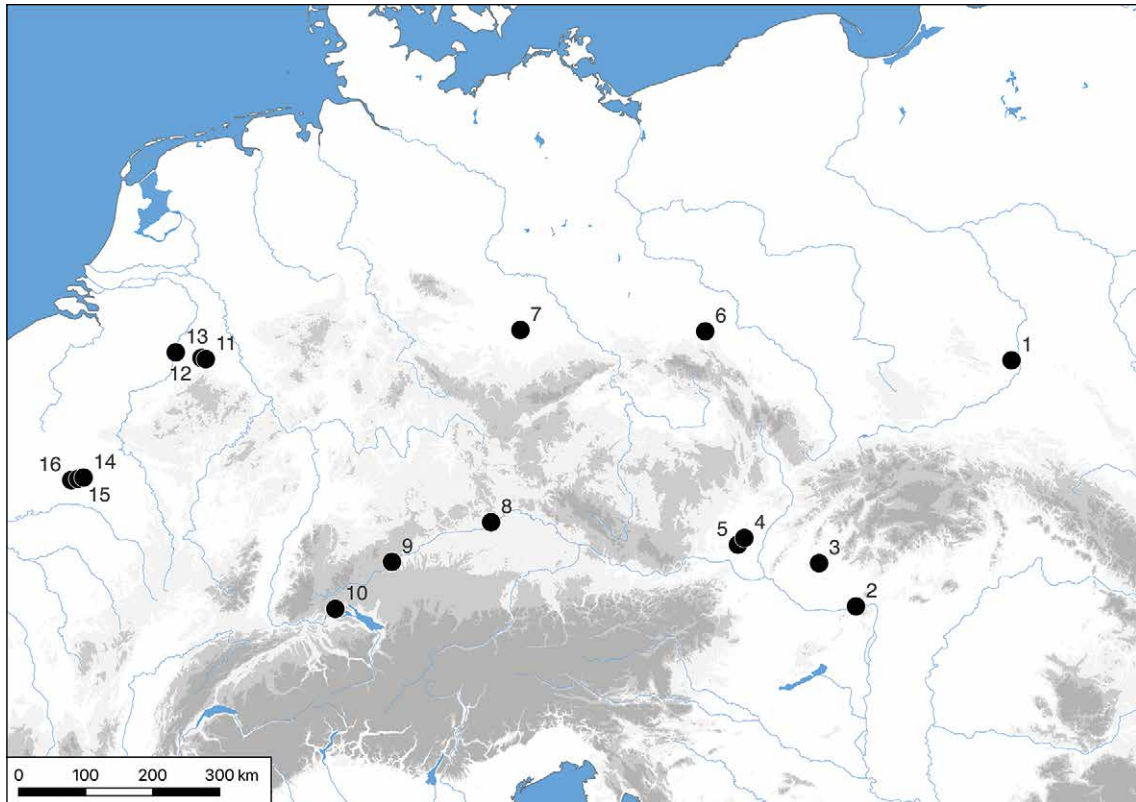


Figure 4.2.1: Sites with satisfactory quality regarding the connection between typochronologically relevant ceramic sherds and ^{14}C dates. 1 Tominy; 2 Štúrovo; 3 Nitra; 4 Kleinhadersdorf; 5 Schletz; 6 Olszanica; 7 Eythra; 8 Hienheim; 9 Ulm-Eggingen; 10 Hilzingen; 11 Aldenhoven-Niedermerz; 12 Langweiler 9; 13 Elsloo; 14 Menneville; 15 Berry-au-Bac; 16 Cuiry-lès-Chaudardes. The numbers 1–6 encompass the sites of the eastern area and the numbers 7–16 those of the western area.

motifs of the Bükk spectrum (Szeliga, 2017: 439). The samples taken for the ^{14}C dating are from larger pits. The sample material consists for Poz-31596 of charcoal, for Poz-31595 and Poz-49591 of a substance addressed as ‘probably wood tar’. The LBK settlement of Tominy was occupied in the period from 5100 to 4800/4700, which corresponds to the time span of the Late LBK in central Europe (Pavúk and Husák, 1994). The dating range of the site, however, is younger than assumed by some researchers for the end of the LBK in its eastern distribution area (Oross and Bánffy, 2009). However, this may also be due to the newly obtained ^{14}C dates that were not included in the 2009 analysis.

Olszanica

The second Polish site, Olszanica, Lesser Poland, is also a settlement excavated between 1967 and 1973 (Milisauskas, 1975; Pavúk and Husák, 1994: 230). In addition to LBK material, finds in the excavated area of just over 1.5 hectares can be assigned to the Lengyel culture, the Funnel Beaker culture, the Corded Ware culture and the Tisza culture. The pottery decoration is particularly characterised by incised lines, which are mostly found only on the outside of the vessel, more rarely also on the inside. Additional elements are notches and punctures, which are in the tradition of note-head ornamentation, but also longer notches in the Želiezovce style (Milisauskas, 1975). The charcoal material for sample M-2011 was taken from pit 6-67, sample M-1986 came from feature 1-67 (Griffin and Crane, 1970; Vogel and Waterbolk, 1972). In addition to 19 sherds corresponding to the spectrum of note-head

decorations, it contained 69 fragments decorated according to the Želiezovce style. The author's attribution of the find to the Želiezovce group is in accordance with the quantitative ratios (Milisauskas, 1975). Nevertheless, for the purposes of the present paper, the number of note-head ceramics is considered sufficient to include the note-head ceramic fragments and the ^{14}C dating in the analysis. A total of eight ceramic fragments had been recovered from pit 1-67 to sample M-1986, two of them belonging to the Želiezovce group. Accordingly, six were assigned to the note-head pottery (Milisauskas, 1975).

Slovakia

Štúrovo

Štúrovo is the only one of two sites from Slovakia¹. Excavations of the two-phase settlement began in 1956. The older phase comprises the younger LBK and the younger the Želiezovce group. Noteworthy are three large buildings, which the excavators place in the older phase of occupation, and storage pits, which fall into the Želiezovce period (Pavúk and Husák, 1994: 264). The samples Bln-557, object 215, and Bln-558, object 229 (Kohl and Quitta, 1970; Breunig, 1987: 13), which were used in the present study, come from two of these pits.

Nitra

The cemetery was discovered and excavated in the 1960s (Pavúk, 1972). It contained about 75 burials, which contained modest burial goods. The ceramics among the latter are attributed to a younger phase of the LBK and the beginnings of the Želiezovce group (ibid. 83). Of the ^{14}C dates that were later commissioned within the project *The First Farmers of Central Europe* (Bickle and Whittle, 2013; Griffiths, 2013), six come from burials with decorated vessels and are thus included in this study.

Austria

Austria is also represented by two sites in the analysis, namely Schletz/Asparn an der Zaya (see among others Windl, 1994) and the cemetery of Kleinhadersdorf (Neugebauer-Maresch and Lenneis, 2015), both in Lower Austria.

Asparn-Schletz

The Schletz site consists of an LBK settlement surrounded by a ditch, in which about 100 skeletons were found. The duration of occupation is assumed to be from the oldest to the youngest LBK. The end of the settlement is brought into connection with the numerous dead bodies in the ditch. By 2018, from 23 of the individuals ^{14}C samples had been taken, two further dates stem from botanical material, placing the end of the settlement around 5040 cal BCE (Riedhammer, 2018). Unfortunately, no diagnostic pottery fragments can be associated with the skeletons. However, the grain samples ETH-13289 and ETH-13290 taken from the well of the settlement can be linked to two vessels via the backfilling of the context (Windl, 1994: figs. 7–8; Lenneis and Stadler, 1995: 217).

¹ With over 200 dates, the LBK sites in the Žitava Valley have yielded more dates than the rest of the LBK sites included in this study together. Because of their sheer amount, they would overshadow any other site. Therefore, it was decided to exclude the dates of the Žitava Valley from the present analysis.

Kleinhadersdorf

Kleinhadersdorf is located near the Moravian border on the north-western edge of the Austrian LBK. The first finds were recorded as early as 1911. Several excavation campaigns followed until 1991 (Neugebauer-Maresch and Lenneis, 2015: 29). A total of 99 burial pits were uncovered, 34 of which contained ceramic artefacts belonging to the LBK. Of the 11 available radiocarbon dates, seven (VERA-2164, VERA-2165, VERA-2167, VERA-2170, VERA-2171, VERA-2172, VERA-2173) have been included (Neugebauer-Maresch and Lenneis, 2015: 149, tab. 36). Based on the oldest pottery found, the occupation of the cemetery begins with the transition of Phase I to Phase II and ends in Phase III of the Moravian LBK. The most frequent decorative elements are note-head motifs, corresponding to phases II a–c. In the latest phase, there are also pottery fragments with decorations of the Sarka type and the Želiezovce group (Neugebauer-Maresch and Lenneis, 2015: 191).

Germany

Most of the sites dealt with in this paper are located within present-day Germany. With 24 samples, this geographical area also provides the largest share of ¹⁴C dates.

Hienheim

The settlement site of Hienheim is the only site from Bavaria included. Modderman began an excavation campaign there in 1965 (Pavúk, 1994: 229), after the site had been discovered by chance finds in 1955 (van de Velde, 1979: 154). The site yielded finds from the LBK to the Charmer Culture on an area of ¾ hectare, with 22 houses attributable to the LBK with seven differentiable ceramic phases (van de Velde, 1979: 154–155; Riedhammer, 2018). Eight conventional radiocarbon dates were taken from the settlement, but their incorporation into the relative typochronological sequence of the site seems quite difficult (de Grooth, 1994: 357, tab. 1; Riedhammer, 2012: 72). Except for sample GrN-5870, measured on charred peas, only charcoal was sampled, which was potentially subject to an ‘old wood effect’ (Riedhammer, 2012: 72). It should be noted for sample GrN 5780 that the associated pit 414 showed a separation into two features. At the time of publication, it was not yet possible to differentiate between the two. Based on the ¹⁴C dating, matching pottery fragments between pit 414 and other pits belonging to the same building, sample GrN-5870 was assigned to the later LBK House 31 (Modderman, 1977: 33, 39). In addition to sample GrN-5870, three of the charcoal samples also date to the middle and late LBK. The others fall into the Middle Neolithic occupation phase or are even younger. The pottery typology of the site further supports the observation that follows from the dating, namely that there is a hiatus between the Old and Middle Neolithic settlement and the subsequent Late Neolithic activity. The end of the LBK can thus be fixed for Hienheim to a period around 5030 BCE (Riedhammer, 2018: 76).

Eythra

At the Eythra site in eastern Germany, activities lasting more than 700 years can be traced over an area of 30 hectares uncovered during the excavations. According to typochronological investigations of the pottery, the settlement of the oldest LBK was slightly shifted in the subsequent phase (Mecking *et al.*, 2013; Veit *et al.*, 2016: 149). The LBK building features consist of 300 houses, a triple circular ditch and an earthwork (Mecking *et al.*, 2013) as well as two wells that are dendrochronologically datable to 5098/5097 den BCE (Veit *et al.*, 2016: 120) and 5231–5211 den BCE (Mecking *et al.* 2013; Veit *et al.* 2016: 147). The samples and pottery of the analysis were taken from

well 17 (5098/5097 BCE), the surroundings of which had already been used during the older LBK. The finds contained in the well consist of inorganic and organic material, more precisely of, among other things, 197 ceramic sherds and archaeobotanical as well as archaeozoological remains (Veit *et al.*, 2016: 159). Within the well, two sherds with organic deposits were found (find numbers 130 and 153), from which samples were taken for radiocarbon dating (MAMS-27131 and MAMS-27132, Veit *et al.*, 2016: 120).

Hilzingen

The LBK occupation at Hilzingen has been known since 1971 (Fritsch, 1998: 11) and the excavations covered an area of about one hectare (Fritsch 1987). The site belongs to the regional group of the south-western LBK. Following W. Meier-Arendt's chronology, settlement begins in the middle phase of the LBK (Fritsch, 1998: 173), whereby a contemporaneity with Late Mesolithic groups can be assumed (Fritsch, 1998: 176). The latest phase of the LBK is no longer represented on the site (Fritsch, 1998: 174). In the course of the excavation carried out in 1985, various pottery fragments were recovered in addition to archaeobotanical and -zoological finds. The decoration elements of the fine pottery, especially incised lines, stitch patterns, impressions and individual stitches, allowed it to be dated to the later LBK. However, there are also isolated fragments with older stylistic elements. Based on of the organic materials (charcoal and grain), sample material was taken for 10 radiocarbon dates. On the basis of these, the settlement could be dated to the period between 5300 and 4700 BCE (Fritsch, 1987). Eight of these samples have been integrated into the present analyses: Hd-9905-9732, Hd-9906-9733, Hd-9907-9734, Hd-9908-9748, Hd-9909-9750, Hd-9911-9752, Hd-9912-9760, Hd-9913-9765 (Fritsch, 1998: 154).

Ulm-Eggingen

Ulm-Eggingen is another settlement of the LBK, which, however, was partly destroyed by the following cultural groups until the Middle Ages (Kind, 1989: 33). The excavations took place from 1982 to 1985. During this time, about 1/6 of the settlement (about 1.6 hectares with 34 house ground plans) was investigated, which began in the older LBK, had its peak during the middle phase, and again experienced a decline during the younger LBK. The majority of the finds are pottery sherds. On the basis of the decorated fine pottery, C.-J. Kind (1989) differentiated six stages. Some fragments with decorative elements of Bohemian note-head pottery were also found (Kind, 1989). The three recorded ¹⁴C dates Hv-13595, Hv-14727 and Hv-14730 were all taken from pits belonging to buildings and dated on charcoals (Kind, 1989: 408, tab. 179).

Aldenhoven-Niedermerz

The cemetery of Aldenhoven-Niedermerz was discovered through initial finds in connection with construction work. Following these, further construction and research campaigns were carried out until 1975 and about half a hectare (5600 m²) was uncovered. As a result, there is evidence of an uninterrupted sequence of burials from phase Ib (Flomborn) to phase IIc. The largest part of the burials are inhumations, whose associated pottery shows typical decorations for the middle and younger LBK (Dohrn-Ihmig, 1983). In addition to six secure cremation burials, 102 burial pits were documented. Of all burials, 49 had ceramic grave goods. The radiocarbon dates KN-1530, KN-2125, KN-2127, KN-2286, KN-2289 come from five of the grave contexts (Dohrn-Ihmig, 1983; Breunig, 1987: 128).

Langweiler 9

The settlement Langweiler 9 is located in the southern part of the Aldenhovener Platte as one of several settlement sites within a brown coal mining area. Major campaigns were carried out here between 1971 and 1973. In the course of these, an area of about 4 hectares was opened up, containing 17 houses and 425 LBK pits. In addition, a three-phase ditch was discovered. The pottery was typochronologically divided into 12 phases, from which an occupation of the settlement over almost the entire duration of the LBK in this region can be deduced (Kuper *et al.*, 1977: 334–337).

Only four charcoal samples from pit contexts (pit 1061, pit 1062, pit 1090 and pit 616-6) are available from the Langweiler 9 site. For pit 1061, it was possible to attribute it to a younger phase of the settlement. Despite a detailed chronological discussion (Kuper *et al.*, 1977: 131–138), no information is available on the backfilling of the pits. Thus, no further statements and qualitative subdivisions can be made here. An old wood effects cannot be excluded with certainty, especially since the dates even uncalibrated cover a relatively broad range from 7090 bp at the earliest (KN-2695) to 5930 bp at the latest (KN-2698).

The Netherlands

Elsloo

In 1970, the results of the first excavation in Elsloo were presented by P. J. R. Modderman (Modderman, 1977; Balkowski and Hartmann, 2015). Based on the ceramic decorations and changes in the house ground plans, it was possible to differentiate two phase, an older one (Phase I) and a younger one (Phase II), each of which has subphases a–d. In 2002 and 2006, excavations were carried out again under the direction of Porreij. A total of 102 datable house ground plans are now available. The nearby cemetery was assigned to phases IIc and IId by Modderman (Balkowski and Hartmann, 2015). Of the dates selected for analysis, two are from the settlement (GrN-2160; GrN-2310) and two from the cemetery (GrN-2311; GrN-5733; Vogel and Waterbolk, 1963; Lanting and Mook, 1977: 41).

France

The French LBK (Rubané Récent) is mainly found in eastern France along the upper reaches of the Rhine and in the Paris Basin. Individual sites were also discovered west of the Seine, for example Eure-et-Loire (Birkenhagen, 2003). However, the French sites included in this study, Menneville, Berry-au-Bac and Cuiry-lès-Chaudardes, are all located in the Paris Basin along the Aisne (Ilett *et al.*, 1982).

Menneville

The LBK settlement of Menneville was discovered in 1976 through aerial photography about 20 kilometres on the eastern side of the Aisne. Excavations in 1976, 1989 and 1990 provided evidence of pits on the six-hectare settlement area. Based on the associated finds, two settlement phases can be identified, dating to the later LBK of the Paris Basin. Most of the pits yielded human burials with little pottery (Thevenet, 2009). The three radiocarbon dates recorded were from Pit 1 and Pit 39 (Ly-1734 and Ly- 2323) (Delibras *et al.*, 1982; Breunig, 1987: 127, 130) and Pit 19 (Evin *et al.*, 1983; Breunig, 1987: 127, 130).

Berry-au-Bac

The Neolithic structures at Berry-au-Bac have been known since 1975. They consisted of two larger houses as well as a further possible house (Lassere and Dobouloz, 1981). The ceramic material found in the pits accompanying the houses as well as the building ground plans can be divided into two phases (Constantin, 1976). For both features, differences to those of the site of Cuiry-lès-Chaudardes, which lies in the immediate vicinity, can be noted. In the opinion of the excavator, Berry-au-Bac is therefore a younger phase of the Rubané récent. However, at the time of publication, no detailed analysis of the find material was available (Lassere and Dobouloz, 1981). The radiocarbon dating Ly-2327 from pit 124 (Evin *et al.*, 1983: 106; Breunig, 1987: 130) overlaps with the samples from Cuiry-lès-Chaudardes, although no statistical representativeness can be claimed here.

Cuiry-lès-Chaudardes

The Cuiry-lès-Chaudardes site covers a total area of six hectares, half of which has been excavated. The most common type of finds is pottery, decorated fine wares, undecorated fine wares and coarse wares. The most common decorative motifs consist of vertical bands of comb impressions, the same as an accompaniment to incised lines and incised lines in a V-shape made of comb strokes with two or three prongs. Accompanying incised lines and rim decorations of various designs of comb impressions and lines appear (Ilett *et al.*, 1982). According to studies by Lefranc 2007, the end of the LBK in the Paris Basin and the Rhine area dates approximately at the same time (Lefranc, 2007: 227), although elsewhere the relatively isolated location of the French sites to those of the Rhineland and the Netherlands is emphasised. Five samples were used here, Ly-1736, Ly-1737, Ly-2321, Ly-2333 (Evin *et al.*, 1983: 106; Breunig, 1987: 130) and Ly-2552 (Evin *et al.*, 1985: 434; Breunig, 1987: 130).

Ornamentation of ceramics

In order to be able to guarantee a supra-regional comparability of the partly very small fragments of the ceramics, the decorations were divided into coarse types of decoration patterns based on Kneipp 1998. The finer regional chronologies cannot be applied with sufficient agreement to the wide-ranging area under investigation.

A total of 16 motifs were distinguished in the analysis (Figure 4.2.2–4). These are further subdivided into single lines, different types of band decorations, decorations as well as note-head motifs and notches. A ceramic unit can have several of these features, or the entire motif on a sherd can consist of several individual motifs (cf. Poz-49591 Tominy [spiral, note head, lines]). Due to the high level of fragmentation, characteristics such as base and vessel shape were not taken into account, as information on these categories was not available in sufficient quantity.

According to Pavúk (1969), note-head motifs are decorations in the form of an incised line with a dimple placed on or in contact with it (Fig. 4.2.2, 1). Rim ornaments are all motifs placed in close proximity to the rim, although these are further assigned to one of the other styles of ornamentation (Fig. 4.2.2, 8). Filled bands can be filled with lines as well as with punctures but have a clear border of lines (Fig. 4.2.2, 4–5). Closed bands are also delimited at their ends by a marked line (Fig. 4.2.2, 5), while open bands show no lateral border (Fig. 4.2.2, 3, 6). Puncture bands and line bands, unlike filled bands, do not show bounding lines, but consist only of the features that define them (Fig. 4.2.2, 11–12). Line patterns are further differentiated between arcs (Fig. 4.2.2, 14), angles (Fig. 4.2.2, 8) and spirals (Fig. 4.2.2, 2). Ornaments that consist of several angular units and thus form an ornamental characteristic as a whole have been included as angle patterns (Fig. 4.2.2, 7). They thus differ from the

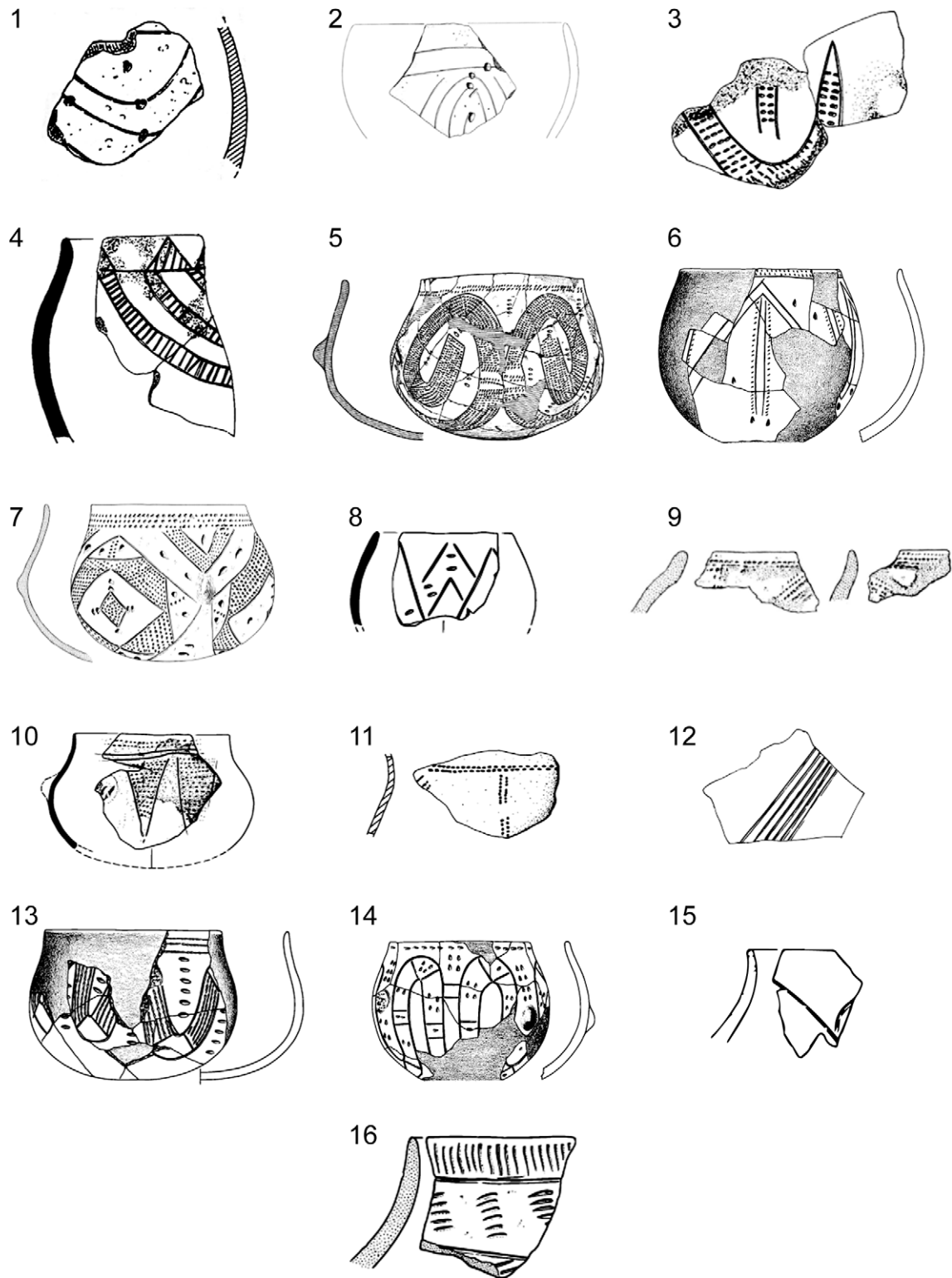


Figure 4.2.2. Examples of the motifs: 1 note head (Olszanica , pit 1-67; M-1986); 2 spirals (Tominy, feature 108; Poz-49591); 3 filled bands punctures (Cuiry-les-Chaudardes, pit 246; Ly-1737); 4 filled bands lines (Cuiry-les-Chaudardes, pit 246; Ly-1737); 5 closed bands (Aldenhoven-Niedermerz, grave 31; KN-2125); 6 open bands (Langweiler, pit 1090; KN-2695); 7 angle patterns (Elsloo, grave 98; GrN-2311); 8 angles (Hilzingen, pit 334; Hd-9911-9752); 9 rim ornaments (Elsloo, grave 98; GrN-2311); 10 extensive ornamentation (Hilzingen, pit 338; Hd-9913-9765); 11 puncture bands (Menneville, pit 39; Ly-2323); 12 line bands (Berry-auc-Bac, pit 124; Ly-2327); 13 band interruption (Langweiler, pit 1090; KN-2695); 14 arcs (Langweiler, pit 1090; KN-2695); 15 single line (Hienheim, pit 141; GrN-5870); 16 notches (Hienheim, pit 141; GrN-5870).

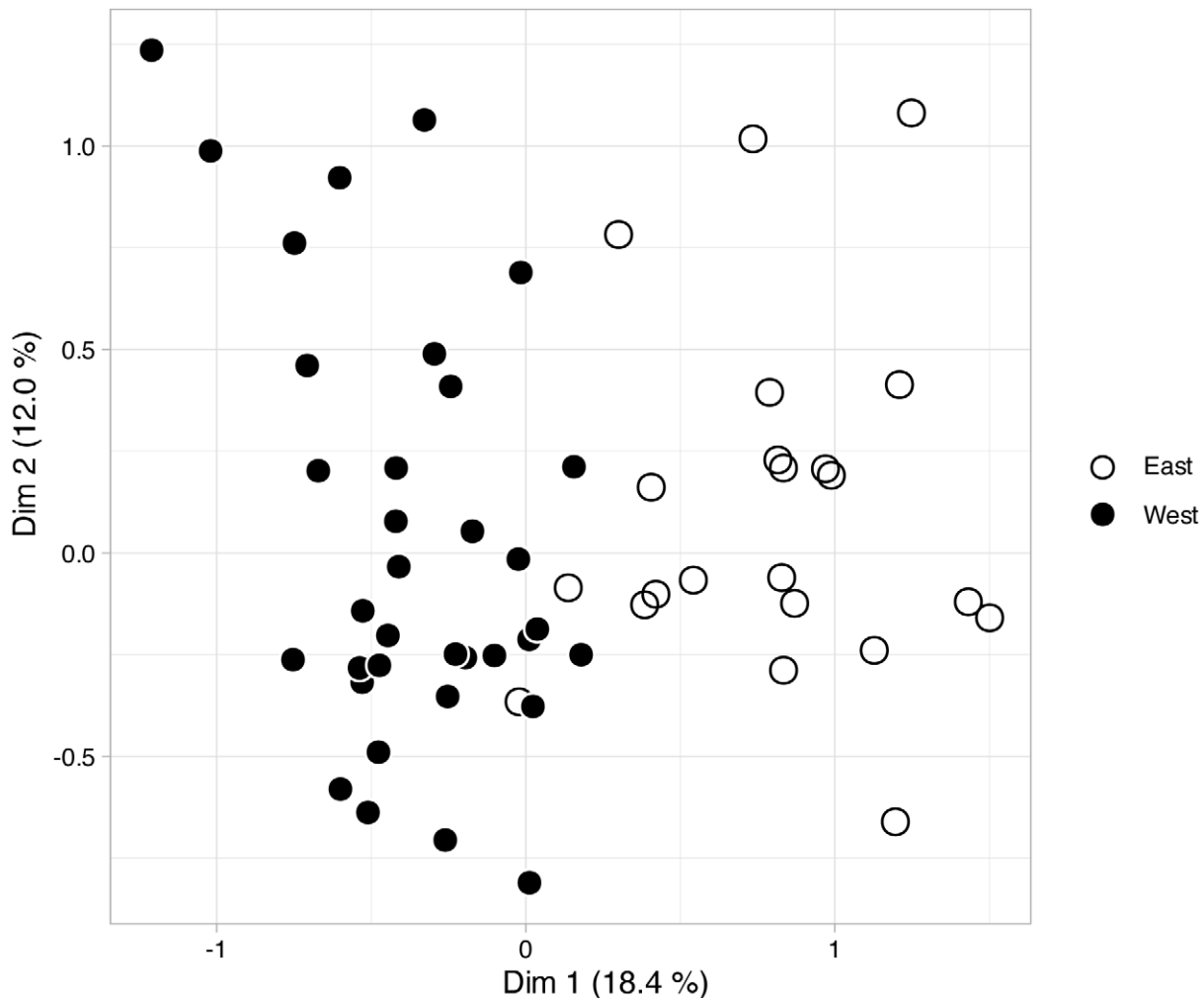
simple category ‘angles’, as these can also be formed from individual lines without boundaries. If the bands are interrupted by empty areas or alternative patterns, this is classified as band interruption. A further differentiation is made concerning the type of interruption (Fig. 4.2.2, 13 – blank fields). Single lines (Fig. 4.2.2, 15) and notches (Fig. 4.2.2, 16) are isolated decorative features, and no finer subdivision has been applied in the type of notching either.

Statistical analysis

Correspondence analysis is a well-established statistical, multivariate method to represent and describe relationships between at least two variables (Greenacre, 2007). In this work, it is used to order LBK pottery by similarity to each other. The less difference there is, the closer the artefacts are to each other in the graphical evaluation of the analysis. The results of the analysis are presented graphically in the form of a scatterplot oriented on two axes (principal axis) and can be evaluated for certain geometric patterns that allow a conclusive interpretation of the underlying data structure (Müller, 1997).

In order to be able to take into account the regional peculiarities and characteristics of the of the younger LBK, the data were subdivided and separate analyses were carried out for the eastern and western sites (Fig. 4.2.1) as a run with all data shows a nearly perfect separation along the first axis between western and eastern

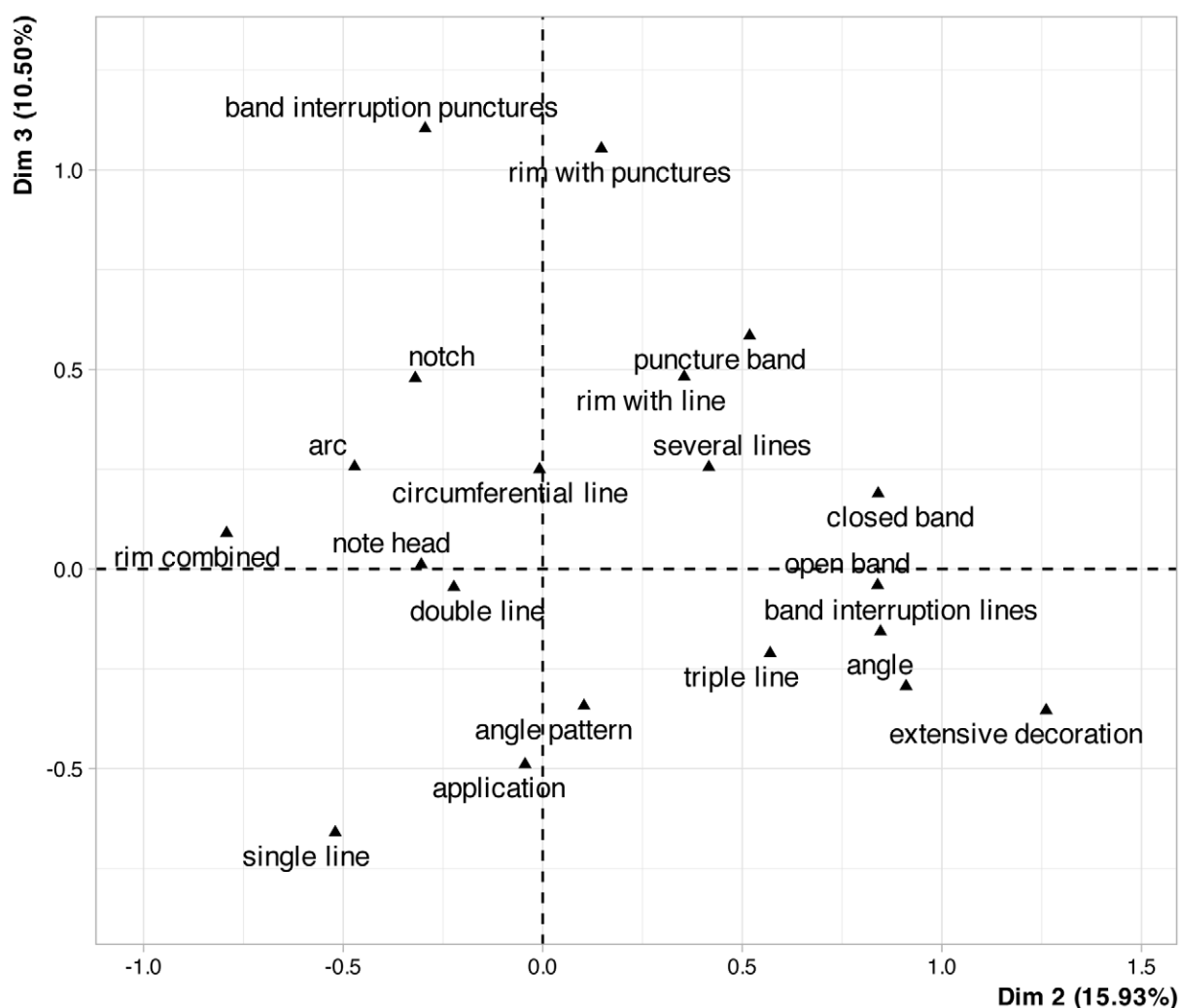
Figure 4.2.3. Result of the correspondence analysis of ceramic units and motives with a geographic separation according to Figure 4.2.1. Plotted are the 1st and 2nd axis which show a nearly perfect separation between ceramic units belonging to western and eastern sites, respectively, along the 1st axis.



samples (Fig. 4.2.3). On the basis of the existing typologies and relative chronological investigations, the arrangement of the decoration units was examined for chronological features and characteristic sequences. For the western samples, the 1st axis was identified as the axis that mainly carries temporal information while for the eastern sites, it is the 2nd (see below).

The motif of note-head ornamentation stands as a feature of the beginning of the Late LBK (Pavúk, 1980; 2012). This motif is found in an early position on the 2nd axis at -0.30 (Fig. 4.2.4). Along the axis, the increasing complexity of the decoration with lines can be traced from single lines to double lines to triple and multiple lines. According to Pavúk, double lines as decorative elements only appear in the late phase of the 'spLBK', but they are quite frequent in this phase. The triple lines, which also belong to the late phase, occur less frequently than the double line ornament (Pavúk, 1969). Accordingly, the triple lines are found at position 0.570. A corresponding development in terms of the increasing number of lines was seen by Meier-Arendt in 1966 in his work on the LBK in the Lower Main area (Meier-Arendt, 1966: 40). Single incised lines (single line at -0.520) also mark the beginning of the Late LBK in the eastern areas. There, they represent a further development of the previously frequent groove decoration (Pavúk, 2005). In the course of the younger LBK, following Pavúk's (1969) classification during the late phase, the circumferential line under the rim (here the motif 'rim decoration line' at 0.354) emerges (Pavúk, 1969). The position of the motif in the positive part of the axis thus corresponds to expectations. Accordingly, the

Figure 4.2.4. Result of the correspondence analysis of ceramic units and motives from the sites of the eastern area according to Figure 4.2.1. Plotted are the 2nd and 3rd axes as the main temporal gradients.



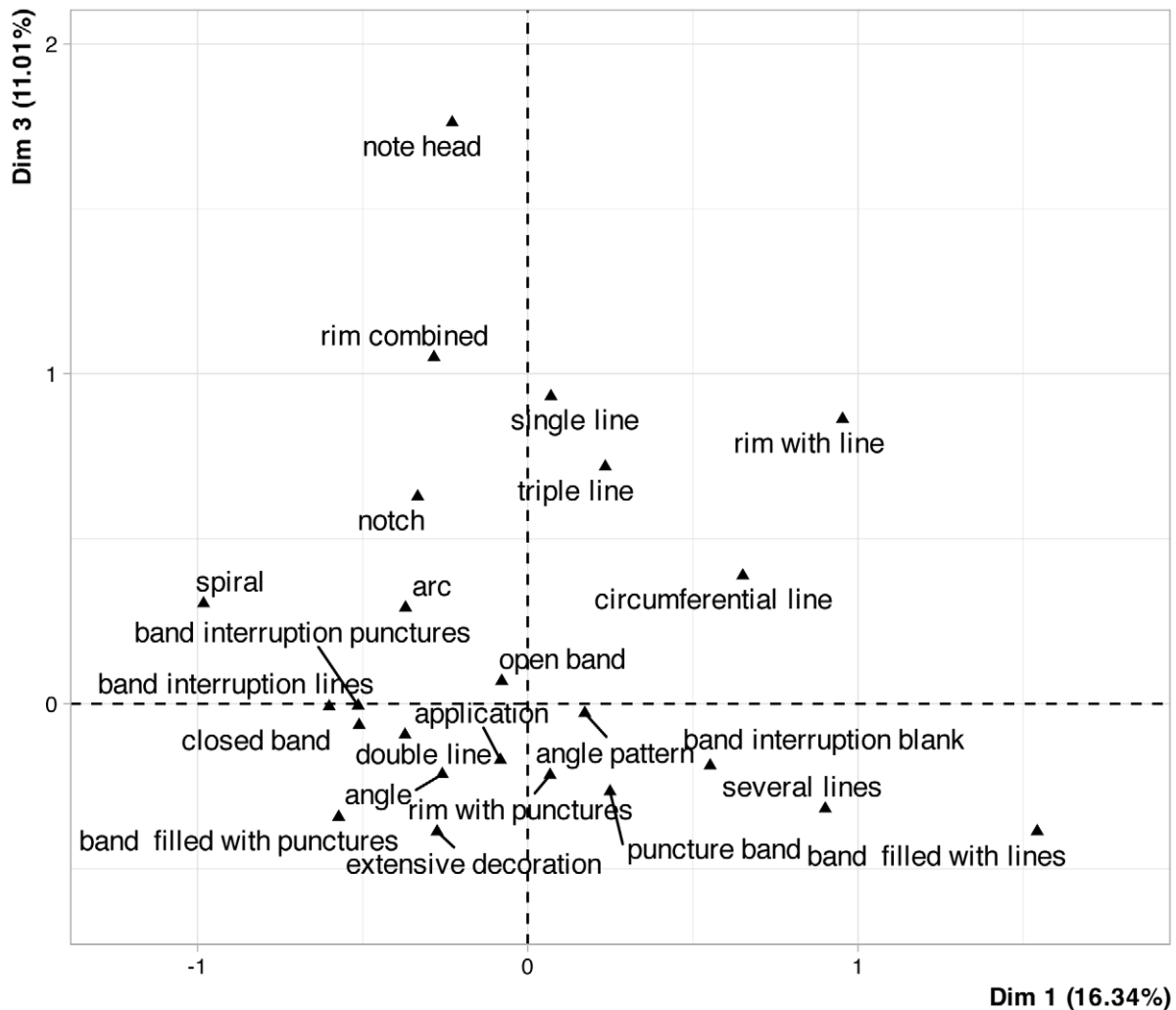


Figure 4.2.5: Result of the correspondence analysis of ceramic units and motives from the sites of the western area according to Figure 4.2.1. Plotted are the 1st and 3rd axes as the main temporal gradients.

interpretation of the 2nd axis as a carrier of temporal information is supported by the comparison with established typological divisions, with the negative part as earlier and the positive part as later. The distinct position of notches in the more negative area of the 2nd axis at -0.319 is striking.

On the 1st axis of the correspondence analysis for the western sites, a similar arrangement of motifs is found (Fig. 4.2.5). In his analysis of 1966, Meier-Arendt singles out the angular band as the most frequent linear motif of the Late LBK (Meier-Arendt, 1966: 38). The observation of angle bands (-0.259) in the negative half, according to the chronological interpretation to be ascribed to the early Late LBK, confirms the presumed chronological arrangement according to the eastern sites. Nevertheless, some details and specifications for the western regions should be mentioned. Bands filled with punctures (-0.572) can be seen as a variant of the filled band. Like the spirals (at -0.982), their occurrence is rather limited to the western area of the Late LBK and is considered to be a characteristic of the beginning late phase of the LBK (Pavúk, 1980). In accordance with the eastern area, the motif of rim decoration is also found on the western sites as a characteristic of the younger LBK. While the older phases, according to the typology of Meier-Arendt (1966), do not show any rim ornamentation in the Rhine area, these become more frequent with the beginning of phase 3. In contrast to the eastern area, however, rows of punctures are found in the west, which may additionally be accompanied by lines. The combination of both motifs can already be observed at the beginning of the Late LBK but becomes

frequent only in the course of further development. The interruption of the bands by rows of stitches (–0.513) also appears as an ornamental element in phase 3 according to Meier-Arendt (1966: 34). Plastic mouldings, which were included in the analysis as applications in the broadest sense, are rare in all phases. In general, they begin later in more western sites (Meier-Arendt, 1966: 35). Meier-Arendt notes an increase in straight-line decorative elements such as angular bands and open band motifs that give the impression of free-standing, angular lines (in the broadest sense, angles as flat decorations in the analysis). This change in the spectrum of motifs also coincides with the beginning of the 3rd phase, as the emergence of Late LBK (Meier-Arendt, 1966: 32). Following these observations, it is also legitimate for the western regions to interpret the 1st axis of the correspondence analysis carried out as an expression of the temporal dimension.

As stated above, the 2nd and the 1st axis, respectively, were found to carry chronological information. Building on these results, further Bayesian modelling will be done on the two regionally subdivided correspondence analyses.

Bayesian modelling

Based on a model for depositional computation, Bayesian modelling serves to establish a probability sequence of the dates and their contexts (Koch, 2000; Bronk Ramsey, 2006). In OxCal, the U_Sequence command takes the depth information of the respective samples into account. These z-values establish a relationship between the relative position of the sample with respect to the whole sequence and its (temporal) ‘stratigraphic’ position in the correspondence analysis (Bronk Ramsey, 2006). In our case, the z-values are taken from the results of the correspondence analysis. For both correspondence analyses, spatially differentiated according to eastern and western sites, the 2nd and the 1st axis was recognised as temporal gradient according to the arrangement of the motifs along it. The values of these axis are used as z-values and thus as ‘depth values of time’ linking the relative arrangement of the ornamental elements and the absolute dating of the radiocarbon dates. Unless otherwise noted in the following, the data mentioned are exclusively the datings of the 2 σ -range.

Result of the analysis for the eastern area

The output of OxCal contains the so-called A_{model} -value which allows an estimation of the quality of the underlying Bayesian model. Normally, a convincing model should reach a value of at least 60% as empirical threshold. To achieve this index value of at least 60, some of the 23 samples had to be excluded from the dataset (VERA-2164; VERA-2171; Poz-31595; VERA-2165; OxA-24582). Thus, an improvement of the index towards 83.7 (A_{model}) and 86.0 (A_{overall}) could be achieved. Two more of the remaining samples (OxA-22934; VERA-2167) also show insufficient agreement (26.6; 32.2). Nevertheless, the index of the model can be considered sufficient overall (Table 4.2.2).

The revised model sets the beginning of the Late LBK in the eastern area between 5290 and 5145 cal BCE (95.4%). The end falls in the period between 5193 to 4906 cal BCE (95.4%; Fig. 4.2.6). The median values are situated at 5224 and 5001 BCE, respectively. Thus, there are 378 years between the earliest beginning of the eastern late phase of the LBK and its latest end. The shortest possible span from the latest start date to the earliest end date is only 20 years. The median value for the span of the Late LBK in the eastern area is 223 years.

The depth model (Fig. 4.2.7) based on the calculation shows a very steep, linear progression, starting with the lowest date ETH-13289 to the sample GrN-5870, which is positioned highest in the depositional sequence. The dark and light blue colouring of the interpolated bar describes the probability distribution of the depositional

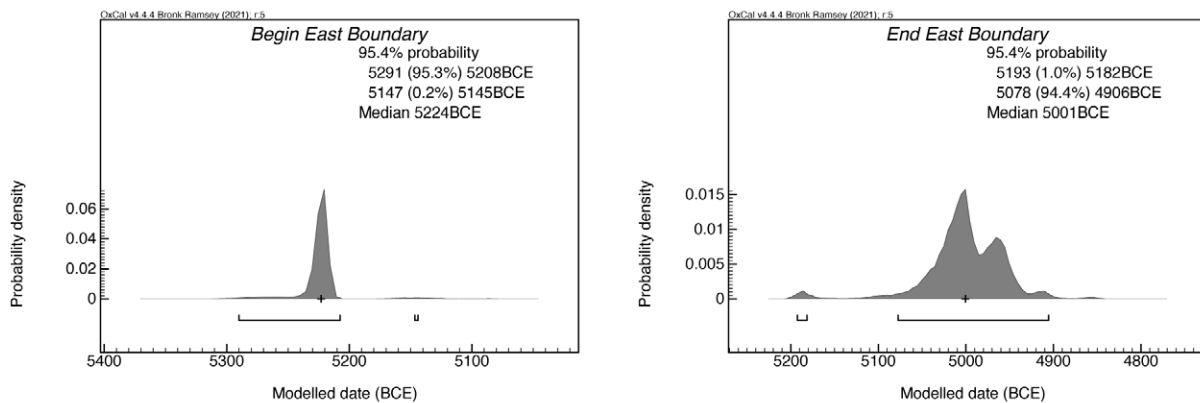


Figure 4.2.6. Calculated probabilities for the boundaries of the LBK in the eastern area.

	Unmodelled (95.4%)		Modelled (95.4%)		Index
Boundary Begin East			-5291	-5145	
R_Date OxA-24579	-5360	-5216	-5291	-5145	104.6
R_Date VERA-2173	-5302	-5047	-5280	-5142	90.3
R_Date OxA-24580	-5305	-5055	-5272	-5197	125
R_Date M-1986	-5470	-4450	-5236	-5172	113.8
R_Date M-2011	-5989	-4365	-5226	-5166	130.2
R_Date VERA-2172	-5211	-5001	-5217	-5156	115.7
R_Date OxA-24577	-5303	-5046	-5215	-5134	114.3
R_Date OxA-23793	-5303	-5051	-5213	-5122	122.2
R_Date OxA-22940	-5300	-5051	-5210	-5101	127
R_Date OxA-22934	-5209	-4945	-5210	-5099	26.7
R_Date OxA-24575	-5305	-5053	-5210	-5099	116.4
R_Date VERA-2167	-5209	-4847	-5209	-5092	32.3
R_Date ETH-13289	-5304	-4946	-5205	-5055	125.4
R_Date ETH-13290	-5309	-5010	-5205	-5055	118.6
R_Date Poz-49591	-5216	-4994	-5200	-4999	102.5
R_Date Bln-558	-5327	-4843	-5197	-4961	113.5
R_Date Poz-31596	-5208	-4849	-5197	-4953	114
R_Date VERA-2170	-5211	-4956	-5193	-4906	74
Span East			20	378	
Boundary End East			-5193	-4906	

Table 4.2.2. Result of the calculated *U_Sequence* model for the LBK of the eastern area. The two samples OxA-22934 and VERA-2167 show an insufficient index-value, but the Aoverall index is considered sufficient (*Amodel* = 83.7; *Aoverall* = 86).

process according to the calibrated ^{14}C dates. Accordingly, the range becomes wider in the areas of the model for which less data are available and thus expresses a corresponding uncertainty of the interpolation for these areas (Bronk Ramsey and Lee, 2013). The linear increase shows that a temporal development could be calculated from the relation between the results of the CA and the calibrated radiocarbon dates and that the model works. The steep slope obviously reflects the short temporal span that the model covers.

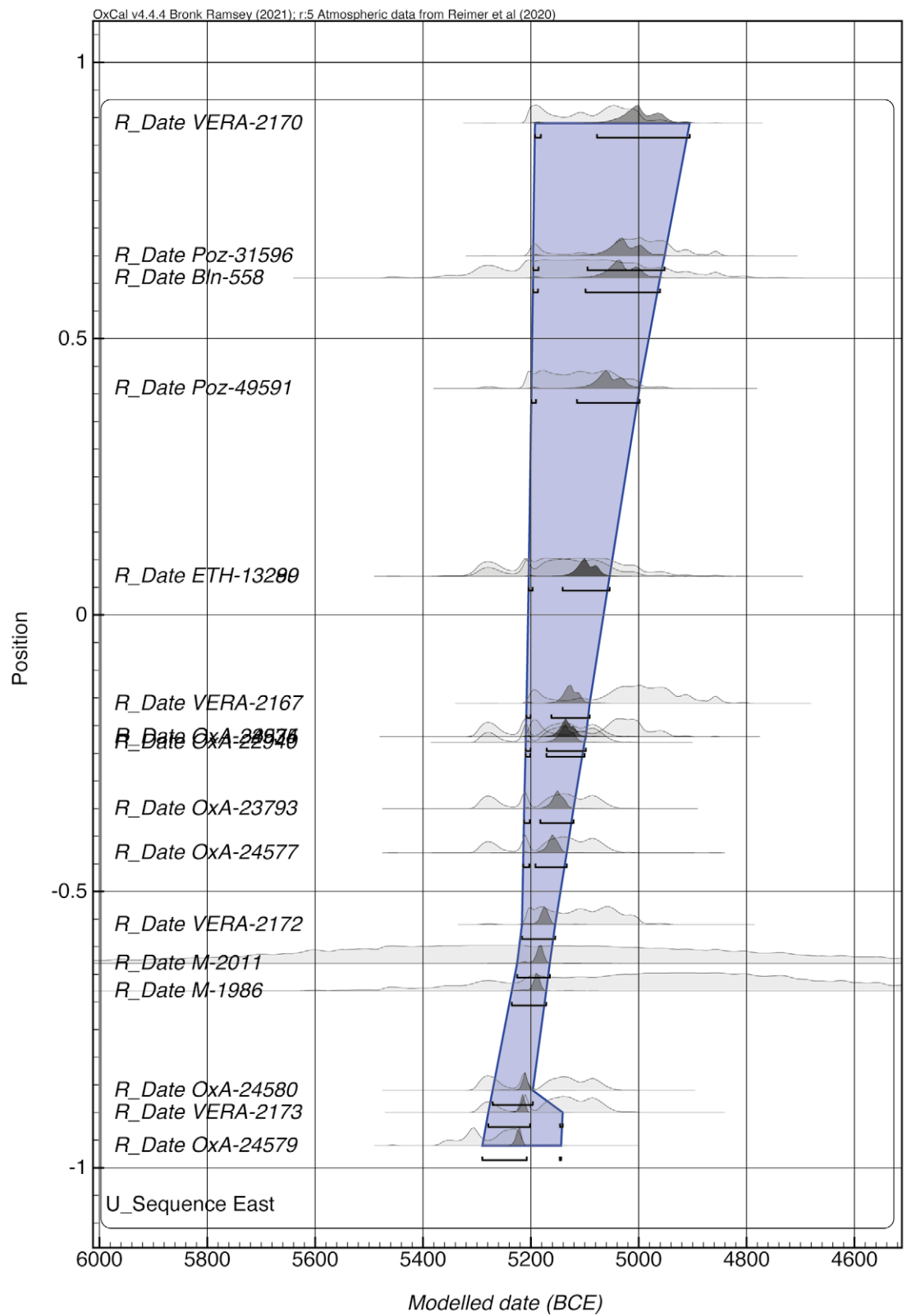


Figure 4.2.7. Calculated depth model for the LBK in the eastern area.

Result of the analysis for the western area

The western analysis required significantly more refinements and data exclusions to arrive at a sufficient A_{overall} index. In the final analysis, 24 of the original 36 data sets are still available (Tab. 4.2.3; Fig. 4.2.8). The strongly reduced model arrives at an

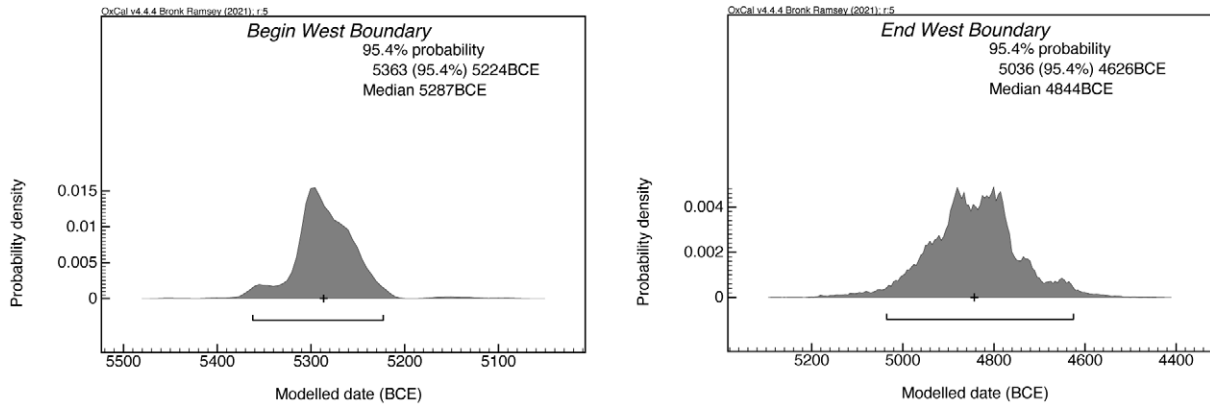


Figure 4.2.8. Calculated boundaries for the LBK in the western area.

	Unmodelled (95.4%)		Modelled (95.4%)		Index
Boundary Begin West			-5363	-5223	
R_Date MAMS-27132	-5365	-5211	-5363	-5223	96.9
R_Date GrN-5733	-5470	-5060	-5327	-5202	132.4
R_Date Hd-9911-9752	-5370	-4957	-5294	-5176	104.5
R_Date KN-2496	-5734	-5078	-5293	-5173	38
R_Date Hd-9909-9750	-5314	-4794	-5284	-5162	88.5
R_Date Hv-14730	-5465	-4706	-5274	-5152	112.9
R_Date KN-2286	-5462	-4800	-5270	-5150	120.9
R_Date Hv-14727	-5637	-4946	-5269	-5147	69.6
R_Date GrN-2160	-5300	-4856	-5266	-5145	106.3
R_Date KN-2488	-5312	-4998	-5245	-5121	106.4
R_Date Hd-9912-9760	-5301	-4838	-5221	-5092	106.3
R_Date Hd-9905-9732	-5459	-4853	-5199	-5057	129.3
R_Date Hd-9906-9733	-5312	-4461	-5196	-5053	81.4
R_Date GrN-5870	-5209	-4951	-5188	-5037	63.6
R_Date Hd-9908-9748	-5468	-5010	-5173	-5007	74.7
R_Date Ly-1737	-5622	-4617	-5161	-4980	129.4
R_Date KN-2127	-5996	-4904	-5136	-4924	41.7
R_Date Ly-2327	-5301	-4614	-5127	-4898	111.9
R_Date Ly-1734	-5481	-4551	-5125	-4895	128.8
R_Date KN-1530	-5308	-4957	-5107	-4850	45.5
R_Date Ly-2322	-5301	-4614	-5084	-4779	126.7
R_Date Ly-2321	-5299	-4457	-5064	-4712	127.3
R_Date Ly-2333	-5209	-4612	-5062	-4708	119.9
R_Date Ly-2323	-5209	-4356	-5036	-4626	113.8
Span West			187	698	
Boundary End West			-5036	-4626	

Table 4.2.3. Result of the calculated U_{Sequence} model for the LBK in the western area. The index values are considered sufficient ($A_{\text{model}} = 64.6$; $A_{\text{overall}} = 72$).

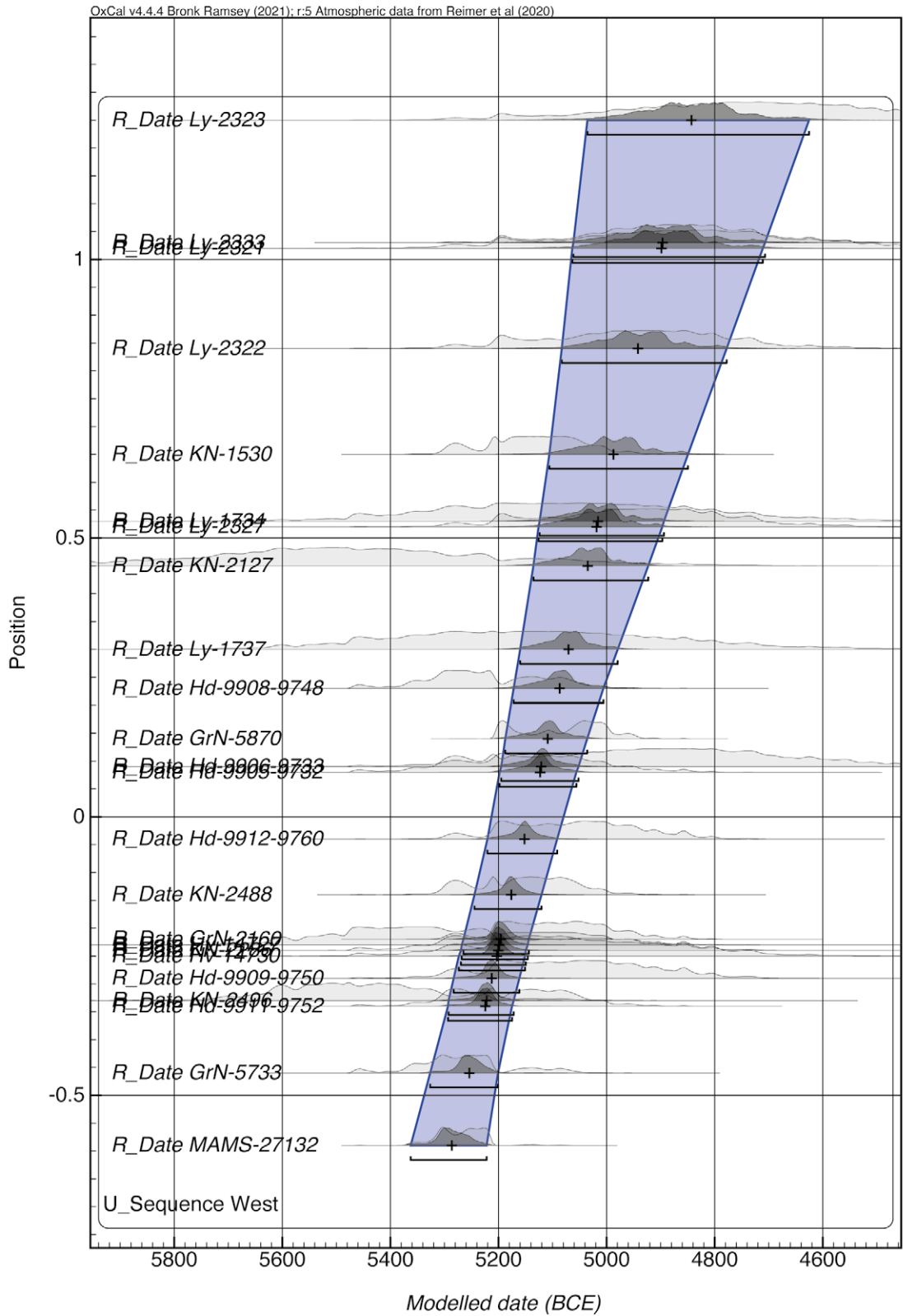


Figure 4.2.9. Calculated depth model for the LBK in the western area.

$A_{\text{index}} \text{ of } A_{\text{overall}} = 72.2$ ($A_{\text{model}} = 64.6$). Only the dates KN-2496, KN-2127 and KN-1530 do not meet the threshold of 60, they show an agreement of 37.9, 41.7 and 45.5, respectively.

The beginning of the Late LBK was calculated by Bayesian modelling in the range between 5363 and 5224 cal BCE. According to the calculations, the end of the phase falls into the range between 5030 and 4626 cal BCE. The earliest start of the western Late LBK and its latest end date, based on the analysis, thus differ by 698 years while the latest beginning of the phase and its earliest end date are 187 years apart. The median value is 445 years. Also, the median values of the boundaries – 5287 and 4834 cal BCE – differ by more than 400 years.

The depth model for the western area looks even more convincing than that for the eastern area as the band signalling the uncertainty is more gradual than that for the eastern area (Fig. 4.2.9). Accordingly, the estimated start and end points of the Late LBK are farer apart than those for the eastern area. However, it is to be pointed out that this is only possible because many of the dates in the western area show considerable standard deviations which makes it easier to accommodate them to the depth model.

Discussion and conclusion

The often-unsatisfactory connection between the observed ceramic ornaments and the radiocarbon dated samples has already been mentioned several times. A large part of the data used in the analysis carried out does not meet the standards established above with regard to sample quality (Tab. 4.2.1). Accordingly, the requirements set up for the data basis of the correspondence analysis as well as the Bayesian modelling could not be completely fulfilled. Nevertheless, in the following and taking into account the existing limitations, the results and their significance for future research are discussed.

The comparison of the boundaries of the eastern and the western LBK shows only partly agreement between the two hemispheres. While the Late LBK starts at about 5225 cal BCE in the eastern area, in the western area a start shortly after 5300 cal BCE seems likely. Likewise, while the end of the LBK in the east appears to happen around 5000 cal BCE, this date is by far not reached in the western area. However, in both cases, because the credible intervals are so wide it also cannot be excluded that both start and end of the Late LBK happened about the same point in time in the two hemispheres.

The earliest start date for the eastern LBK (5291 BCE) corresponds relatively well to the dates assumed by Bánffy and Oross in 2009 for the start of the Late LBK for the eastern area between 5300 and 5250 BCE. Other records also suggest a start during the last decades of the 53rd century. Likewise, the authors place the end of the Transdanubian LBK in the period between 5000 and 4900 cal BCE (Bánffy and Oross, 2009). The boundary of the end dating between 5078 and 4906 cal BCE (excluding the small probability value around 5190 cal BCE) as calculated here also fits well into this range.

Riedhammer (2018), in summarising older dates from the literature (Stehli, 1989; Lüning, 2005: 67–72; Zimmermann *et al.*, 2006: 162, 176–179; Jeunesse and Strien, 2009: 243–261), places the end of the western LBK between approximately 4975 and 4950 cal BCE. Newer dates, however, predate the end of the LBK according to Riedhammer: The sites Hienheim and Schletz, for example, indicate that the end of the LBK already occurred around 5020 BCE and 5050–5040 cal BCE, respectively. In the Paris Basin, on the other hand, the LBK seem to last until about 4950 cal BCE. In a paper published by Denaire *et al.* in 2017, the authors place the limits of the LBK for the area of Alsace, thus included in the western area in this chapter, in the range of 5600–4900 cal BCE. In their analysis, 112 assemblages were used, based on 87 typological characteristics.

The CA of chronologically sensitive types and combinations resulted in a subdivision into seven phases for the Alsatian LBK, which was confirmed by stratigraphic findings of the surrounding settlements (Denaire *et al.*, 2017).

Such a late ending of the LBK in the west is also suggested by our model while it does not preclude an earlier end around or even before 5000 cal BCE. Regardless of all the obvious difficulties, it must be noted that currently the model postulates an earlier onset of the Late LBK in its western area than in the eastern region. A more in-depth analysis would be worthwhile to follow up this observation, either to confirm the earlier dating or to correct it with more detailed data. Many contexts included in the work could not be linked to any published contextual information, which meant that no statements could be made about stratigraphic connections of the pottery with the sample material. In part, this can be attributed to the circumstances of emergency excavations and the resulting lack of time (Hilzingen). The problem of missing stratigraphic information is also evident in the case of the well contexts from Eythra and Schletz. The attribution of a radiocarbon date to specific pottery is particularly problematic when several stylistic groups are present within a particular context. However, the inclusion of such samples was often unavoidable in order to obtain a sufficiently large database. Samples from grave contexts, which would establish a high degree of certainty that the ceramics belong to a certain date, make up far too small a proportion of the data base. Moreover, even in these contexts the majority of the samples consist of charcoal, which is why the qualitative assessment is again diminished by possible old wood effects. The dates classified as qualitatively most valuable come from graves where bone material was sampled. This is the case for Kleinhadersdorf or Nitra in the eastern region with nine and six dates (respectively 65.2% of the dates) and the French sites, also with nine dates (25.0% of the samples), in the western region. Overall, the percentage of qualitatively more valuable samples is higher for the eastern region and thus apparently sufficient to compensate for the quantitatively lower number of samples. This is an indication that a high number of ^{14}C dates does not guarantee sound results. This observation leads on to the problem of the publication of both date and context.

In order to establish a highly qualitative data basis, the most detailed contextual information is necessary. Publications containing both the radiocarbon dates and the ceramic fragments associated with the corresponding contexts are particularly helpful for this purpose (cf. Milisauskas, 1975; Neugebauer-Maresch and Lenneis, 2015; Szeliga, 2017). For the Eythra site, a qualitatively particularly valuable connection between pottery fragment and datable sample material is available through the organic matter on sherds 130 and 153. Unfortunately, this situation could not be used to the greatest advantage in the present analysis as the sherds are not among the fragments depicted (Veit *et al.*, 2016: 119). Similar cases, albeit less blatant, are publications of ^{14}C dating with contextual information but without representative pottery images or publications without contextual information, images or references (cf. among others Werra, 2010; Crombé *et al.*, n.d.; Werra, 2010; Crombé *et al.*, 2015; Wotzka *et al.*, 2001; Schietzler, 1965; Lenneis, 2009; Wechler, 1993). It is certainly not possible to publish a comprehensive catalogue within the framework of every research project or especially in the context of emergency excavations. However, sufficient information on contexts and references to existing publications, museums, collections or excavation reports as well as the publication of corresponding documents would be desirable to enable anyone interested to conduct adequate research within the framework of their present research question without having to make numerous and time-consuming personal enquiries for unpublished excavation documents.

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Section 5: Integrating scales

5.1 Simulating land use scenarios for the LBK and Želiezovce settlement site of Vráble

Julian Laabs

Abstract

The Linearbandkeramik and Želiezovce Group settlement site of Vráble offers important and detailed insights into subsistence strategies but lacks high-resolution palaeoenvironmental records to estimate the land use implications of past environmental conditions. A land use simulation modelling approach is employed to explore possible human impact on the landscape, and to gain further insight into and explore possible social implications of the assumed subsistence strategies. The available data on land use and subsistence were formalised under three population scenarios, three resource access scenarios, and two cultivation-system scenarios and then simulated with the agent-based simulation model Land Use and Technological Evolution Simulator. The simulation results show the scale of opening up of the landscape around the settlement, in agreement with the results of the geomorphological investigations around the site. The possibly available manure could have been sufficient to reduce soil fertility loss, so that shifting to a different field after several years or decades was not necessary. Labour availability due to restricted resource access could have been a problem in regard to freeing labour for communal building activities.

Keywords: LBK, land use, agent-based simulation, resource access

Introduction

The Linearbandkeramik (LBK) and Želiezovce Group settlement site of Vráble offers the possibility to estimate population size (Müller *et al.* 2020); to make elaborate statements about the subsistence of the three neighbourhoods within the settlement (Eckelmann *et al.* 2020; Filipović *et al.* 2020; Gillis and Makarewicz 2020); and to infer land use strategies (Furholt *et al.* 2020b). However, the palaeoenvironmental records at Vráble are patchy (Nowaczinski *et al.* 2015). Therefore, information on the past vegetation cover at and around the site is coarse-grained and had to be deduced from geomorphological coring (Dreibrodt and Bork 2020) and from the bioarchaeological record, such as plant macro-remains (Filipović *et al.* 2020), charcoal (Schroedter 2020)

and snail shells (Schlütz 2020). To explore possible environmental conditions that operated in the landscape and possible ecological or social implications of the reconstructed land use strategies, a simulation modelling approach seems promising (Barton *et al.* 2016; Baum *et al.* 2020). Here, I employ the agent-based simulation model Land Use and Technological Evolution Simulator (LUteS; Laabs 2022).

Why simulate land use? Simulations can be considered as experiments that are used to gain knowledge about an observable or conceptualised process or context in order to make statements about reality. Simulations can be an important part of scientific knowledge production. When real-world experiments are not feasible (due to restrictions on costs, time, space, *etc.*), computer simulations are a way to approach the task of the experiment. In this context, a simulation is the translation of a theoretical or merely descriptive model of an object under study into computer code that generates artificial datasets based on the model's inherent hypotheses, processes and relationships. In this regard, a simulation is, as any other model, a reduction of reality and therefore a heuristic tool (Barton 2014, 321–322; Nakoinz and Knitter 2016, 31). Accordingly, the value of simulations is, among other things, that logical tests of theoretical models and their established causal chains are made explicit by formalised and simulated reproducible processes. Another, and for this investigation more important, value is the explorative side of simulation models, where the creation and, later, the output of the model offers entry points to increase understanding of the object under study by exemplifying usually hidden assumptions of narratives (Cegielski and Rogers 2016, 285; Whitley 2016, 145–146).

In the following, the descriptive narrative of subsistence strategies and land use of the neighbourhoods at Vráble (Furholt *et al.* 2020a) is formalised into a systemic, intertwined concept of interrelations and feedback between the entities represented and then translated into computer code. It cannot be stressed enough that simulation results are not a terminal truth but let us experience parts of the possible trajectories of the past.

Questions and possibilities

Two questions will be addressed in this chapter, using the possibilities offered by a simulation approach. The first deals with the explorative task of simulating land use and land cover change under different land use strategies. The second looks into implications of unequal access to the resource fertile soil.

Changes in land use and land cover

Based on the archaeological, bioarchaeological and palaeoenvironmental knowledge about the subsistence economy of Vráble and its neighbourhoods, possible land use strategies are modelled. From there, several ‘What if?’ scenarios are formulated and explored. In an important difference compared with carrying capacity models (*e.g.* Laabs and Knitter 2021), the agent-based approach (*e.g.* Baum *et al.* 2020) implements assumptions about how land use and land cover change constitute a feedback loop with each other, which effectively influences economic choices of the agents. As only sparse palaeoenvironmental information are available for the surroundings of the settlement of Vráble, little is known about the vegetation and landscape openness during the time frame of interest (Dreibrodt and Bork 2020; Schroedter 2020). Therefore, agent-based simulations are useful by visualising how the surrounding landscape of the settlement may have looked like under human impact.

Resource access rights and labour

Based on the results of the population reconstruction and the political situation in LBK Vráble, the question arises if the existence of demographically strong neighbourhoods,

with more people and maybe with a more advantageous demographic structure (*e.g.* more young people), led to asymmetric access to resources, especially fertile patches of soil. The labour investment into subsistence would be impacted negatively by unfavourable access rights, as, for example, field plots would have to be worked that produced significantly lower yields or that were located at longer distances from the settlement. Both circumstances would increase the amount of labour required to provide the goods to satisfy basic needs. So, what consequences, and in what magnitude, would unequal access to fertile soil have had for the socio-economic possibilities of the neighbourhoods?

LUTEs Vráble – A simulation model

LUTEs Vráble is a variant of the simulation model LUTES (Land Use and Technological Evolution Simulator) that was developed to simulate population development, land use, land cover changes and settlement dynamics in Neolithic and Bronze Age western Switzerland (Laabs 2019). LUTES combines the principles of the land use simulation models GLUES (Global Land Use and Technological Evolution Simulator: Lemmen 2009; Lemmen 2015; Lemmen *et al.* 2011; Wirtz and Lemmen 2003) and WELASSIMO (WEtLand Settlement SIMOlator: Baum 2019; Baum *et al.* 2020; Baum *et al.* 2016) and complements them with genuine modules and extensions. Since population size and developments at Vráble are not simulated as a function of land use and environmental utility, LUTEs can be regarded as a version of LUTES that serves land use simulation alone.

Here, only the basic entities, data input and processes of LUTEs are described. The technical implementation is explained in the overview, design concepts, and details protocol, after Grimm *et al.* (2020; 2010; 2006) and in the code. Both are to be found in the supplementary material.

Basics

LUTEs is an agent-based model, but in this study it is agent based in a very limited manner, since there are only three agents (the neighbourhoods) conceptualised as self-sufficient units that interact with the environment, but that do not actively interact with each other. As a result, it is primarily the predetermined courses of action, stochastic dynamics and developments specifically caused by land use that determine the agents' behaviour and decisions. A time step in LUTEs represents 1 year in real conditions. The simulation model environment is represented as a raster data set based on a digital elevation model. Each raster cell has a horizontal spatial resolution of about 25×25 m, which means that a cell has an area of about 0.0625 ha. The economic catchment area is variable and alters with the scenario setup.

Agents and their characteristics

The simulation is driven by the agents who want to satisfy their needs for food, shelter and warmth. For this purpose, they start to interact with the environment, which leads to land use. Their needs and ways to satisfy them are derived from archaeological, ethnographical and theoretical models of diet and subsistence economies.

The acting entities in LUTEs are the three neighbourhoods of Vráble, and their duration time and their population development have been reconstructed by Müller *et al.* (2020) (Fig. 5.1.1). Population size is the determinate variable when calculating land use and human impact, as both scale to population size (Hughes *et al.* 2018). The demographic history is represented by the number of contemporary houses, from which a number of people can be calculated if average household sizes are proposed. The simulation of each scenario is run for a minimum of 5 people per house, a median of 8 people per house and a maximum of 25 people per house.

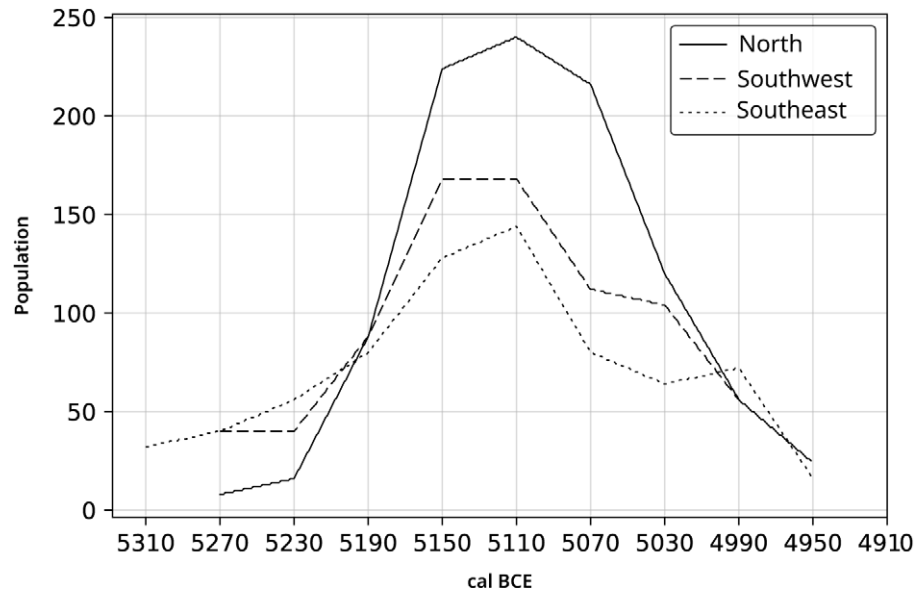


Figure 5.1.1. Vrable. Population development of the three neighbourhoods in an eight people per house scenario.

		North		South-west		South-east	
		Start	End	Start	End	Start	End
Crops	Cereals	60%	55.4%	60%	55.4%	60%	55.4%
	Pulses	2%	3%	2%	3%	2%	3%
Animal products	Cattle	3.1%	5%	5.7%	9.1%	4%	6.5%
	Sheep/goat	3.8%	10.6%	3.9%	6.25%	4.9%	7.3%
	Pig	6.6%	6%	3.9%	6.25%	4.6%	7.8%
	Game	1.5%	2.4%	1.5%	2.4%	1.5%	2.4%
Wild plants		23%	17.6%	23%	17.6%	23%	17.6%

Table 5.1.1. Vrable. Human dietary composition in the three neighbourhoods at the beginning and at the end of the simulation.

Another important input to estimate land use and human impact is the composition of the diet of the modelled communities. The area and intensity of land use needed for a given population is strongly related to the subsistence economy, as crop land use will manifest itself in a different way than woodland pasture, hunting or plant gathering. In this study, the human dietary composition mainly relies on domesticated food sources, combining diet composition models of Gregg (1988) for LBK communities in southern Germany and of Gross *et al.* (1990) for Late Neolithic communities of Swiss lakeshore settlements. To illustrate technological evolution, a steady increase of the proportion of the share of domesticated (animal- and plant-based) in general (from 75% → 80%) and especially that of meat and milk (13.5% → 21.6%) is implemented in LUTeS (see Table 5.1.1). The latter proportion of animal product share follows the suggestions of Gregg (1988, 103–123). The dietary composition of the inhabitants of the three neighbourhoods in the end only differs in the proportion of the three or four species of domesticates animal making up the overall meat and milk consumption. Hunting and wild plant gathering play only a minor role in the Vrable application of LUTeS regarding the land use aspect of the study; the proportion of 20–25% of the diet is reasonable for Early Neolithic farmers (Gregg 1988, 174–176; Gross *et al.* 1990, 113).

Domestic animal herd sizes are important to estimate woodland and open pasture-land, and in this case are modelled on the basis of the proportions of animal taxa identified from the three neighbourhoods (number of identified specimens data from Eckelmann *et al.* (2020)'s investigation into Vrable's zooarchaeological record). Contrary to other

recommendations (Ebersbach 2005, 75; Gross *et al.* 1990, 112), the shares of the respective domestic animal species are directly translated as shares of the animal diet. Through the minimum number of animals consumed – deduced from the share of meat of the respective animal of the total diet – a reasonably realistic herd size can be derived, if we assume that herd sizes for each neighbourhood were stable (Ebersbach 2002, 179–187).

Further needs that agents want to satisfy and that impact the environment are fuel wood for heating and cooking, as well as timber for the construction and repair of houses. Both are inferred from population size, as there is a yearly average demand for fuel wood and a given amount of timber per person for a house. Houses are assumed to have decayed over time and are assumed to have needed to be repaired after a specific time. We assume that an LBK house lasted for about 10–100 years (Burghart *et al.* 2005, 167; Ebersbach 2010, 42; Müller 2011, 174), which means that each year, between 1/10 and 1/100 of the houses need to be ‘rebuilt’. Apart from this constant timber need for construction, a certain amount of timber would have been needed for repairs and maybe also for non-house timber constructions.

Environment and resources

The environment in the simulation model is mostly determined by stable environmental factors (*e.g.* slope) and a dynamic vegetation cover. Wetlands were modelled and labelled on the basis of thresholds of the topographic wetness index (TWI). Streams were simulated as a drainage system based on a digital elevation model and may not accurately represent the expected stream courses, due to the spatial resolution of the latter. Both hydrological-geological factors were calculated using Whitebox tools (Lindsay and Geomorphometry and Hydrogeomatics Research Group 2022) (see also supplementary material). An important environmental variable in LUTeS, derived from several geofactors, is the so-called productivity factor, which alters the average yearly crop yield by its given factor. It is a product of an assessment of soil type, slope, aspect and TWI, and is calculated for each grid cell (Fig. 5.1.2). Even though it will later be used to alter cereal yields, it should be noted that the productivity factor is a measure based on partly subjective judgement of the geofactor’s impact on the productivity. It tries to picture the qualitative differences of the geographic condition in regard of its possible productivity. Cells with high productivity factors are preferred for growing cereal, and other land use decisions are independent of this factor.

Vegetation cover is a significant factor in socioecological systems because it not only provides resources for building materials and utilities, but also serves as habitat for the gathering of plants and wildlife. Most of the landscape in LUTeS consists of a mixed oak forest (Schroedter 2020, 460), the growth phases of which has been quantified in terms of its various economic uses by Baum *et al.* (2020, 7), following a forest development cycle (Scherzinger 2014, Fig. 4). In the case of temporal sequences of land cover categories (fallow cycle: fallow → young secondary forest → old secondary forest → forest; forest cycle: rejuvenation → initial → optimal → terminal → decay), the resource quantification of the generic land cover categories was used to calculate a polynomial function that determines the resource availability for the specific land use activities for each year of succession and forest growth stages (see supplementary material). The initial landscape represents a dense mixed oak forest, with a few patches of wetland.

Agent-environment interaction: Land use

As already stated, the interaction of agents with the environment results in land use, which alters the natural land cover into an anthropogenically shaped landscape. In most cases the choice of which plot to use for a specific land use activity is represented as a function of the amount of accessible resources and the distance to the settlement, with plots located close by being preferred.

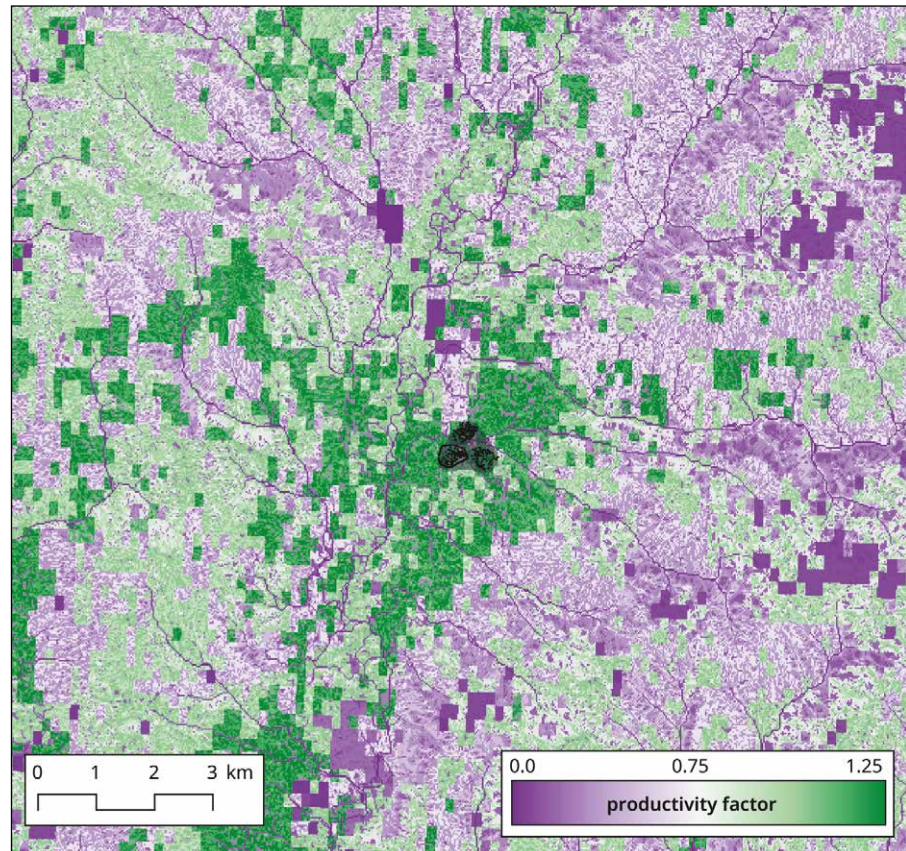


Figure 5.1.2. Vrable. Productivity factors in the site's surroundings.

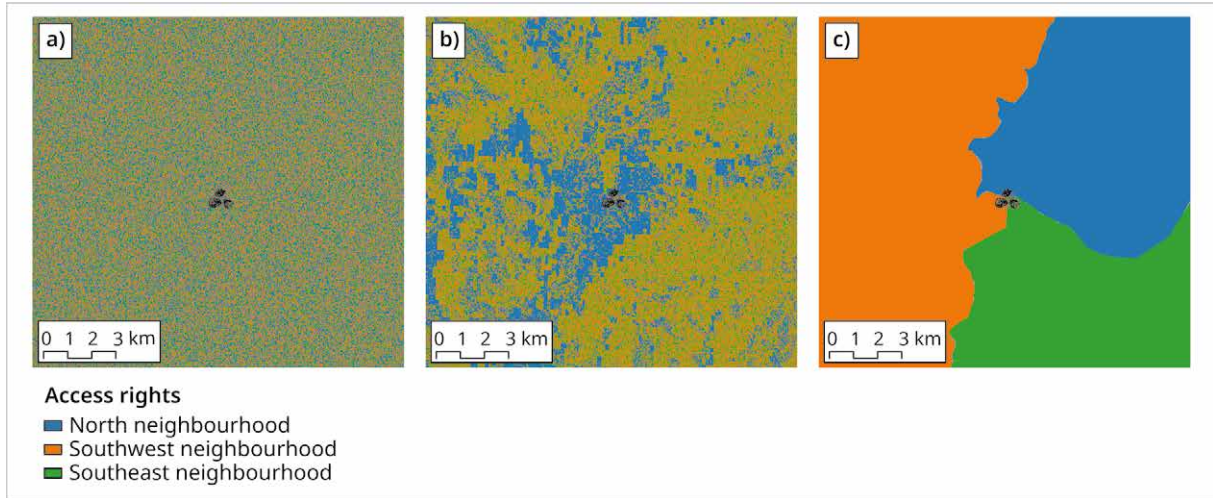
In LUTeS nearly all land use activities result in gradual degradation of the accessible resources. This is true for hunting, gathering, pasture, fuel wood and timber, as well as for soil fertility. Effectively, this leads to an increase of the economic radius over time, as the yields closer to the settlement area decrease due to their constant use.

Especially pasturing and timber extraction over a longer period will lead to the transformation of woodlands into woodland pasture of a more open-space forest, a so-called *Hutewald*. Fallow areas that are constantly grazed by animals will become open pasture. If such land cover categories are no longer used, they will return to the forest, respectively non-forest growth cycles.

For Vrable, we expect permanent cultivation of cereal fields (Bogaard 2004, 41–42; Furholt *et al.* 2020b, 505–506). We assume that the opening of a new field plot is performed involved some kind of slash and burn practice. 800 kg per ha is the expected average yield of the cereals emmer and einkorn; most sources range little higher or lower around that value (Baum *et al.* 2016, 617; Bogaard 2004, Table 2; Gregg 1988, 72–74; Hughes *et al.* 2018, supplementary material). This average yield is altered by the productivity factor (see Environment and resources), which creates a spatially differentiated potential of good yields in the research area. An acceptable realistic diversity of yields ranges between a maximum yield of 1000 kg per ha (Baum *et al.* 2016, 617) if a flat, moderately moist plot with good substrate for soil development is chosen and 720 kg per ha on present-day luvisol with little slopes. The soil fertility, and therefore the average yield of a plot, is sustained by manuring or by fallowing and manuring.

Simulation scenario setups

We simulated 18 scenarios, of which not all will be presented in the results section. The scenarios combine the questions about the fallow system (2 scenarios), resource access (3 scenarios) and population sizes (3 scenarios).



Fallows vs. no fallows

In the light of the stable isotope analysis of the cereal grains, which shows high nitrogen values, it seems very likely that the neighbourhoods at Vrable manured their cereal fields (Gillis and Makarewicz 2020, 484–485). This finding is accordance with findings regarding the LBK site of Vaihingen (Bogaard *et al.* 2013, 12591).

How should we imagine the manuring? One possibility is that the dung of the animals, and maybe the humans, was collected, stored and brought on the fields when needed. The other possibility would assume that the animals were grazed on the fallows and their droppings manured the plot for the next cultivation season. In the latter case, a full-year fallow can be assumed, as the time between harvest and tillage would seem too short for a strong manuring effect. The role of domestic pigs should not be underestimated in this regard, as they still find food when cattle, sheep and goat do not and, further, as they dig for their food, they loosen the soil. To sustain a constant average yield, manuring of ca. 10 000 kg per ha is assumed to be needed (Baum *et al.* 2016, 619).

Two simulation setups according to the fallow system are simulated. One without fallows, where animals mostly browse in the woods and fodder on the harvested fields, and the other with a 2-year cycle of cultivation and fallowing of cereal fields and with fallows being grazed by the animals. In addition, the dung production of the animals is tracked to later assess if the need for manure could have been met by the simulated number of animals.

Resource accessibility

Vrable shows a diverse and tension-rich history of socio-political and socio-economic interaction among the three neighbourhoods (Wunderlich *et al.*, 2020, 520–522). With the land use simulations, it is possible to explore the scope of resource accessibility, respectively restrictions, especially in regard to labour.

Three resource access rights systems are simulated (Fig. 5.1.3). The first scenario represents a baseline simulation, where all cells of the raster map are assigned randomly as the ‘property’ of one of the three neighbourhoods (Fig. 3 A). The second scenario assumes a highly biased distribution of productive plots (productivity ≥ 1.0) in favour of the northern neighbourhood (Fig. 3 B). The northern neighbourhood was chosen as agent to have control over the more productive plots because with its population size development, it seems to have had the potential to dominate the settlement of Vrable. However, it could also be argued that the south-western neighbourhood had more territorial rights than the other two, because it was

Figure 5.1.3. Vrable. Resource access: a) random scenario; b) highly biased scenario; and c) territory scenario.

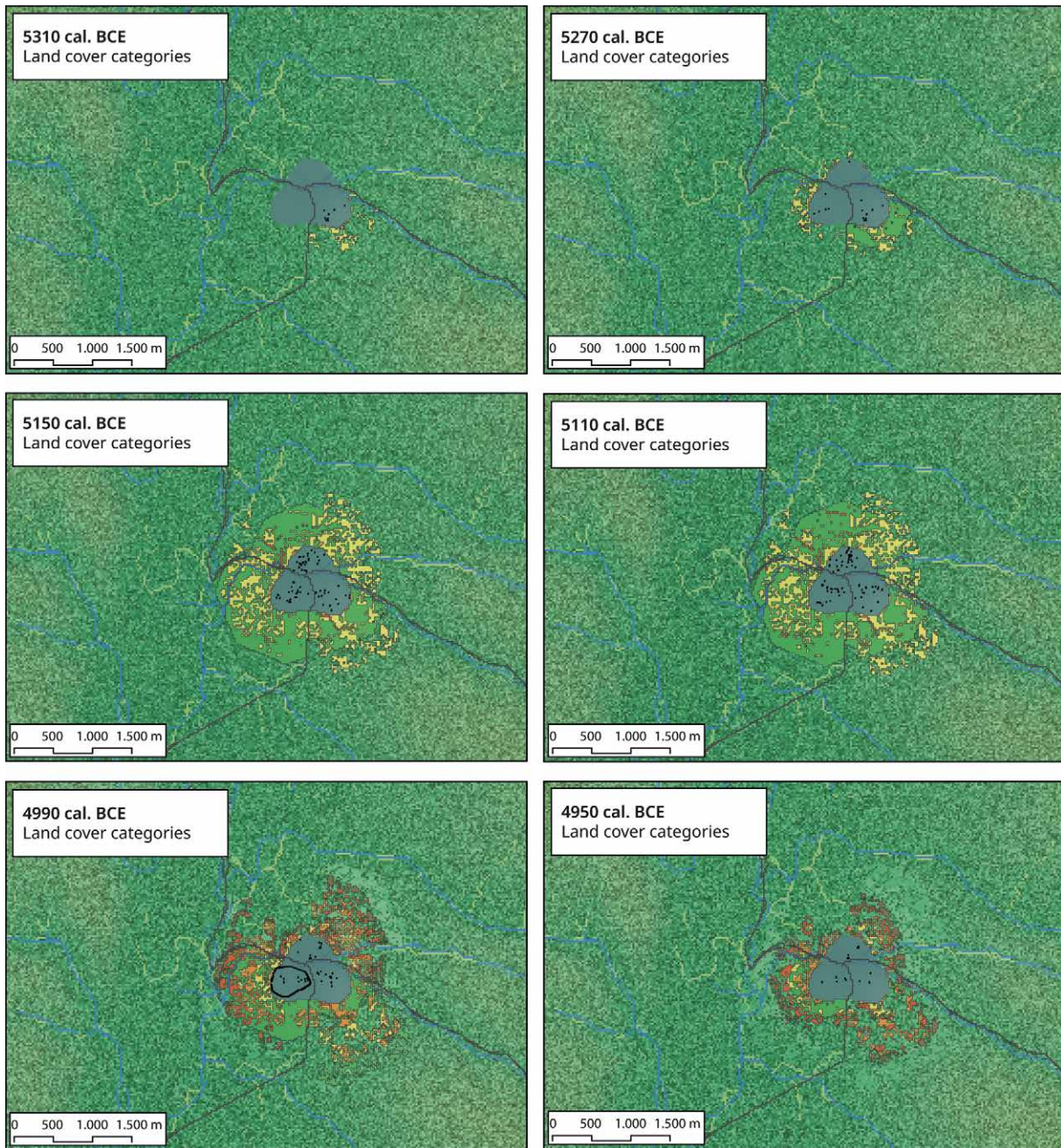


Figure 5.1.4. Vrable. Land use and land cover change under the territory simulation scenario with no fallows and a population estimate of eight persons per house.

the founding neighbourhood and also ‘owned’ the enclosure. The third and last simulation offers a ‘property’ assignment based on topography and stream courses (Fig. 3 C). This scenario is of course only a suggestion of how the landscape may have been split among the neighbourhoods into related territories.

All three scenarios formulate ‘property’ distributions where no communal land is present and the neighbourhoods are treated as independent and non-cooperative entities. I am aware that these are extreme scenarios, but cooperative setups very quickly become overly complex and would need a highly extended version of LUTeS.

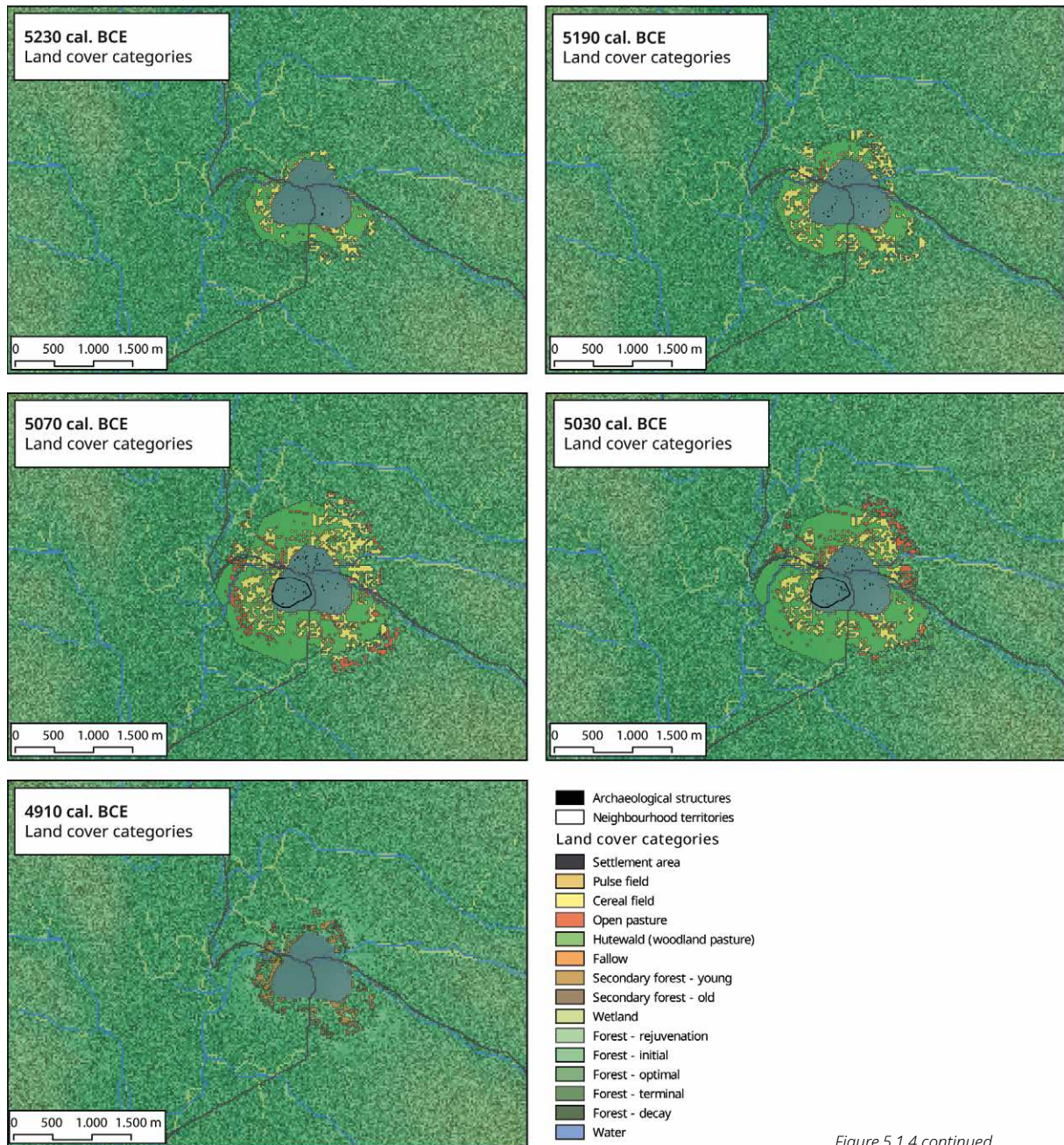


Figure 5.1.4 continued.

Results

In the light of the amount of data produced, not all results can be presented in detail. Some model runs from the random and territory access scenario for example yield quite similar results.

Changes in land use and land cover

The maps in Figures 5.1.4 and 5 depict the land cover changes around Vrábale from 5310 cal BCE to 4910 cal BCE for the population estimate of eight persons per house under the territory scenario without (Fig. 5.1.4) and with (Fig. 5.1.5) following. The main difference between the two scenarios is that following results in more

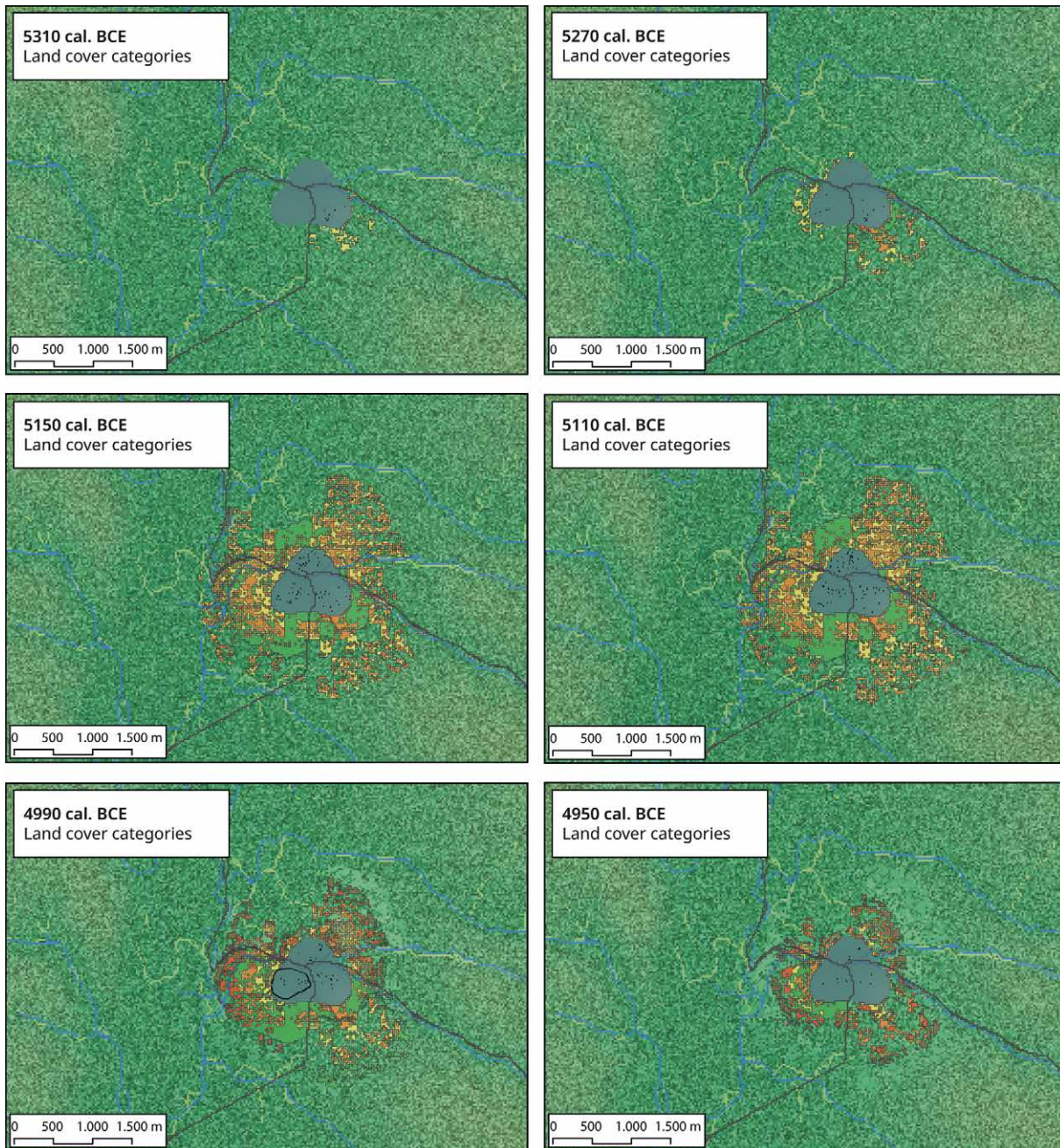


Figure 5.1.5. Vrable. Land use and land cover change under the territory simulation scenario with 1 year of fallowing and a population estimate of eight persons per house.

open landscape around the settlement. The simulated mosaic of different land use follows the estimated productivity of the soils, whereby less productive soils are used for browsing and grazing animals. This explains some of the bigger 'free' spaces between fields to the north and south of Vrable. The general development until 5110 cal BCE can be described as follows: with the increase in population, land use is expanding onto plots suitable and available for the given subsistence economy. Over time, forests continuously browsed by animals turn into *Hutewald*. At the peak of Vrable's population, the settlement of Vrable is surrounded by about 114 ha of cleared landscape without and 219 ha of cleared landscape with fallowing in use for cereals and pulses, as well as patches of *Hutewald* covering an area of 153 ha, respectively, 76 ha. Between and around that intensively used area, woodlands are found which can be described as heavily browsed or managed.

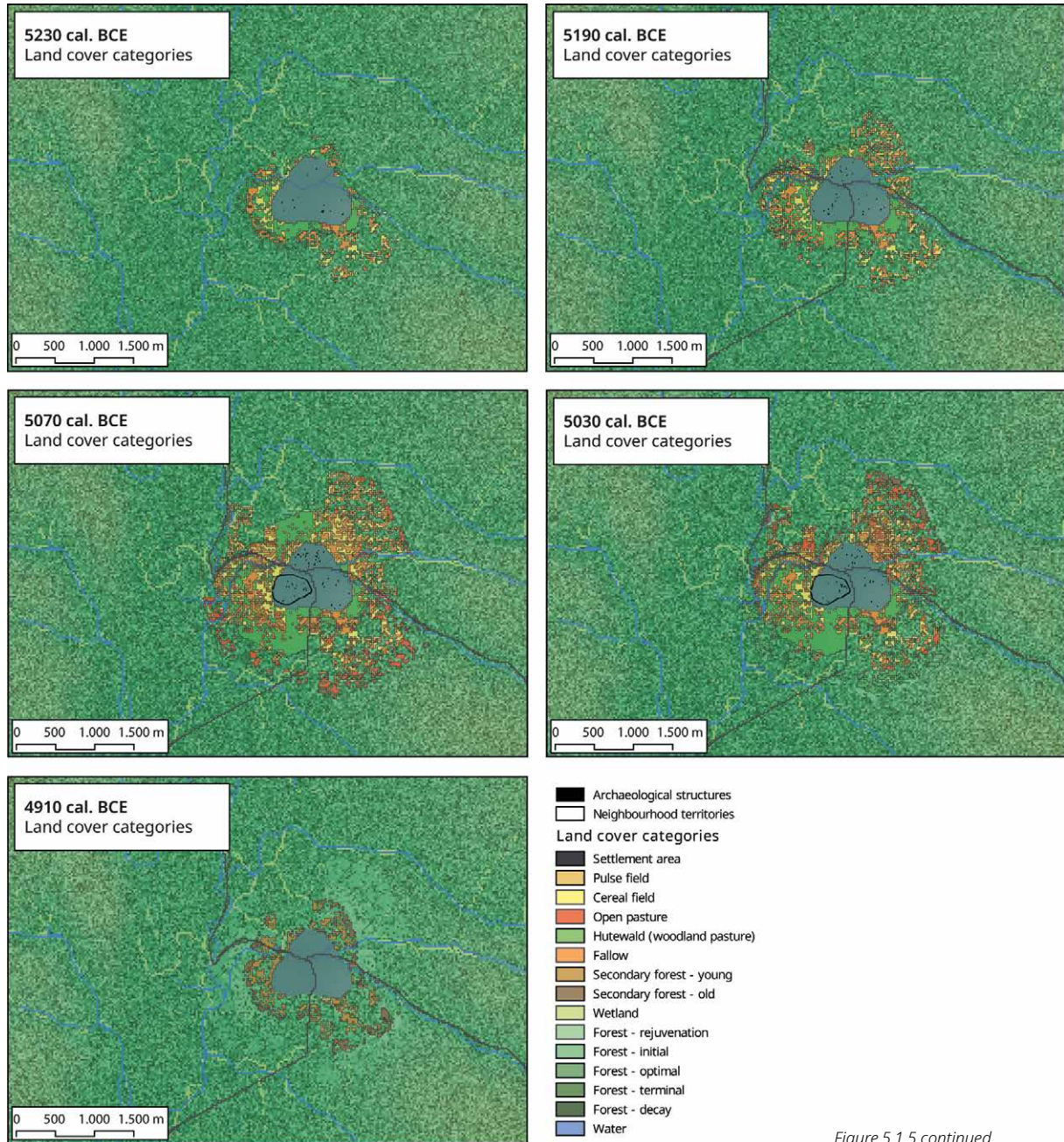


Figure 5.1.5 continued.

Maximum distances to the fields are less than 1 km if no fallowing is applied and less than 1.5 km if fallowing is applied. Only under the maximum population setup, with 25 people per house, do distances to fields exceed 1.5 km. From 5110 cal BCE onwards, population is decreasing and the abandoned fields either turn into open pasture or enter the fallow cycle.

Animal herd sizes scale to the population and are not dependent on anything else. Over the time, the human–animal ratio increased due to the increased share of animal product in the diet. Using the archaeozoological proportions of domesticated animal remains in the neighbourhoods, and the assumed dietary proportion of the animal product share, reasonable herd sizes for cattle and pigs are produced, developing from 0.25–0.45 to 0.35–0.625 cattle per person and from 0.525–0.9 to 0.8–1.3 pigs per person. The human–animal ratio of sheep

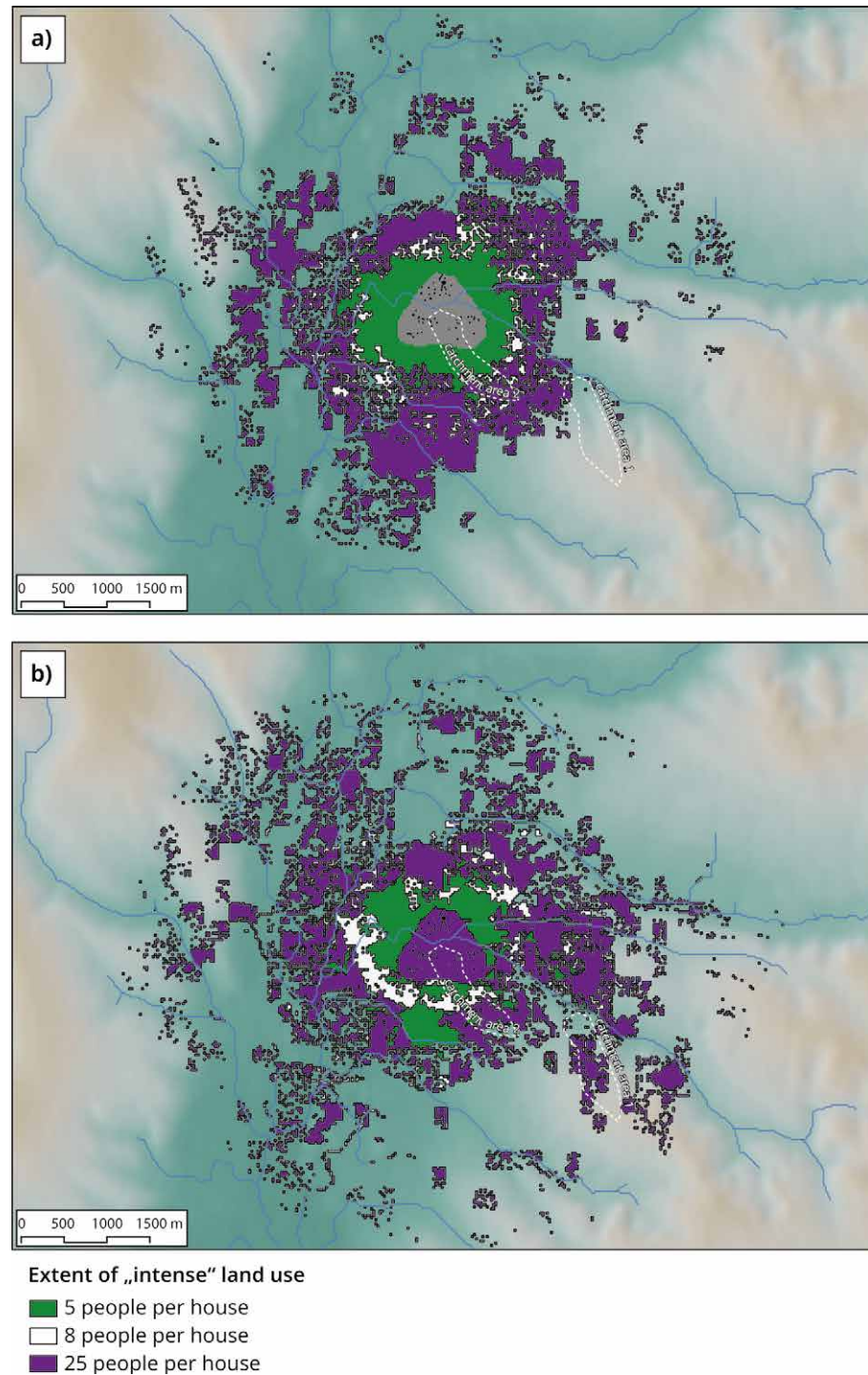
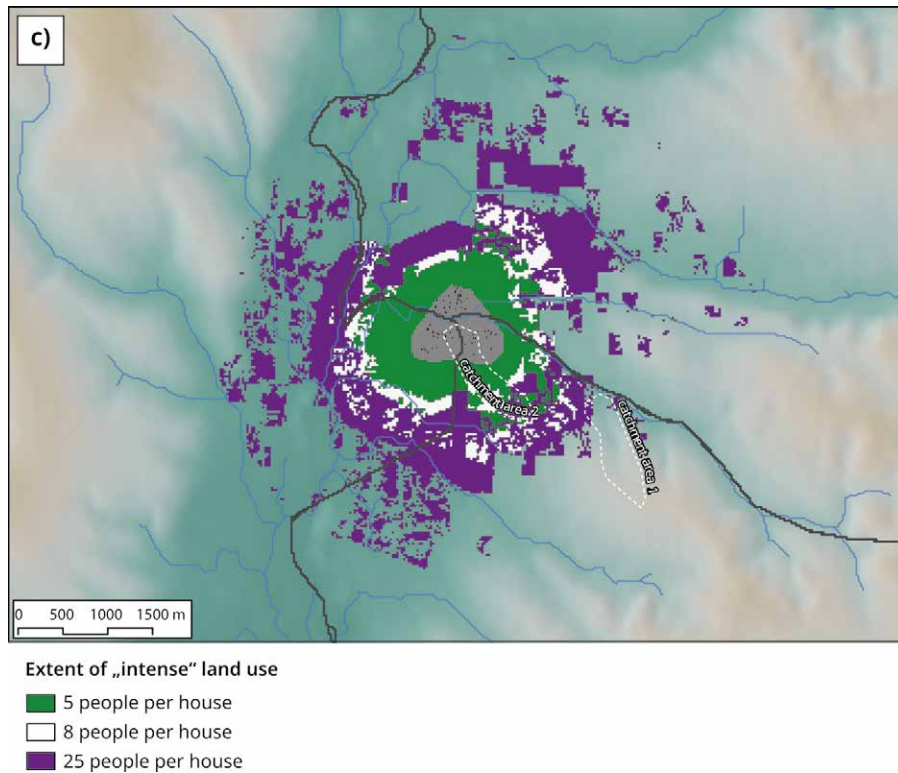


Figure 5.1.6. Vrable. Extent of intensive land use (cereal and pulses cultivation, fallows, open pasture and Hutewald) of the three population simulation scenarios under a fallowing regime (a), b), c), see text for details) and the erosion catchments cored for geomorphological investigations.

and goat may be overestimated with a development of 4.0–5.0 to 5.5–7.2 animals per person.

The effect of browsing and grazing of the animals in the fallow scenario (Fig. 5.1.5) shows a smaller portion of *Hutewald*, as the fallows provide a fair amount of the needed food for the animals; the other dynamics are very similar to the no-fallow scenario (Fig. 5.1.4). The population increase, especially at the beginning, leads to a constant high timber demand that results in clearance of woodland, and through browsing and fuel wood gathering those patches become woodland pasture or



Hutewald. Wetland that had been identified by the TWI around small streams turn into open pasture. This happens too at the beginning of the simulation. Over the course of the population increase, especially the grazing pressure continuously transforms forest stands into woodland pasture. Browsing other parts of the forests is mostly important during the steep population increase but does not result in pressure to alter all of the used forest into *Hutewald*. After the population peak, around 5110 cal BCE, the population decline results in the transformation of former cereal fields into open pasture and a shrinking of the *Hutewald* areas. Browsing the nearby forest, however, should not be excluded as a strategy to keep parts of it, such as pathways, open, nor should cutting leaf fodder for the winter. The *Hutewald* land cover category should be treated as very diverse in its appearance, where some areas only have a few old trees and some shrubs with pasture-rich ground in between and other parts may be more reminiscent of a light forest with a denser layer of weeds and herbs.

The geomorphological investigation of a small valley (Catchment 1) near Vráblé shows only minor traces of erosion during and directly after the LBK occupation of the region (Dreibrodt and Bork 2020). The majority of simulations do not reach Catchment 1 for land use if we assume that people engaged in a subsistence economy would stay as close as possible to the settlement. Figure 5.1.6 shows the extent of intensive land use, including the cultivation of cereals and pulses, fallowing, open pasture and *Hutewald*, under the three resource access setups for the minimum to maximum population estimated under the fallow scenario. In most simulations, the area of intensive land use did not extend as far as Catchment 1. Only the biased maximum population scenario under a fallow regime would need to use land in the area of Catchment 1 (Fig. 5.1.6 B). Both lines of evidence – the geomorphological record and the land use simulation – show that the land use of Vráblé either never reached Catchment 1 or was not significant enough to open the vegetation and thus make the soils vulnerable to erosion and leaving a trace in the geoarchaeological record. However, some land use, such as browsing domestic animals or cutting of leaf fodder, should be assumed for this area.

Resource accessibility

The outputs of the random and territory scenario are very similar in the case of needed cereal cultivation area (Fig. 5.1.7 A, C). The division of the landscape and the random scenario show that the study area exhibits enough suitable land for the entire population. In the territory scenario, the general suitability for the northern neighbourhood is even lower than that of the south-western and the south-eastern neighbourhoods. If our productivity assumptions (Fig. 5.1.2) reflect reality, this would mean that productive land is abundantly available and should not be a source of tension, as long as 'equal' access is assumed.

In the biased scenario, where the northern neighbourhood dominates resource accessibility (productivity ≥ 1.0), the overall area and the relative amount of land for cereal cultivation needed for each person, on average, rises significantly for the south-western and south-eastern neighbourhoods (Fig. 5.1.7 B). In an unrealistic biased scenario where one neighbourhood 'owns' all plots with a productivity value of ≥ 0.75 , which includes most of the land around Vráble, sudden peaks of needed area are simulated. Those peaks indicate that all soils of a given productivity are used and that the next-best category of soil needs to be cultivated. In general, however, situations where soils of lesser productivity would need to be used would result in a period of increased stress, as in the first years predicted yields would not be reached and much labour would need to be invested into preparing larger areas for cultivation to meet the needed yields.

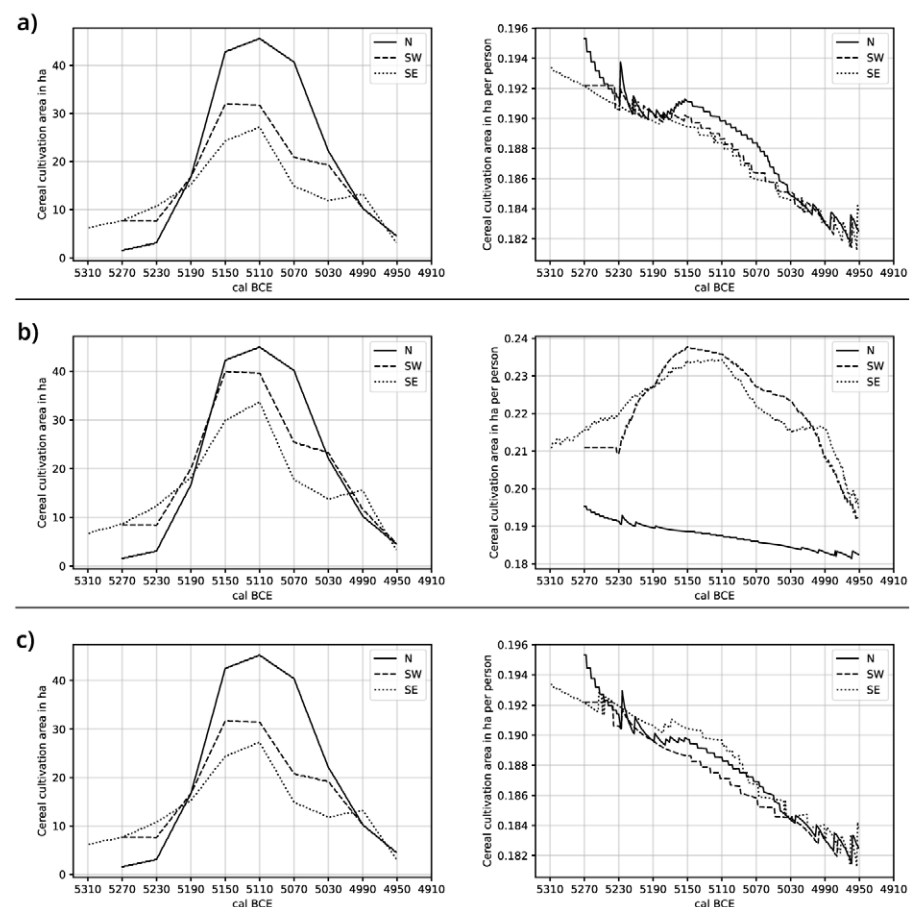


Figure 5.1.7. Vráble. Needed cereal cultivation area in ha and needed cereal cultivation area per person for a) random scenario; b) highly biased scenario; and c) territory scenario.

Excursus: Labour

The question about resource access rights, but also the finding of socio-political tension in LBK and Želiezovce Group Vráblé can be theoretically related to labour input into the subsistence economy and free labour for endeavours such as communal building efforts.

With the area under cultivation simulated, we can assess if the labour force of the community is enough to bring in the harvest. Within 16.56 days, one person was able to reap, thresh and winnow the cereal harvest of 1 ha during Roman times. In a harvest period of 4–5 weeks, one person could have harvested about 2 ha (Laabs and Knitter 2021, 7–8). Although silex blades and composite sickles of the Early Neolithic may not have been as efficient as Roman iron tools were, one should not underestimate the output trained personnel with supposedly inferior tools. For a setting lacking vehicular transport, we can add an estimated labour input for carrying the harvest to the settlement. A conservative estimate of ca. 1000 kg of grain plus parts of the stem from 1 ha results in 33 trips (there and back again) with a one-way load of about 30 kg, assuming an average walk of 20 minutes from field to storage. The overall labour for the harvest would increase to an average of about 18.5 days per ha. The decrease in speed due to a heavy load or exhaustion has not been taken into account. From here it is possible to estimate a range between a minimum and a maximum area that could be harvested by one person in 2–6 weeks, namely 0.75–2.25 ha. All calculations relate to averages to approximate needed labour inputs into specific tasks, as tracking labour estimations in this detail is not yet implemented in LUTeS.

Figure 8 shows the proportion of the overall population that is assumed to have work full days to bring in the harvest. Under the hypothesised conditions of ‘equal’ resource accessibility (random and territory scenario) ca. 8–25% of the overall and 12–35% of the labour-able population (~70% of the overall population) would have been involved in the main task of harvesting (Fig. 5.1.8 A, C). This picture changes for the south-western and south-eastern neighbourhood under the biased scenario (Fig. 5.1.8 B); here, up to 30% of the overall and 45% of the labour-able population could have been bound if the harvest period was short. The access restriction to good soils results in the need to cultivate more land and therefore in more labour input, especially transportation- and walking-related labour would have been increased due to more and more distant areas being under cultivation. The true labour input for the cereal harvest probably ranges between these poles.

The comparison between the scenarios can be taken as a reference for how access to more fertile land can decrease labour-intensive times during the year. Labour availability scales to population, but due to extra workload due to lower efficiency of resources, the extra work force is bound. This is true for each task related to the given resource. In regard to cereal cultivation, tasks such as clearance or tillage field plots will be more laborious for the deprived group. The overall physical and psychological stress will increase, which in turn can have physiological as well as social effects, influencing biological reproduction or fostering tensions between the communities.

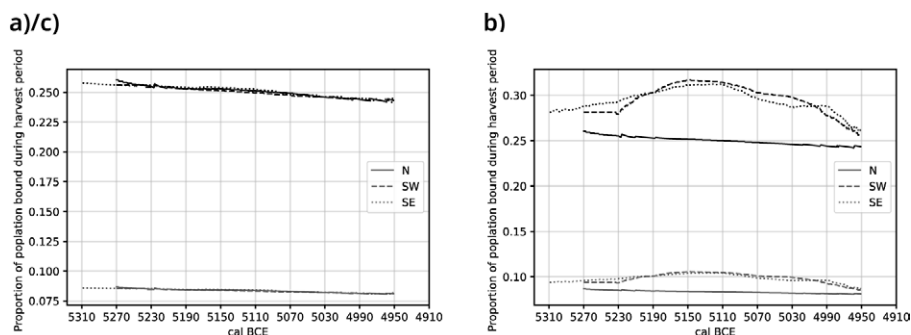
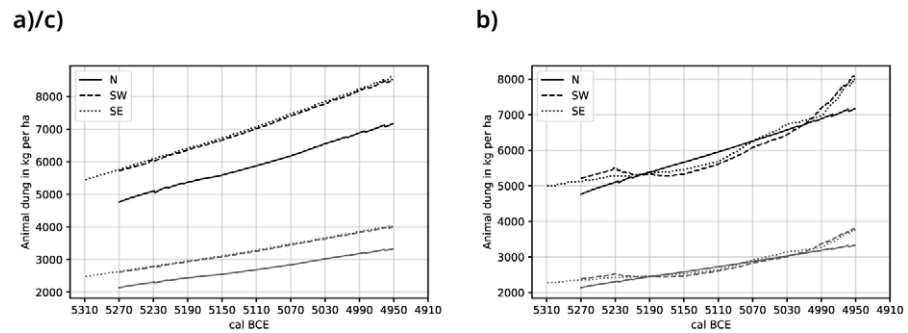


Figure 5.1.8. Vráblé. Proportion of the neighbourhoods' populations under full labour during harvest periods of 2 (black line) to 6 (grey line) weeks for a/c) random and territory scenario, respectively, and b) highly biased scenario.

Figure 5.1.9. Vráble. Ratio of manure to cultivated cereal area under an animal dung-only (grey line) and maximum-available-manure (black line) manuring regime for a/c) random scenario and territory scenario, respectively, and; b) highly biased scenario.



Excursus: Dung production

According to the dung production estimates of cattle with ca. 500 kg/year⁻¹ and goat, sheep and pig with ca. 62.5 kg/year⁻¹ per animal (Ebersbach 2002, 152), the neighbourhoods do not meet the assumed amount of 10 000 kg per ha (Baum *et al.* 2016, 619) to sustain a high average yield (Fig. 5.1.9). If mixed with plant waste or other organic material, an increase of up to 100% of matter can be achieved (Ebersbach 2002, 158). Adding human faeces, ca. 47 kg/year⁻¹ per person (Rose *et al.* 2015, 1863), as fertiliser, a high manuring regime becomes possible over time for the south-western and the south-eastern neighbourhoods because of the increased animal product share of the diet. The addition of human faeces, but especially the mixing of faeces with plant remains, would have increased the sustainability of the cultivated areas significantly.

In addition to the assumed animal product share of the diet, the different animal husbandry regimes of the neighbourhoods, derived from the archaeozoological data, play a huge role in the abundance of dung. In the simulation, the south-western and the south-eastern neighbourhoods, which had larger cattle herds and fewer small animals (pigs and caprines) would have had an advantage fertilising their fields. This is even true in the biased scenario, where they have disadvantages in terms of access to good soils. Although they need to have more area under cultivation to meet their demands for cereals, the manure-field ratio of the northern neighbourhood is just slightly higher than that of the south-western and the south-eastern neighbourhoods (Fig. 5.1.9 B). The general trend of increasing manure availability over time is coupled with an increase in animal products consumption and a decrease in cereal consumption.

A short synthesis

The landscape around Vráble was diverse and productive enough to sustain all three neighbourhoods without any problems. The settlement's surrounding can be described as an open landscape with wood pasture (*Hutewald*) between cereal and pulse fields. The farming regime played an important role in the openness, whereby the following scenario produces more field and fallow area but less *Hutewald*. The forest adjacent to the open landscape around Vráble was browsed by domesticated animals and was used for fuel wood collection, timber extraction, hunting and gathering. It can be described as managed. Even in high population scenarios, intensive land use did not exceed a radius of 2 km from the site.

The simulation results are in agreement with the land use assessment from the geomorphological investigation at Vráble, which shows that erosion in Catchment 1 (Fig. 5.1.6) starts after the LBK, during the Lengyel period, around 4700–4400 cal BCE (Dreibrodt and Bork 2020, 82). We might assume that communities after the LBK changed their land use strategies to more extensive cultivation, but it is also

possible that a different site location causes the used of Catchment 1 or that more communities were involved in the use of the landscape around Vráble. However, the finding that areas in and around Catchment 1 were not used for intensive land use in the simulation raises our confidence that the heuristics of assessing the suitability of the environment and land use simulations of LuteS are acceptable.

Animal dung production, together with human faeces production supplemented with plant remains, seems – in our scenario of diet and herd sizes – to have been high enough to sustain the fertility of the soil. When we drastically lower the number of domesticated animals, especially cattle, in the simulation, soil depletion is to be expected over time due to the permanent cultivation of fields. The simulation also shows that cattle as manure producers are not to be underestimated, as the population wise smaller neighbourhoods have a higher input of manure per area because of their better animal-human ratio, of ~0.5.

It could be demonstrated that biased access to productive soils would be a disadvantage in a situation of constant labour availability, especially in times of increased labour need (e.g. harvest). The construction of the enclosure system of the south-western neighbourhood is remarkable, as it seems to be an endeavour launched by this single neighbourhood. As labour estimations for the construction are missing, it is hard to say if it was built in a single effort scheduled between the periods of tillage and harvest. The enclosure was constructed during the time of population decline, around 5070 cal BCE (see Fig. 5.1.1), when easily workable cereal fields were available – old fields having already transformed into pasture or entered into a succession cycle (see Fig. 5.1.4–5) – and when, due to fallowing or manuring, average yields could have been expected on those plots. This period would be the one with the lowest labour investment in subsistence in the settlement's history, as labour-intensive related tasks, such as clearing woodland for fields or preparing and weeding a plot for the first years, were no longer necessary.

In conclusion, simulations do not necessary produce 'new' knowledge, but simulating and quantifying makes the descriptive models much more tangible, not just visually, but also scale wise, in its different scopes. Exploration becomes easier, and the assumptions much more explicit.

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Supplements

Code and ODD (Overview, Design concepts, Detail) protocol are available under the following DOI:10.5281/zenodo.7981551.

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5.2 Spatial modelling of LBK and Lengyel settlement territories: a new approach to understanding population dynamics, social structures, and exchange networks

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Abstract

In this chapter, we explore settlement distribution in the LBK and Lengyel periods in south-western Slovakia, Lower Austria, and Transdanubia (western Hungary) in order to model settlement territories and to compare territory size, geographical location, and temporal developments in the three regions. We show that the shift from LBK to Lengyel is accompanied by a shift towards increasingly higher elevation and stronger slope of the territory. The fact that settlement territories across the regions, and indeed across the entire LBK area, are best characterised by the same density value (the 4 km isoline) indicates a common underlying socio-spatial pattern. It probably reflects the dispersed, extensive settlement of mostly smaller sites with strong inter-site links across space. The rather uniform settlement area sizes in the Early LBK period and the relative persistence of these areas in some regions indicate that there is something like a preferred group size, which would be somewhere around a median of 1600 inhabitants.

Keywords: Settlement territories, population estimation, rondels, lithic exchange networks

Introduction

In this chapter, we explore settlement distribution during the LBK and Lengyel periods in south-western Slovakia, Lower Austria, and Transdanubia (western Hungary; Fig. 5.2.1) in order to model settlement territories and to compare their size, geographical location and temporal developments in the three regions. Our GIS-based approach to modelling is built upon a set of methodologies developed and applied by Zimmermann *et al.* (2009) and Herzog (2010), who investigated the size of LBK

settlement territories in Germany. The relationship of LBK to Lengyel territories has barely been researched from a quantitative perspective (see, however, Trampota and Pajdla, 2022), and has so far only been researched from a qualitative perspective in selected regions (e.g. Lenneis, 2017; Neubauer, 2017). In south-western Slovakia, corresponding studies are lacking. However, numerous settlements are recorded for both phases, so a quantitative comparison from a macro perspective is possible.

A preliminary study by Furholt *et al.* (2013), which they presented at the annual EAA conference in Pilzen only, was the starting point for the present study. Furholt *et al.* (2013) had promising outcomes, but they had restricted the geographic scope to the LBK in south-western Slovakia and Transdanubia only, and their data rested fundamentally on the compilation by Preuß (1998), which vary in quality (see below). For the current study, we used an updated database for south-western Slovakia, which has much denser geographic coverage. Moreover, we included data from Lower Austria published by Lenneis (2017). For all regions, we expanded the scope to the Lengyel phase, and we also separated the earliest LBK (following Fischer, 2016) where possible to enable us to better recognise chronological developments.

The aim of the present study is to explore patterns of socio-spatial organisation by comparing the size of the settlement area and number of settlements between the LBK (5500–4900 BCE) and Lengyel (4900–4500 BCE) periods and between regions. Furthermore, we analyse settlement location within the landscape in relation to geographical features, especially the usability of the terrain. Finally, we examine the spatial relationship of the identified settlement areas to deposits of lithic raw materials as well as roundels (the latter only in the Lengyel period).

Our main findings can be summarised as follows: The size and number of inhabited areas varies by region during the LBK and Lengyel phases. While in western Hungary there is a significant increase in the number of settlement areas after the transition to Lengyel, in south-western Slovakia and Lower Austria there is a significant decrease. Furthermore, the transition from LBK to Lengyel is associated with a shift in the location of settlement areas. In the Lengyel phase, they move to higher and steeper terrain. This finding confirms the observations of other researchers (e.g. Lenneis, 2017) statistically for the first time. Strikingly, across the LBK, and extending into the Lengyel period, settlement territories are characterised by comparable distances between sites (as expressed in the 4 km radius in the kernel density estimation algorithm), a fact we interpret as the result of a common underlying socio-spatial system. This underlying system, which probably serves the purpose of inner-territory interaction, and social relations remain constant, while the size and number of territories develop differently in different regions, as do the relations to regional gathering places, such as rondels. We interpret this as diverse trajectories of political organisation.

Study area, chronology and terminology

We are interested in a comparative perspective on settlement territories across the transition from LBK to Lengyel communities and thus expand the Collaborative Research Centre (CRC) 1266 ‘Scales of Transformation: Human-Environmental Interaction in Prehistoric and Archaic Societies’ C2 study area to all of south-western Slovakia (Bratislavský kraj and Zapadoslovenský kraj [Trnavský kraj, Nitrianský kraj, and the south-western part of Trenčianský kraj]); Transdanubia (western Hungary counties of Győr-Moson-Sopron, Vas, Veszprém, Zala, Somogy, Komárom-Esztergom, Fejér, Tolna, and Baranya); and Lower Austria (Waldviertel, Weinviertel, Mostviertel, Industrieviertel, Wien; Fig. 5.2.1).

Approach

In research in German-speaking countries, there are various approaches for determining the size of LBK settlement territories, using spatial statistics charac-



Figure 5.2.1. Locations of the modern borders of the study area, of the regions and lakes mentioned in the text, and of Vrátile.

terising the density patterns of sites on the map. In her 2010 paper, I. Herzog discusses the advantages and disadvantages of two methods that have been used in various scientific communities to date: The largest empty circle (LEC) method and kernel density estimation (KDE). Undesirably, the LEC sometimes expands point density areas into areas without points. The KDE can be extended and adjusted very easily, and points of different sizes can be included if desired. In contrast to the LEC, the KDE provides a better fit of the calculated density distribution to what would be expected from visual inspection. In short, the KDE convinces with its advantages in application and informative potential (Herzog, 2010: 207).

To identify and compare potential settlement territories of the LBK and Lengyel periods in south-western Slovakia, western Hungary and Lower Austria, the procedure of Herzog's study (2010) was replicated, with minor differences. Initially, we performed KDE mapping with gradations up to 8 km and colour marked certain distances to clusters differently ('break zones'). On this basis, we examined which radius made the most sense for the definition of settlement territories. The idea is that as many findspots as possible should be grouped into clusters, without them becoming too large. A 4 km radius seemed the most suitable to serve this purpose, which is in line with the approach of Zimmermann *et al.* (2009), who chose 3–4 km radii for the LBK in the Rhineland.

Before we merged the findspots within the clusters into bounded settlement territories, we carried out two corrections. A few clusters did not fit perfectly to the KDE, so we expanded or reduced them, and we combined some isolated clusters more generously (this is clearly visible for south-western Slovakia, by comparing Fig. 5.2.4 and 5), which obviously adds a measure of subjectivity. For the second correction, we assessed and partly modified the clusters according to qualitative characteristics of the underlying

landscape. For the reconstruction of settlement territories, it is important not only to consider calculated data based on 2D mapping, but also to critically assess the territories on the physical terrain. This is because the terrain is naturally structured and can thus influence the mobility of actors positively or negatively. Thus, Herzog also emphasises that a cost-adjusted density estimate must be ensured (2010: 206). The basis for the analyses presented here is thus a procedure that combines quantitative data and qualitative observations – in other words, a readjustment of calculated data on the basis of qualitative characteristics. The qualitative characteristics were obtained by including bodies of water, elevation and a slope model. This correction is visible in the areas south and north of the River Danube in the part of Austria known as the Weinviertel (wine quarter; compare Fig. 5.2.2–3 and 5.2.4–5).

Subsequently, the radii of contiguous settlement territories were firmly joined into one (dissolved). This is necessary to determine the area of the clusters, which is given here in km². Based on previous considerations, we decided that at least three sites must be included in clusters. Two adjacent and completely isolated sites were therefore not combined to form clusters and are therefore not included in the analyses. However, they are considered in the discussion of regional specifics (see below).

For the calculation of population numbers, we follow Zimmermann *et al.* (2009). The basis for the calculations is the assumption that there was one house per 0.7 km² and that this accommodated five to 10 individuals (8.5 average).

For the analyses of geographical preferences, we took the terrain into account. The landscape of the study area is characterised by watercourses, valleys and lowland areas, as well as highlands and mountains. The different landscapes have effects on the choice for human settlement and communication potential and, more generally, the morphology of the settlement areas. Put simply, flat terrain allows easy passage and thus facilitates communication on a regular basis. Steep slopes tend to have the opposite effect. Valleys in particular, *i.e.* flat terrain enclosed by steeper terrain units with rivers in their middle, direct communication. The lowlands are potential floodplains, which can hinder communication. Based on these characteristics, the settlement areas were adapted to the terrain after they had been calculated at a two-dimensional level (cf. Herzog, 2010: 206). For our quantitative analyses, we concentrated on the slope. The higher the slope value, the steeper the terrain and the more difficult it is to pass through. To this end, the slope (in %) of the terrain was determined, and we separated the study area into hexagons of 10 km diameter. For each hexagon, we calculated the slope values (lowest values present in the area covered by the hexagon, highest values present, median, arithmetic mean and standard deviation).

We then followed two different paths of analysis: First, for each of the periods, the slope values of the hexagons (median and standard deviation) covered by the respective settlement agglomerations were recorded. Second, we checked how much of the potentially available terrain was used. For that purpose, 12 classes based on the mean slope value of the hexagons were defined so that each of the classes occupies one twelfth of the total area of ~89 374 km², *i.e.* ~7448 km². This size represents the potential area of land that was available in each class. In order to discern how much of the land potential was used by the Neolithic settlers, we calculated how much of the land in each of these classes was occupied by the settlement areas in a regionally and chronologically comparative perspective.

Sources and source criticism

There are no standardised and comparably well-resolved datasets of settlement numbers and their locations from all regions. For this reason, we draw from different sources, of varying quality and representativeness (see Table 5.2.1), which can negatively affect representativity and thus our results. We therefore need to be critical of our sources.

Dataset	Source
Earliest LBK all regions	Fischer, 2016
LBK south-western Slovakia	Preuß, 1998; Milo <i>et al.</i> , 2004; Gabulová, 2015; data obtained during the surveys of the CRC 1266, subproject C2
Lengyel south-western Slovakia	Preuß, 1998; Milo <i>et al.</i> , 2004; Gabulová, 2015
LBK and Lengyel Transdanubia	Oross, 2013; Archaeological Archives of Janus Pannonius Museum, Pécs, Hungary; Archaeological Archives of Wosinski Mór Museum, Szekszárd, Hungary; Hungarian National Museum Archaeology Database, Copyright © 2023 Ariadne
LBK and Lengyel Lower Austria	Lenneis, 2017
Rondels	Barna <i>et al.</i> , 2016; Lenneis, 2017; Chebenová and Cheben, M., 2019
Lithic sources	Biró and Regénye, 2003; Cheben, M. <i>et al.</i> , 2020; Mining and Geological Survey of Hungary (MBFSZ) Felszíni földtan URL: https://map.mbfisz.gov.hu/arcgis/rest/services/atlasz200/atlasz200/MapServer

For south-western Slovakia, high-resolution datasets deal with only minor parts of the landscape (Gabulová, 2015: Microregion Upper Žitava Valley; CRC 1266: Žitava Valley; Milo *et al.*, 2004: Microregion Upper Žitava Valley). Although these more recent data cause stronger clusters, basically they cover the same areas as Preuß (1998). The stronger clusters did not turn out to be problematic for the analysis of this paper. This is due to the underlying procedure of determining territory sizes, *i.e.* it does not make much of a difference if many or just a few sites are registered within the agglomerations.

In Furholt and colleagues' (2013) presentation, the rather coarse dataset of Preuß (1998) was the only source used for the comparative region of Transdanubia. In contrast, in the present study, the data for Hungary come from a comprehensive dataset compiled especially for this purpose. The datasets in Preuß (1998); the archives of the local museums; the Hungarian National Museum's Archaeology Database; and the PhD thesis of Krisztián Oross (2013) are only partly in accordance with each other. There is a significantly larger number of datasets on the LBK in the region of Veszprém County in Preuß's mapping. Because we were unable to verify which data and criteria Preuß used for his mapping, we used the new data collection from the archives of Hungarian museums and Oross (2013) as the basis for the region of western Hungary, omitting the Preuß data. This leads to deviations compared with the previous study by Furholt *et al.* (2013; see below) in this region.

Also, in Lower Austria, the datasets by Preuß (1998) and Lenneis (2017) are very different. For the LBK, they cover same regions, and thus their data result in similar clusters. However, the clusters are denser and broader in Lenneis (2017) due to the much larger dataset. In Lower Austria, Lengyel is completely missing in Preuß's dataset, which raises doubts about the general representativeness of his mapping and further supports the approach of using more recent datasets.

Table 5.2.1. Sources used for our assessment of settlement territories.

Comparison of sizes of settlement agglomerations during the LBK and Lengyel periods

Figures 5.2.2 and 5.2.3 show the settlement territories identified and adjusted using the method described above. Densely populated areas are located between the mountains and the lowlands, often in the river valleys, as can be observed especially in south-western Slovakia (*e.g.* the Žitava Valley). From there, clusters scatter in a semi-circle from north-west western Hungary to south-east of the Balaton. Lower Austrian clusters at Lake Neusiedl join the Hungarian ones. From there, several neighbouring settlement territories can be observed south and north of the Danube.

While regional centres are present in south-western Slovakia, Furholt *et al.* (2013) speak of a dual model of social organisation for western Hungary, which includes both clusters and isolated (large) settlements with divergent social organisation.

Figure 5.2.2. LBK settlement territories in south-western Slovakia, Lower Austria and western Hungary, based on kernel density estimation, and the underlying find points.

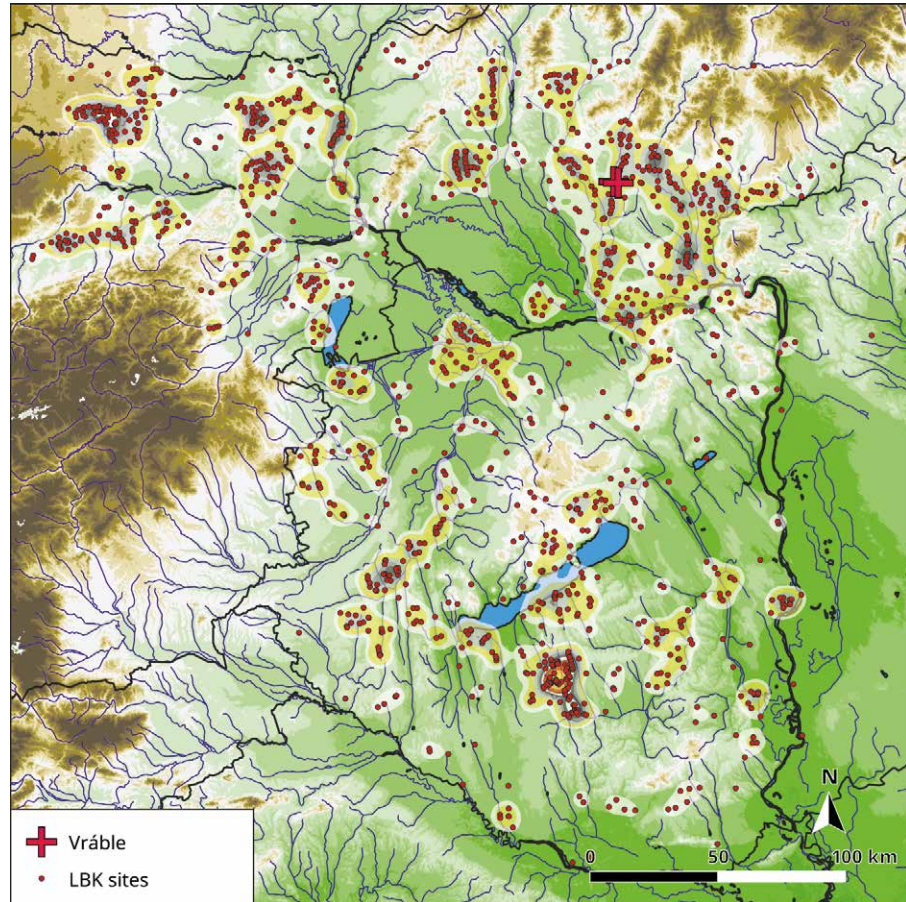
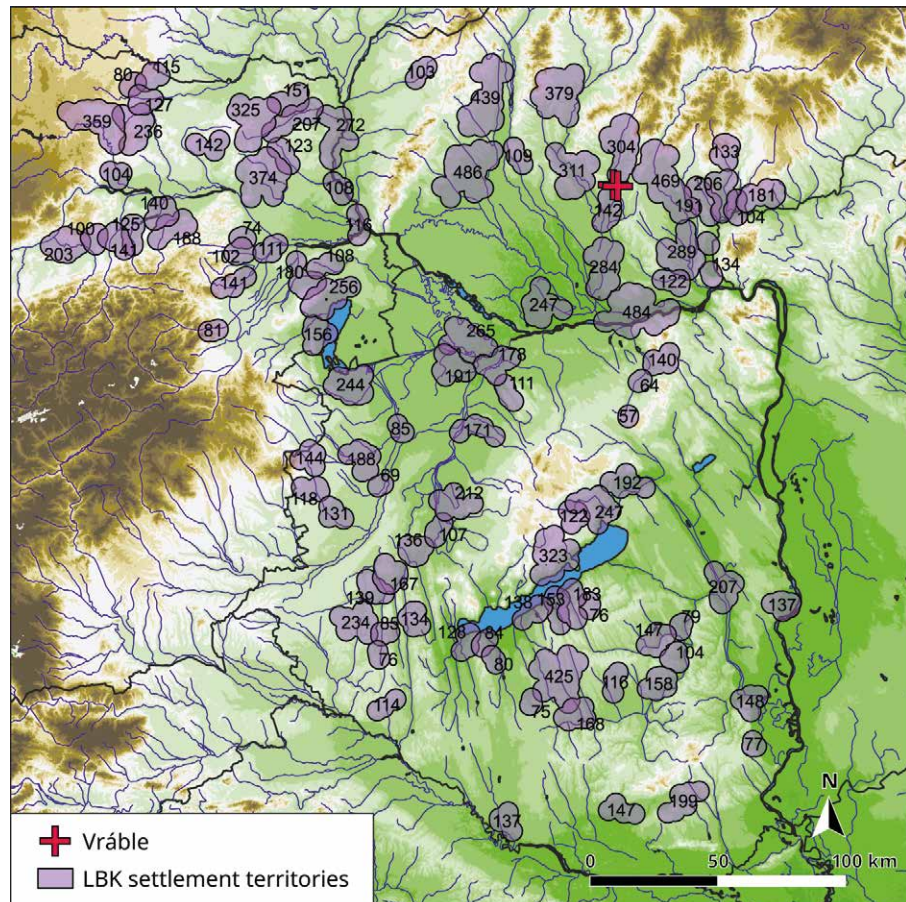


Figure 5.2.3. LBK settlement territories in south-western Slovakia, Lower Austria and western Hungary, based on 4 km radii and the clusters of the kernel density estimation. The numbers refer to the sizes of the settlement territories in km².



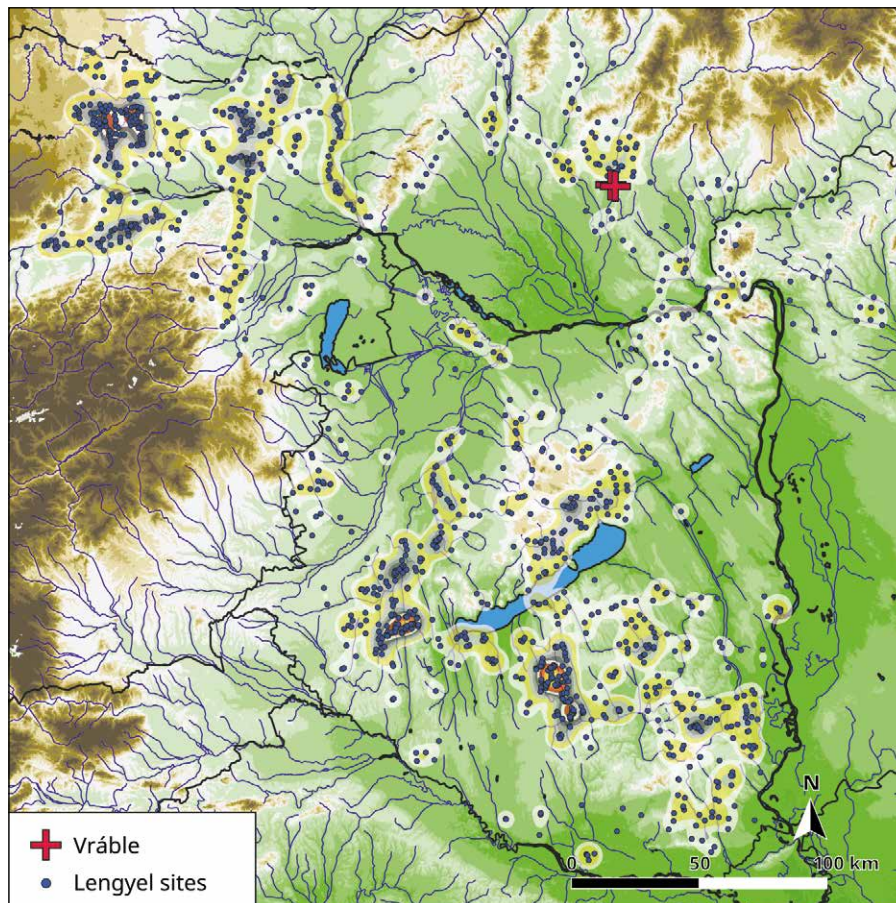


Figure 5.2.4. Lengyel settlement territories in south-western Slovakia, Lower Austria and western Hungary, based on kernel density estimation, and the underlying find points.

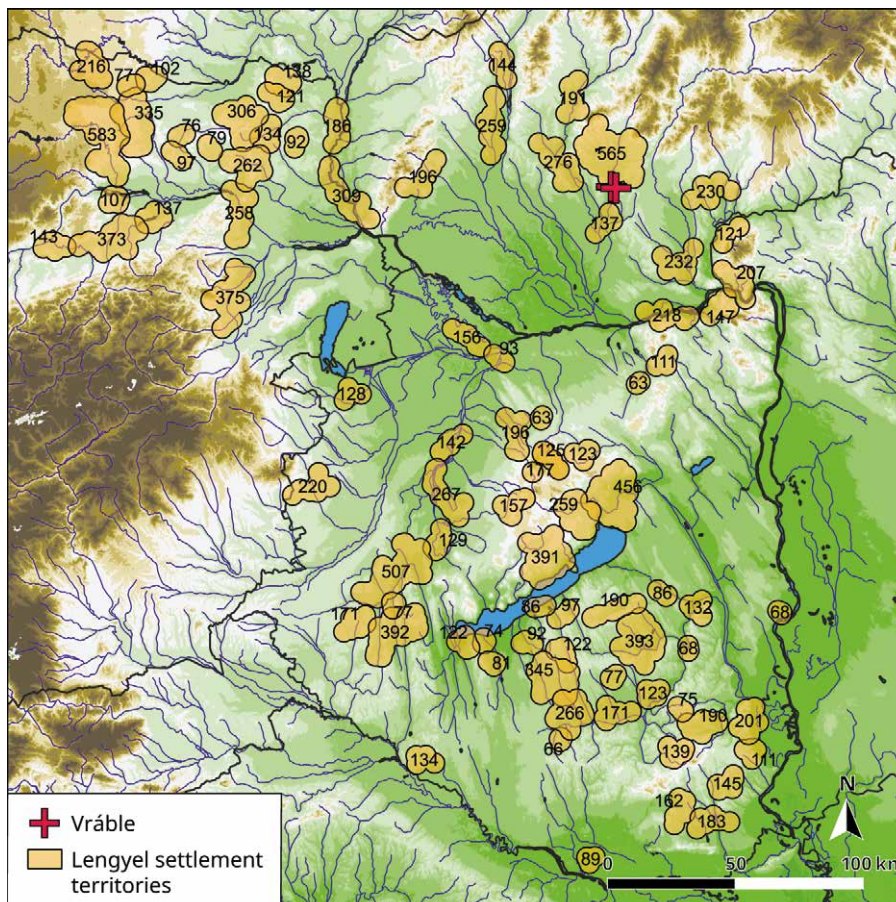


Figure 5.2.5. Lengyel settlement territories in south-western Slovakia, Lower Austria and western Hungary, based on 4 km radii and the clusters of the kernel density estimation. The numbers refer to the sizes of the settlement territories in km².

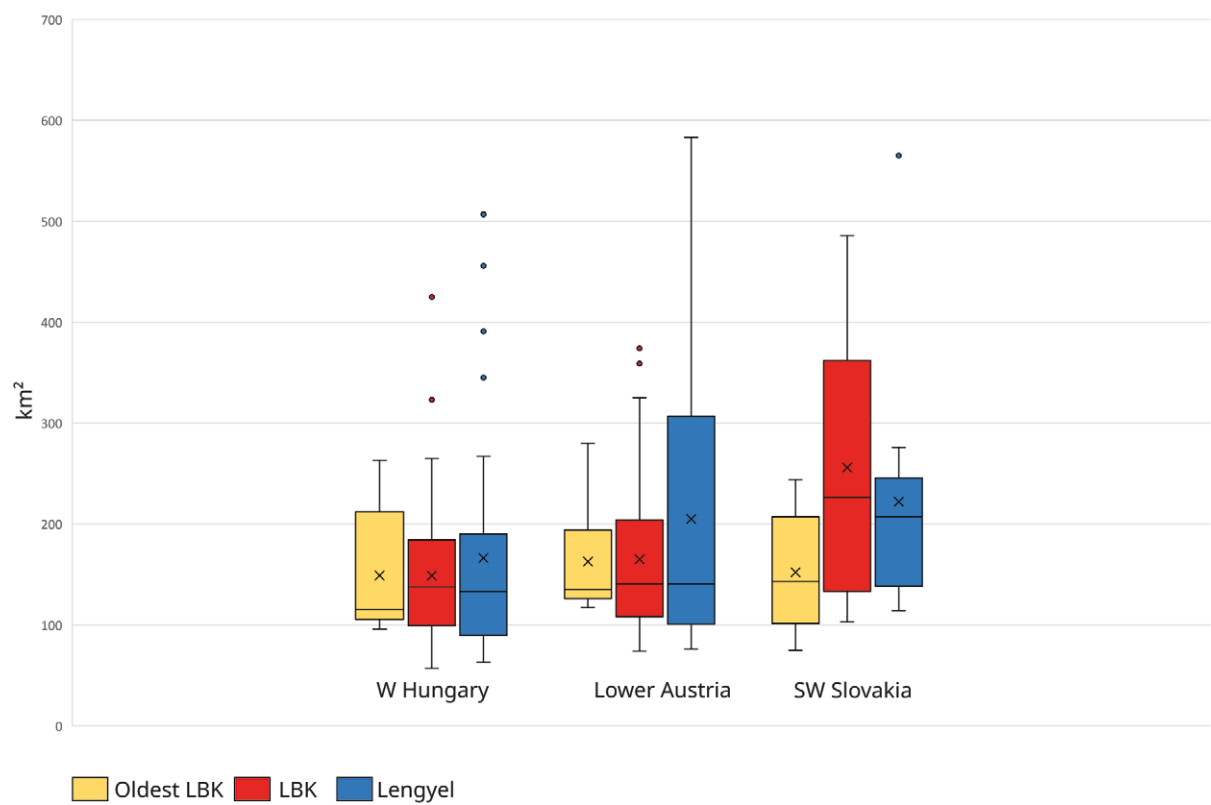


Figure 5.2.6. Boxplots of the sizes of the settlement territories in km² during the oldest LBK, the LBK as a whole and Lengyel in western Hungary, Lower Austria and south-western Slovakia.

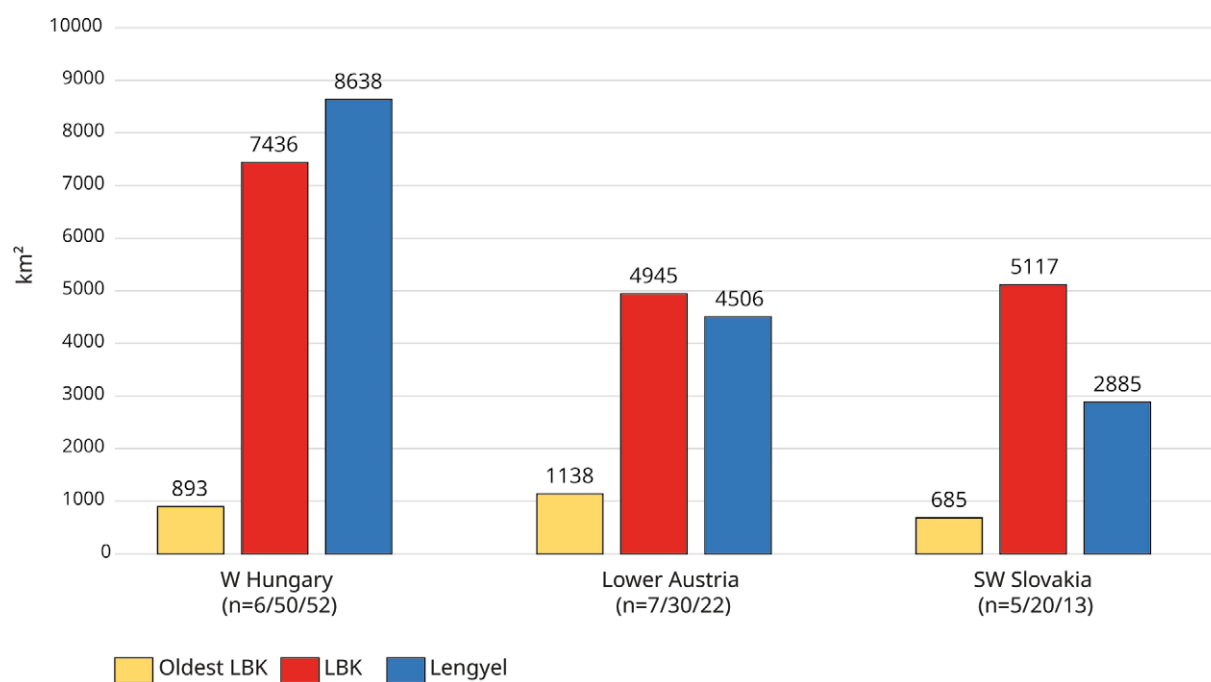


Figure 5.2.7. Comparison of areas occupied by the settlement agglomerations in km², chronologically and spatially.

They relate this to the proximity to south-eastern European cultures, where a corresponding pattern of scattered, self-sufficient large settlements is documented (cf. Chapman, 1989; Rassmann *et al.*, 2021: 458).

Based on the comparison from the macro perspective (cf. Figs. 5.2.2–3 with Figs. 5.2.4–5), the same regions are covered with settlement areas during the Lengyel period. A noticeable difference is the absence of settlement areas in the central region, the lowland plain between the three countries. Furthermore, the settlement in south-western Slovakia seems to decrease in extent, while in western Hungary the opposite situation occurs. However, the difference in the data sets used may have influenced this patterning. While a comprehensive data set is available for both phases of western Hungary, the data on south-western Slovakia (apart from the Upper Žitava Valley: Gabulová, 2015; Milo *et al.*, 2004), is based on Preuß (1998) only. Thus, the lack of Lengyel agglomerations in the area of Lake Neusiedl is probably not real. In Lenneis (2017), this region is missing because it does not belong to Lower Austria. The data set for Lengyel in Preuß (1998) is insufficient for this region (see above). Rondels are present here (see below), showing that the area was inhabited.

In Figure 5.2.6 we show the difference in the sizes of the settlement areas. It is striking that the median value in all three of our study regions is very similar in the Early LBK – around 120 to 150 km², with a low variation between the first and the third quartiles, largely between 100 and 200 km². The median stays at this 120 to 150 km² through the entire sequence in western Hungary and in Lower Austria, while in south-western Slovakia it is above 200 km². In south-western Slovakia, as well as in Lower Austria, the spectrum of area sizes widens in terms of the interquartile range, from 100 to 300 or 350 km², respectively, while it stays low in western Hungary, with the exception of a smaller number of outliers above 300 km².

In a chronological comparison, the regions of south-western Slovakia and western Hungary share the decreasing trend in the sizes of the settlement areas. The settlement pattern of Lower Austria develops contrary to this trend. The number of defined Lengyel clusters differs significantly (Fig. 5.2.7). In western Hungary, the number slightly increases during the Lengyel period compared with the LBK (from 50 to 52), and in Lower Austria and south-western Slovakia the numbers decrease (from 30 to 22 and from 20 to 13, respectively).

If we calculate the settlement areas of the respective phases of all regions combined, no clear differences are visible. The LBK occupies 17 498 km² and Lengyel 16 029 km². A superficial view would thus give the impression of quite constant sizes of the settled areas. But if we consider the three regions separately, differences become apparent (Fig. 5.2.7). While the inhabited area of western Hungary grows from 7436 to 8638 km², the area of south-western Slovakia shrinks from 5117 to 2885 km². In Lower Austria, the area shrinks only slightly, from 4945 to 4506 km² (cf. Figs. 5.2.2–3 and 4–5). In other words, we see two opposing trends in the regional comparison. In western Hungary, the settled area increases in the Lengyel period, whereas in Lower Austria and especially in south-western Slovakia, the settled area decreases.

Thus, the situation was initially relatively homogeneous in the LBK period, but it becomes heterogeneous in the Lengyel period. Regionally distinctive settlement dynamics emerge. This corresponds to the general finding of regionalisation, which defines the transitional phase from LBK to Lengyel (cf. Kreuz, 2012: 27; Shennan, 2018: 101–104).

The difference between the oldest LBK and the LBK as a whole is equally clear in all regions. The number of settlement areas and the area occupied are significantly lower in the pioneer stage of the LBK. It should be noted that the data on the oldest LBK are included in the data labelled just LBK in the figures, which means that a limited spectrum is a logical consequence. Furthermore, the time period is much shorter. Nevertheless, this observation describes a real phenomenon: the initial settlement area is significantly smaller in extent.

Table 5.2.2. Calculation of minimum, maximum and average number of inhabitants in the three phases: oldest LBK, entire LBK and Lengyel.

Period	Range of number of inhabitants	Average calculated
<i>Inhabitants at all</i>		
Oldest LBK	19,400–38,800	32,980
Entire LBK	124,986–249,971	212,476
Lengyel	114,492–228,986	194,638
<i>Inhabitants per settlement territory (n = 18 oldest LBK; n = 100 entire LBK; n = 87 Lengyel)</i>		
Oldest LBK	1077–2156	1832
Entire LBK	1250–2500	2125
Lengyel	1316–2632	2237

Calculation of number of inhabitants

The result of applying Zimmermann's model of the number of inhabitants to our data is shown in Table 5.2.2. Some words of caution are in order here. First, our calculations suggest that while in the oldest LBK territories the number of inhabitants is lower than in those of the other periods, but much less so than one would have expected. These calculations are based on the premise of a similar settlement density, a premise that of course may not be valid for the earliest, pioneering phase. Second, again under the premise of similar settlement densities, Lengyel territories would have housed the most people per territory. Yet, the real settlement density remains unknown, and we therefore do not suggest that our calculations here could be used to represent real social dynamics. Rather, we present them here in order to give an impression of the dimension of settlement and population numbers we are dealing with.

Continuities and discontinuities in the location of settlement agglomerations

Macro perspective

Figure 5.2.8 shows the continuities and discontinuities of the LBK and Lengyel settlement territories in our study area. In areas where there is an overlap between LBK and Lengyel settlements, a continuity can be observed from the macro perspective (for the micro perspective, *i.e.* on-site, see below). Conversely, the absence of such an overlap indicates a change in the local settlement pattern.

We observe that large parts of Lower Austria and south-western Slovakia, as well as the regions around Lake Balaton, were continuously used for settlement in the LBK as well as in the following period. Especially in Lower Austria and south-western Slovakia, it is clearly visible that those areas that lie between steep areas and the lowlands were selected in both periods. This observation is in line with observations in central Europe west of our investigation area, where the Stroke-Ornamented Ware culture follows the LBK (Kaufmann, 1976: 112; Zápotocká, 2007: 207).

We observe continuous areas of gravitation in Lower Austria in particular. One concentration south of the Danube (and west of Vienna) and two concentrations north of the Danube (and west and north of Vienna, respectively) are reflected in both the LBK and the Lengyel data sets. In south-western Slovakia, a continuous centre seems to exist in the area of the Upper Žitava Valley only, but this could be due to our own research focus on this region, creating a bias in the dataset (see above).

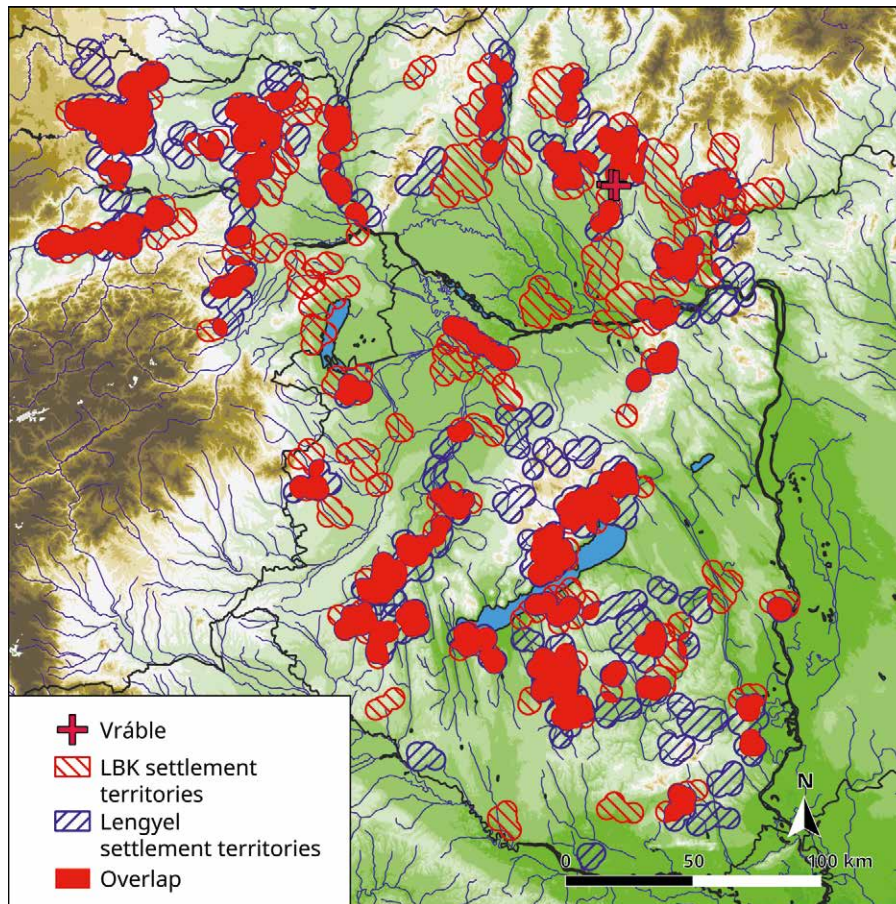


Figure 5.2.8. Settlement territories of the LBK and Lengyel in south-western Slovakia, Lower Austria and western Hungary. Marked in red (filled) are overlaps between the two phases, marked in red (hatched) are areas abandoned during Lengyel, marked in blue are areas newly settled during Lengyel.

In western Hungary, the centre in Somogy County, south of Lake Balaton, is likewise continuous. Southwest of the Balaton, on the border between Zala and Somogy counties, a weaker centre remains, but another emerges directly south of it in the Lengyel phase. The relatively dense settlement north of the Balaton remains. South-east of the Balaton, in the region covered by Somogy and Tolna counties, an LBK centre remains during Lengyel, but it becomes denser and enlarged towards the south. Thus, the biggest changes seem to happen in western Hungary. There are more and larger gravitational zones or clusters of settlements and settlement areas.

In Lower Austria, we note the pattern of Lengyel-only clusters being north-west of the overlap areas and LBK-only clusters being south-east of the overlaps. This pattern is further explored below.

Clear discontinuities in territorial behaviour are present in the central area of the map section, in the border zone of the three analysed countries. LBK agglomerations line up around an open area in the central region. If Lengyel agglomerations are located nearby, they are found farther away from the central region and tend towards the high altitudes. We also deal with this pattern below.

Micro perspective

Although on a macro level the same spaces were settled in Lower Austria in particular, on a micro level only few continuities in the settlement structure can be observed. The settlements and rondels of the Lengyel period are almost never found in the immediate vicinity of earlier LBK areas, and only a few settlements have yielded

artefacts of both periods (Neubauer, 2017: 285). In the Lengyel period, settlements move closer to spring areas in the hilly landscape (Neubauer, 2017: 294f.).

In Moravia, as many as 37 per cent of LBK settlements have yielded material of the subsequent Stroke-Ornamented Ware culture (4900–4800 BCE). Trampota and Pajdla (2022) differentiate between the Stroke-Ornamented Ware and Lengyel cultures and place the latter a century later. This phase shares only 5 per cent overlap with the preceding phase (Trampota and Pajdla, 2022: 16). Thus, here too, a clear break can be seen.

For south-western Slovakia, studies on the relationship between the LBK and Lengyel periods at the micro level are lacking. However, fieldwork of recent years suggests that at least in the eastern and northern parts of Žitava Valley there were regularly settlements covering both phases. This is shown by the Čierne Kľačany site, where we see both LBK and Lengyel houses, and where features interpreted as classic Lengyel houses contained Želiezovce pottery (Cheben *et al.*, 2019; Cheben, I. *et al.*, 2020). In addition, as our field surveys have demonstrated, both LBK and Lengyel house features co-appear at the settlements of Čifáre, Telince and Mochovce (see Chapter 2.3). Furthermore, Želiezovce-style pottery and presumably later, (proto-) Lengyel pottery was found at Vráble (Cheben and Bistáková, 2020). A few spatially isolated Lengyel houses were found just to the south of the LBK and Želiezovce site of Vráble. In the Žitava Valley south of Vráble, Lengyel sites are located several kilometres away from LBK sites. The sites Žitavce and Podhájska contain rondels but no clear house structures.

According to the current state of knowledge, on the micro scale there is a clear difference between the regions in terms of continuity and discontinuity of settlement, which requires further research.

The location in the landscape

Neolithic economic activity potentially required different sites for different purposes. The starting point for our analysis is the assumption that the relationship of settlement agglomerations to the slope of the terrain reveals something about the potential use of the landscape (cf. Mischka, 2007: 147–149).

Figure 5.2.9 shows boxplots of the location of LBK and Lengyel agglomerations in the terrain, as well as the total potential of the study area (green). We see that the median values of the terrain roughly correspond to the utilised areas. However, the extreme positions (>10 per cent slope) present in the study area were not used during either the LBK or the Lengyel periods. The chronological comparison of the entire area (Fig. 5.2.10) shows that the mean values of the average slope covered by the settlement areas increase from LBK to Lengyel. Thus, the settlement areas shift towards higher and steeper terrain over the course of the centuries.

The chronological comparisons in Figures 5.2.11–13 confirm this from a regional perspective for two of the three regions. Lower Austria deviates from the trend in that here the median slope (50 per cent of the data) also increases, but the total range of used slope values (100 per cent) is lower in the Lengyel than in the LBK period. In western Hungary, the total slope range of the Lengyel phase is markedly larger. In south-western Slovakia the range in the Lengyel period is slightly larger, but also starts at a higher elevation. The comparison based solely on the second to the third quartiles (from 50 to 75 per cent of the data) shows clearly that steeper slopes were used in the Lengyel period than in the LBK period. This we also seen in western Hungary, but here the pattern is less pronounced.

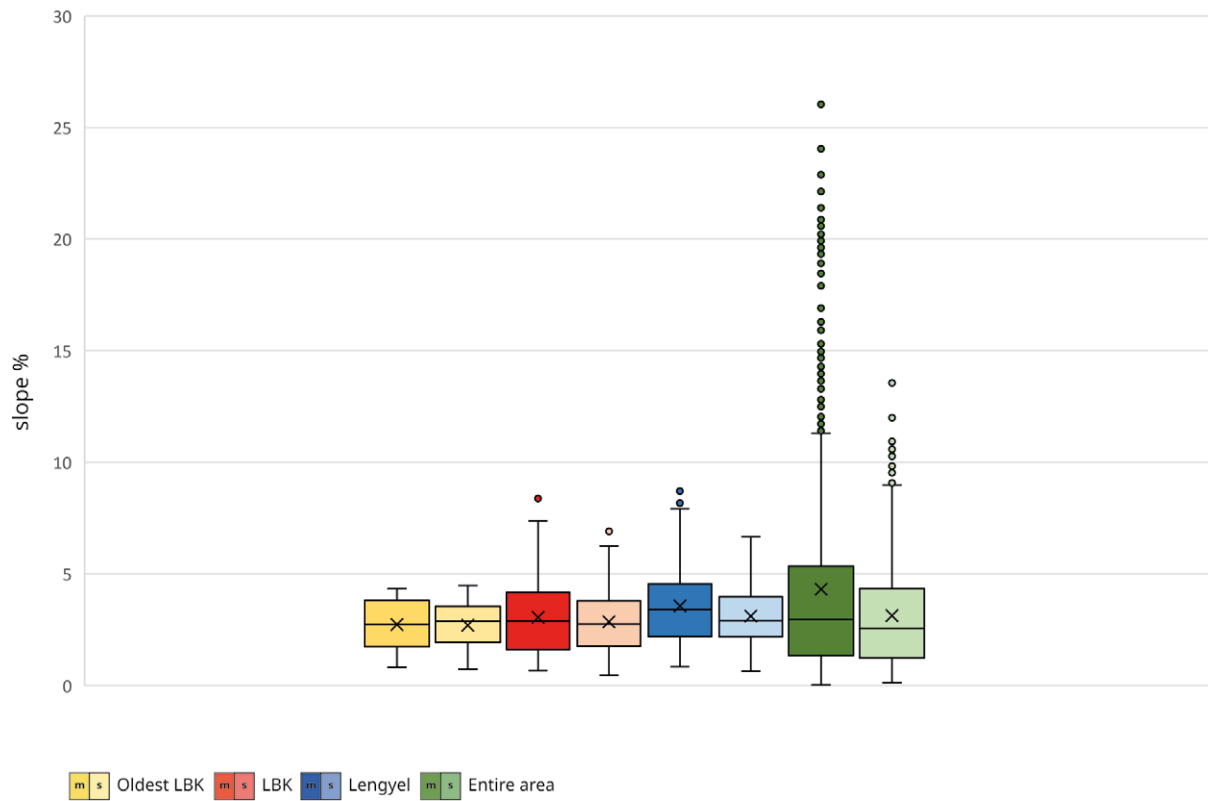


Figure 5.2.9. Regionally undifferentiated location of settlement areas in the terrain in relation to the slope. Shown are the median (m) and standard deviation (s) of the slope in which settlement territories of the three chronological stages appear, as well as the slope values of the entire study area – the overall potential. The higher the values, the steeper the terrain. Crosses mark the arithmetic mean of the values.

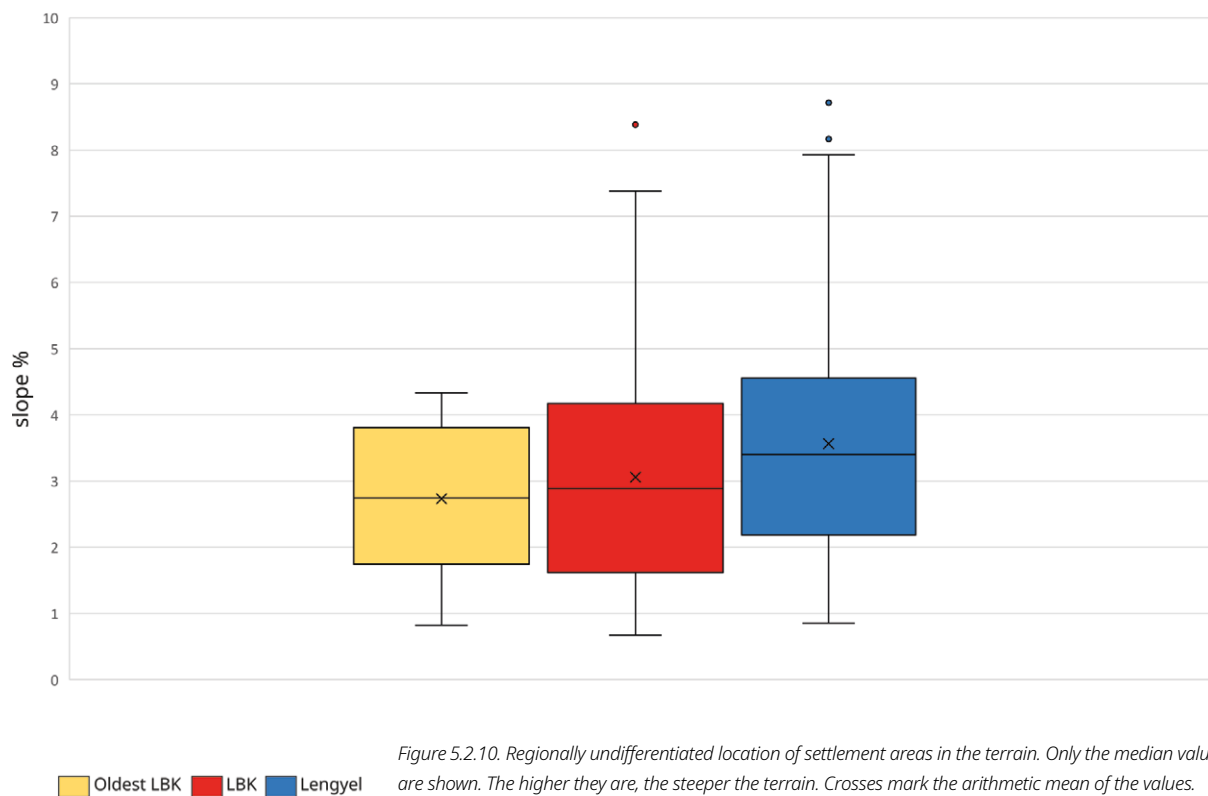


Figure 5.2.10. Regionally undifferentiated location of settlement areas in the terrain. Only the median values are shown. The higher they are, the steeper the terrain. Crosses mark the arithmetic mean of the values.

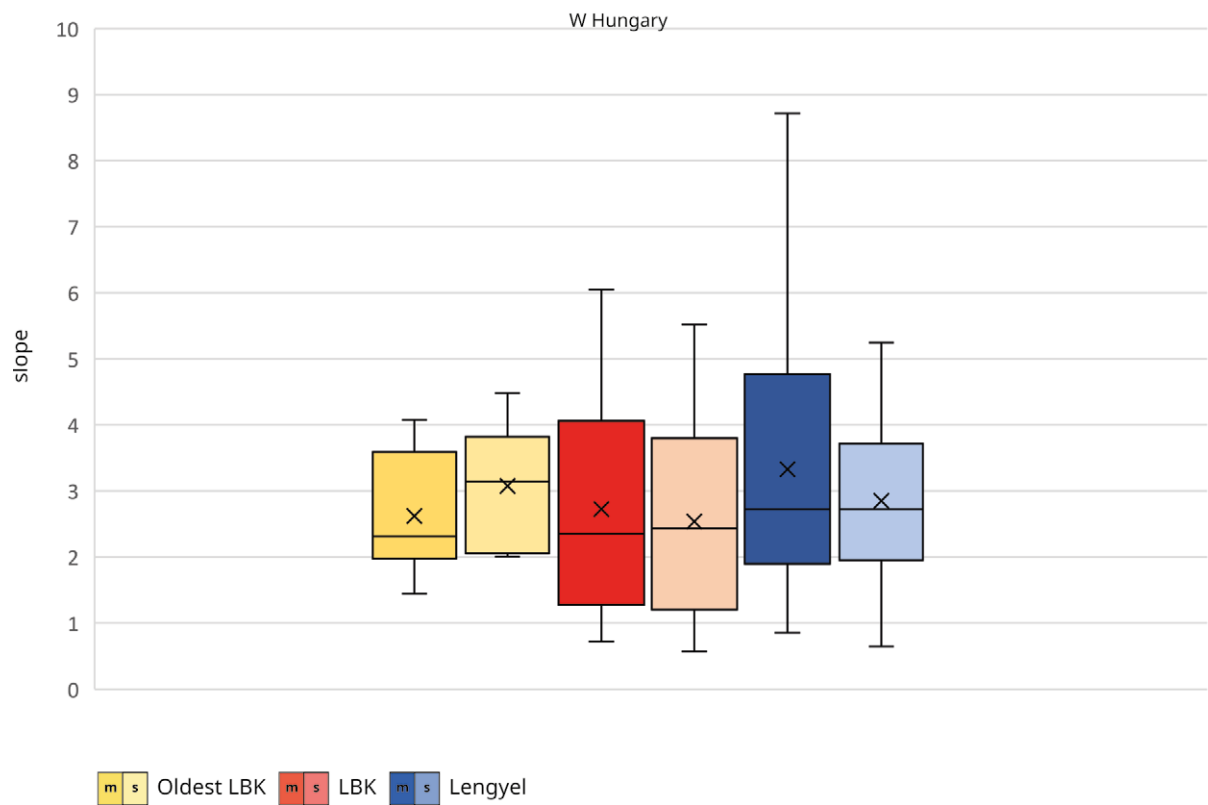


Figure 5.2.11. Location of settlement areas in the terrain for the older LBK, LBK and Lengyel in western Hungary. Crosses mark the arithmetic mean of the values.

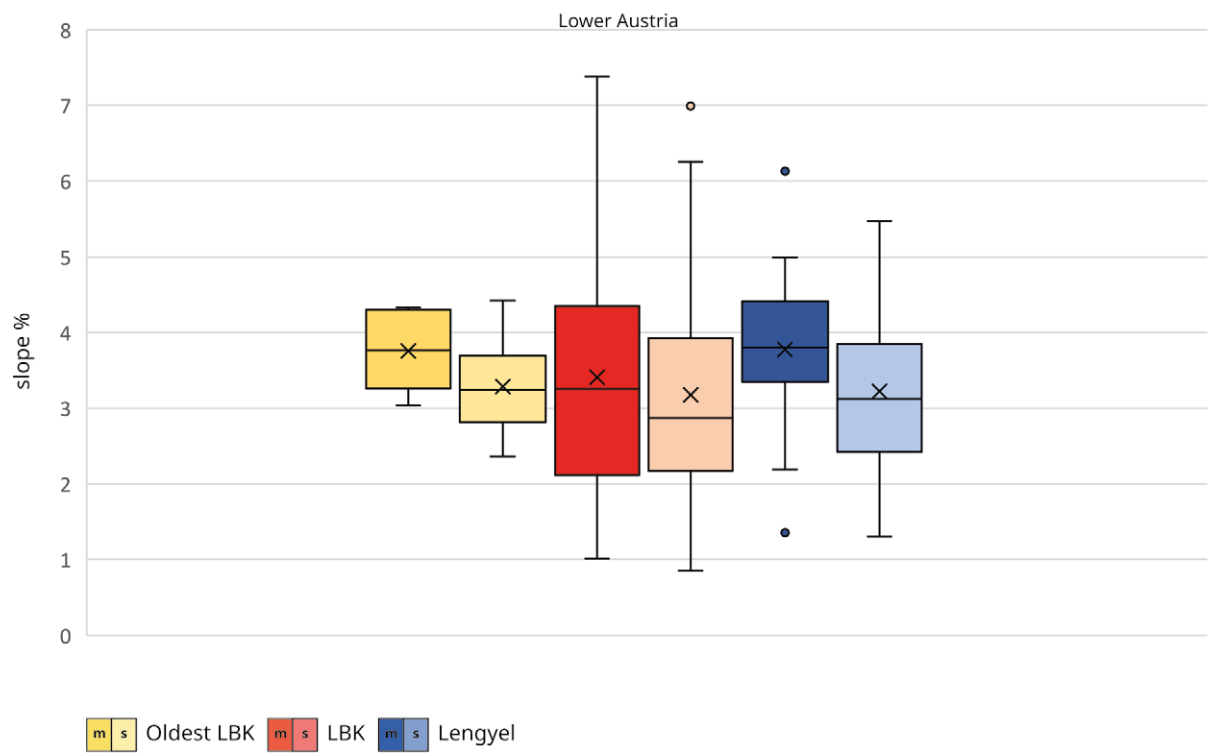


Figure 5.2.12. Location of settlement areas in the terrain for older LBK, LBK and Lengyel in Lower Austria. Crosses mark the arithmetic mean of the values.

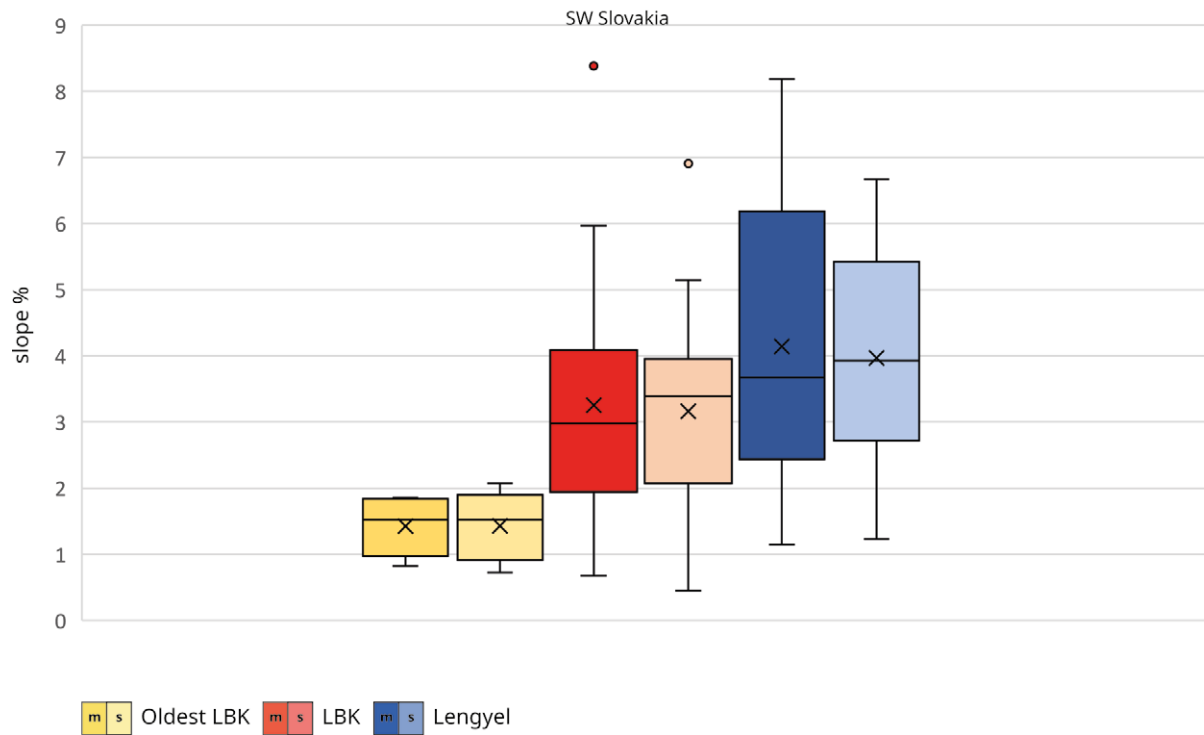


Figure 5.2.13. Location of settlement areas in the terrain for older LBK, LBK and Lengyel in south-western Slovakia. Crosses mark the arithmetic mean of the values.

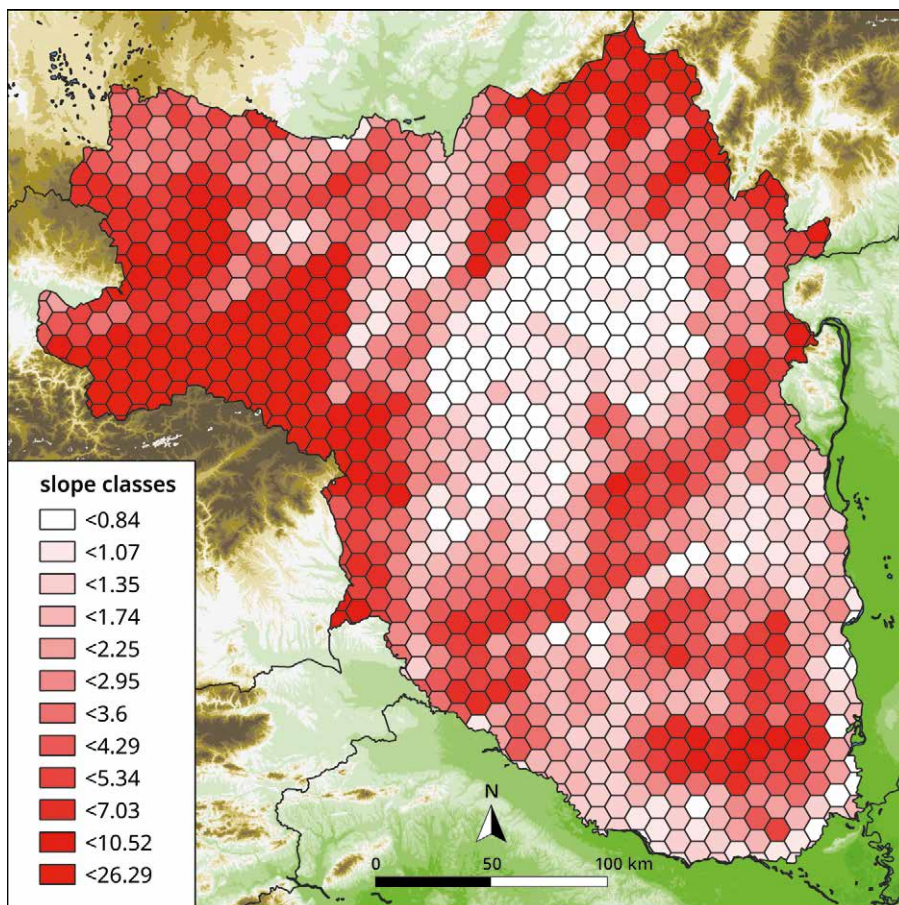


Figure 5.2.14. The study area divided into hexagons and differentiated by steepness. Red marks steep and white marks flat terrain.

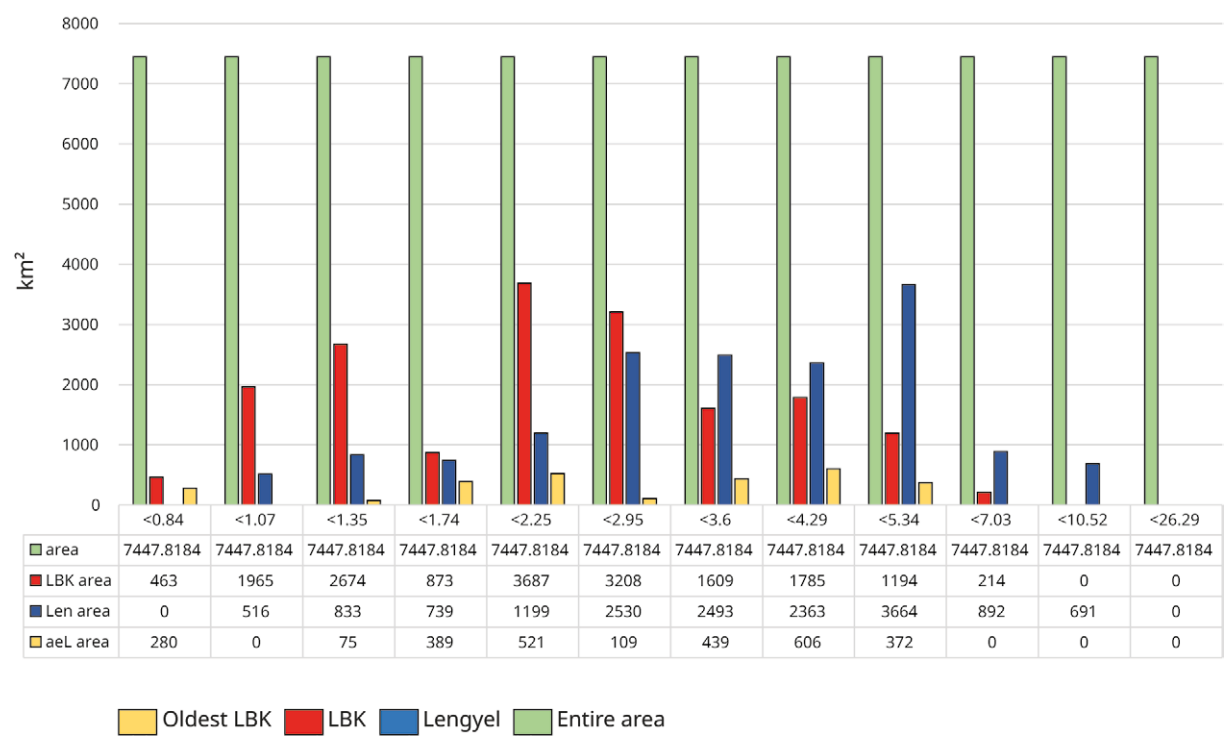


Figure 5.2.15. Extent of the settlement areas by period in terms of the entire land potential, separated into 12 slope-value classes. The bars show the respective share and the table shows the occupied area in km².

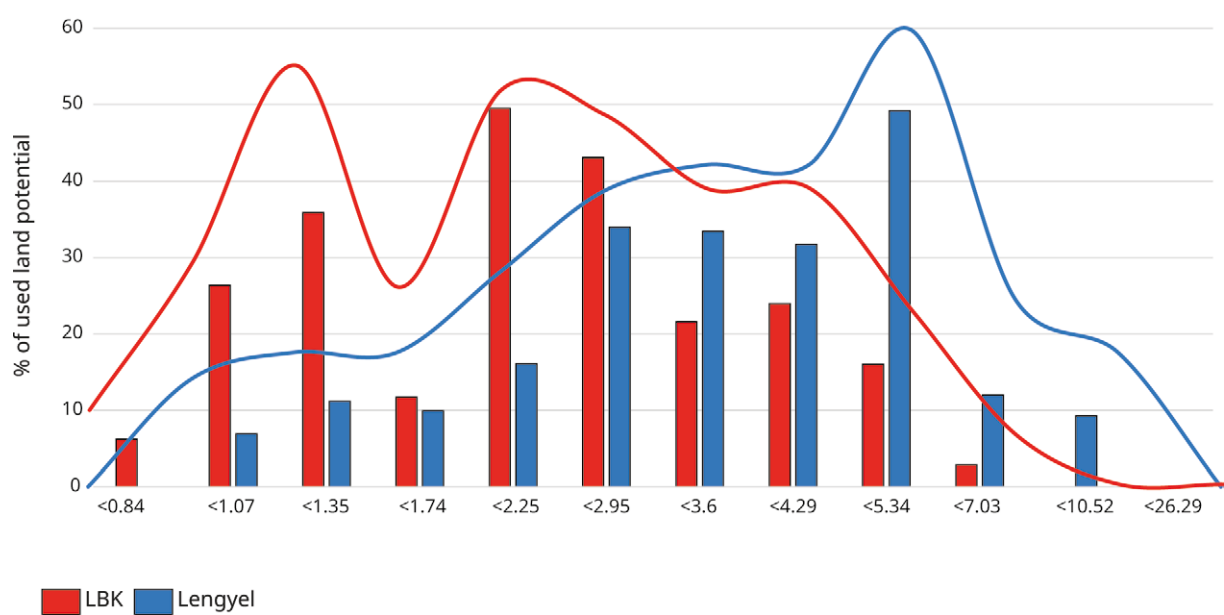


Figure 5.2.16. Extent of the settlement areas of the LBK and Lengyel in terms of the entire land potential, separated into 12 slope-value classes. The bars show the percentage of available land. The curves are re-plotted for visual comparison and do not correspond fully to the values of the Y-axis.

Especially in south-western Slovakia, the settlement areas of the oldest LBK are located in strikingly flat terrain, and 100 per cent of the data on the oldest LBK of south-western Slovakia lie in the range of the lowest 25 per cent of the entire LBK.

Next, we examined in which of the 12 slope classes the settlement agglomerations occur and how much of the area potentially available in each class was occupied (Fig. 5.2.14). The bars on Figure 5.2.15 show the respective proportion of the area taken up by the 12 classes. The first three rows of the table show these proportions. The lower three rows show the area occupied by the settlements in the 12 classes.

In Figures 5.2.15 and 16, within the lowest mean values (slope < 0.84), the entire LBK and the oldest LBK stand out. Areas with values below 0.84 thus only exceptionally represent settlement areas. From 2.95 upwards, Lengyel dominates over LBK. Areas with mean values above 7.03 are rarely used as settlement areas. In the higher range, between 7.03 and 10.52, Lengyel stands alone. Values higher than 10.52 remain unsettled. Thus, areas with values from 0 to 10.52 are settled and areas with values from 0.84 to 7.03 belong to the regular settlement area.

Further, we can see that during the LBK people used almost 50 per cent of the useable area with a slope of 1.74–2.25. The range 2.25–2.95 was also extensively occupied, with 43 per cent. In the areas with slope 0.84–1.35 as well as 2.95–4.29, still more than 20 per cent of the available area was occupied. The question whether the drop in the slope area 1.07–1.74 is real or can be explained by a data representation problem has to remain open here.

During the Lengyel period, people settle more than 30 per cent of the potential area 2.25–4.29. The most pronounced inhabitation occurred in the area 4.29–5.34, where almost 50 per cent of the available area was occupied. This finding is especially striking as the LBK presence in this area is clearly reduced compared with the lower areas.

The continuities in settlement areas, which are mainly found in Lower Austria and south-western Slovakia based on the visual comparison, probably are connected to the use of the same terrain. In both phases, the areas between lowland and elevation were used: In south-western Slovakia both LBK and Lengyel are found in the north-south valleys. Above, we already addressed that LBK settlement areas extended farthest into the non-settled central area of the map section (dark green = lowland). This is reflected in Figures 5.2.15 and 16 by the values <0.84. Lengyel settlement, on the other hand, was oriented towards mountain slopes. This is also evidenced by the statistics on the same figure, as Lengyel dominates in the range from 7.03 and exclusively occupies the range from 7.03 to 10.52.

Similarly, researchers in Moravia, who did not record the slope of the terrain but, rather, the elevation (of individual settlements) in the terrain, observed a *'tendency in the Morava Basin to settle sites at higher elevations from the interval 4800–4600 BC (Early Lengyel)'* (Trampota and Pajdla, 2022: 7). Already Kaufmann (1976) noticed the same trend for the Stroke-Ornamented Ware culture of central Germany (Kaufmann 1976: 112). For western Hungary, Biró and Regénye (2003; 2007: 262–267) describe that many mining areas intensively used during the Lengyel phase are located in the Bakony Mountains (see below), thus towards higher elevations. Lenneis (2017) notes that Lengyel settlements moved closer to spring areas in the hilly landscape. At the same time, an increased use of cattle is evidenced, which is probably related to the now-preferred elevated situations close to springs (Neubauer, 2017: 285, 294f.). Kadrow (2017: 73) describes similar trends for the Lengyel period in Poland. This suggests changed activities in the Lengyel period, probably a change or expansion of economic practices to higher and steeper terrain.

Relationship of settlement to sources of lithic raw materials and rondels

Sources of lithic raw materials

Many studies comparing LBK and Lengyel equally reconstruct a change in the use and exchange of lithic resources and consequently in the spatial-social organisation (Biró and Regenye, 2003; Mateiciucová, 2017a; 2017b; Cheben, M. *et al.*, 2020; Trampota and Pajdla, 2022).

In the Late LBK phase at Vráble, limnic silicite is the most frequent (almost 35 per cent) flint material. It occurs about 70 km away, in the Zierska kotlina basin, but also only 10 km away (Volková Starta complex), as well as in a secondary deposit in the river gravel of the Hron River (Cheben, M. *et al.*, 2020: 366; Cheben, I. and Cheben, M., 2021: 178). The geological sources of the Tevel flint and Szentgál radiolarite materials (both about 8–9 per cent) are also relatively close (about 100 km), in the Bakony Mountains (part of the Transdanubian Mountains). The raw material sources of Cracow Jurassic flint (Kraków-Częstochowa highlands)¹ are farther distant (200–300 km; Mateiciucová, 2008; Přichystal, 2013: 102–104; Cheben, I. *et al.*, 2020: 47–48); this lithic accounts for 8–9 per cent of the Vráble assemblage. Obsidian, whose closest source is 250 km away, in Tokaj-Eperjes Mountain (HU) or Prešovsko-Tokajské Pohorie (SLO) (part of Zemplén/Zemplín Mountain and the Northern Mountain Range; Biró, 1981; Biró, 1998; Biró, 2004; Biró, 2018; Szepesi *et al.*, 2018), is the second most used material (slightly below 30 per cent) (Cheben, M. *et al.*, 2020: 365). On the basis of pieces with original surfaces, Cheben, M. *et al.* reconstructed that during the Late LBK phase most of the materials (Tevel flint, Szentgál radiolarite, Cracow Jurassic flint and obsidian) were brought into the settlement as raw materials or barely processed forms (Cheben, M. *et al.*, 2020: 365f.). In the Želiezovce phase, limnic silicite continues to be the most common flint material, accounting for almost 50 per cent. A clear difference with the previous phase is the proportion of other silices used. Only the distant sources, Cracow Jurassic flint and obsidian, are present in larger quantities (slightly below 30 per cent and about 13 per cent, respectively). All other materials are present in insignificant proportions (Cheben, M. *et al.*, 2020: 372).

Lower Austria provides a good comparison. The high diversity of lithic sources used during the LBK phase is also seen in the Lengyel phase. However, on the one hand, more local resources, such as Maurer radiolarites, are now used, as well as lower-quality materials (such as river gravels). Chert from Krumlovský Les² (at a distance of about 50–80 km) is particularly common (Oliva, 1997; Mateiciucová, 2008: 44–45; Přichystal, 2013: 79–82). On the other hand, artefacts from very distant sources now occur. These are Chocolate flint from east-central Poland, Plattensilex from Abensberg-Arnhofen and jadeite from the eastern Italian Alps (Mateiciucová, 2017a: 193–195; Mateiciucová, 2017b: 387–391; Trnka and Götzinger, 2017: 395; Sudoł-Procyk *et al.*, 2018; 2021).

Thus, on the one hand, nearby sources are increasingly used, as demonstrated at Vráble by the increase in limnic silicite. On the other hand, distant sources are now more important than before, while sources at moderate distances hardly play a role anymore. Thus, at Vráble, the decentralised-autarkic supply strategies of the LBK are

1 Probably already mined (Mateiciucová 2017a, 197).

2 Krumlovský Les chert is important from the younger LBK onwards. In general, Krumlovský Les I and II types can be differentiated. Type I is grey and coarse-grained and typical in the inventory of the Late LBK. Type II is light grey-brown and fine-grained and is particularly associated with Lengyel (Mateiciucová 2017a, 196; Oliva 1997; Mateiciucová 2008, 44–45; Přichystal 2013, 79–82).

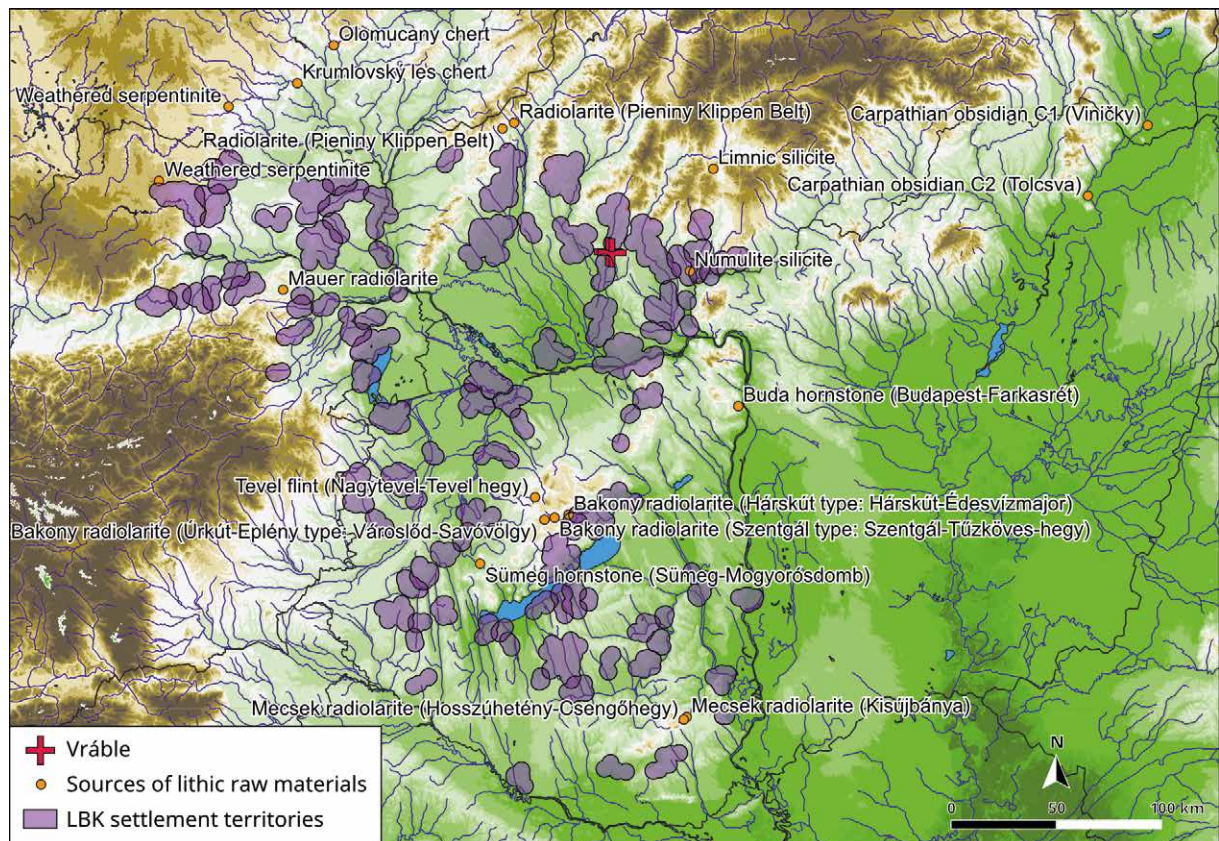
confirmed, but we also see the beginning of a development that culminates in the Lengyel period: the exchange of raw materials from distant sources.

During the LBK in the settlements of western Hungary, flint was processed seasonally and probably on a household basis (according to Biró and Regenye, 2003). This is documented several times in such settlements that are located relatively far away from the respective raw material sources of the materials used. There are no indications for either restricted access to or rights of use of individual raw materials. During Lengyel, the organisation changes. At some settlement sites, people processed flint beyond their own needs and for distribution to other sites. Biró and Regenye (2003) refer to the Bakony Mountain (Veszprém County, north of the Balaton), with its many flint sources. The radiolarites from Szentgál, Hárskút and Úrkút-Eplény play a special role in the exchange systems during the LBK and Lengyel periods in the entire study area (Mateiciucová, 2017a: 194; Cheben, M. *et al.*, 2020: 365, 372). In the Bakony Mountain, we find high-altitude Lengyel settlements with specialised functions (mining, processing and distribution of stone material). This suggests the presence of a division of labour and an elaborate distribution system (Biró and Regenye, 2003: 266).

However, the general change in the intensity of use of lithic sources is not reflected in our maps (Figs. 5.2.17 and 18).

Finally, the role of the flint is worth emphasising in the reconstruction of the potential ‘area of origin’ of the LBK. Many researchers recognise the origin to have been in the vicinity of the Balaton (Bánffy *et al.*, 2007: 232f.). The Bakony radiolarites (Szentgál, Hárskút, Úrkút-Eplény) are found in the settlement material of south-western Slovakia and Lower Austria (see above). However, they are also found more than 800 km away, in Moravia, Bohemia and southern Germany – also in contexts of the oldest LBK (Mateiciucová, 2017a: 193–195). In general, in LBK contexts, several artefacts appear which come from specific sources – think of *Spondylus* items or

Figure 5.2.17. Relationship of the settlement territories to sources of lithic raw materials used during the LBK (data on the mines according to Biró and Regenye 2003; Cheben, I. and Regenye 2003; Cheben, M. 2021; Mining and Geological Survey of Hungary (MBFSZ)).



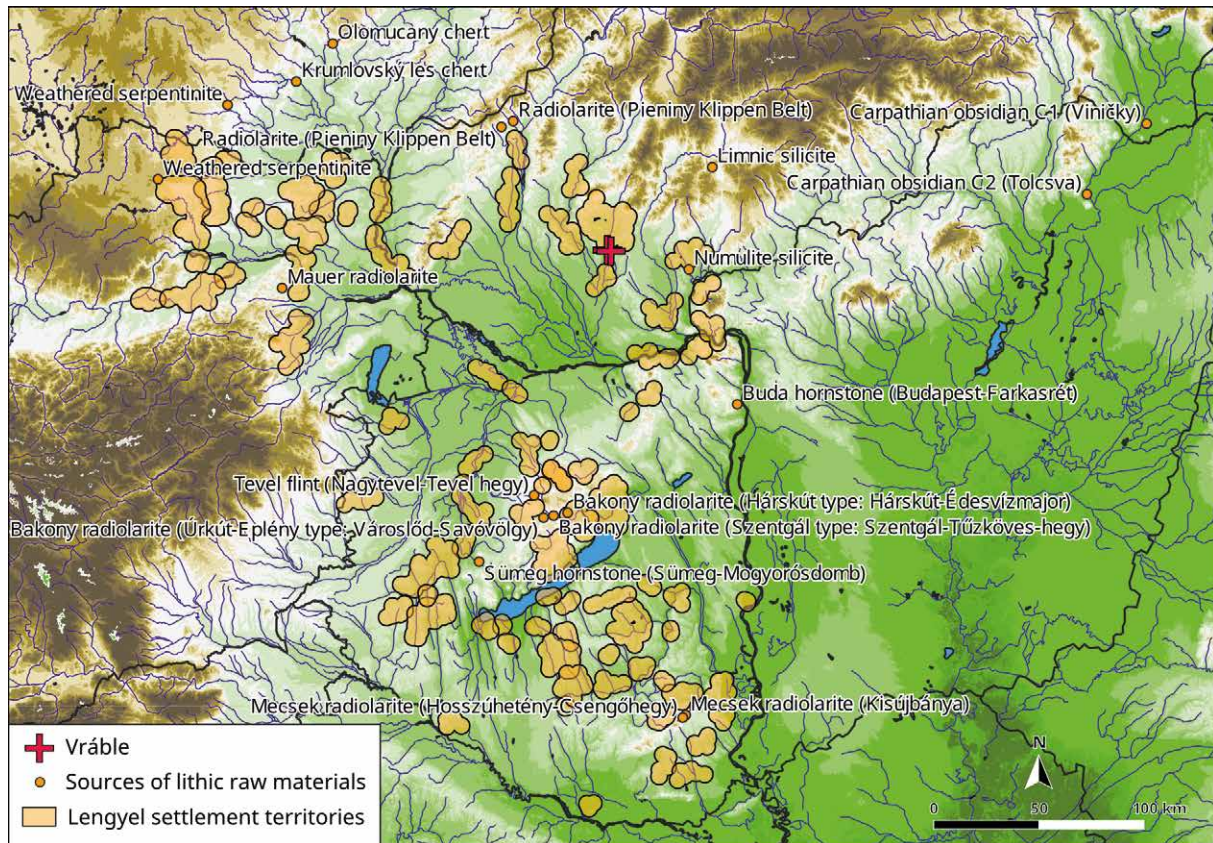


Figure 5.2.18. Relationship of the settlement territories to flint and bedrock deposits used during the Lengyel period (data on the mines according to Biró and Regénye 2003; Cheben, I. and Cheben, M. 2021; Mining and Geological Survey of Hungary (MBFSZ)).

adzes made of actinolite hornblende slate from the Jizera Mountains (Zimmermann, 1995; Nowak, 2008; Windler, 2018). Since we find the Bakony radiolarites also at such great distances and especially in the pioneer phase, it is reasonable to assume that their use represents a form of remembrance or honouring of the inhabitants' region of origin.

The relation to Middle Neolithic rondels

During the Late LBK, enclosures – both roundish and non-roundish – are mainly, but not exclusively, found in the west of the LBK distribution (Meyer and Raetzl-Fabian, 2006). Roundish enclosures are (so far) completely missing in the east, and for a long time, only a few non-roundish LBK enclosures from Lower Austria and one from Hungary were known from the study area (Neubauer, 2017: 285; cf. Müller and Furrholt, 2011: 23, fig. 4). The discovery of Vrábce now adds a single find in south-western Slovakia. Even with the intensive magnetic survey campaign (see Chapter 2.3), in which the structures of numerous settlements in south-western Slovakia were uncovered, no further LBK enclosures were found. Thus, Vrábce is – besides Tolna-Mözs in Hungary – one of the easternmost known sites, and it is unique in its immediate surroundings.

The central European Lengyel period is decisively characterised by the presence of rondels. They form a common element of many regional groups, from central Germany, across the Czech Republic and into Hungary. They are unevenly distributed in the study area. The highest concentration is known in the Austrian Weinviertel (various contributions in Bertemes and Meller, 2012).

As Figure 5.2.19 shows, in Lower Austria, a few rondels are located at the edge of settlement areas. Most, however, are in the centre of the settlement areas. In south-

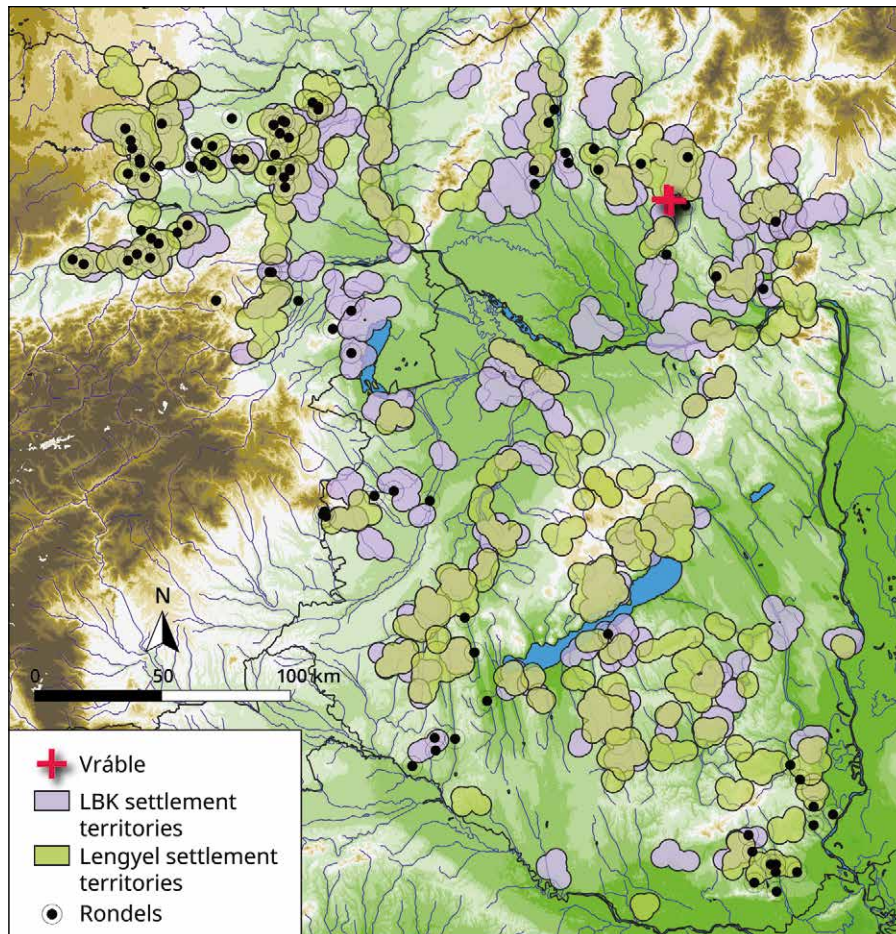


Figure 5.2.19. Lengyel rondels in south-western Slovakia, Lower Austria and western Hungary (after Chebenová and Cheben, 2019; Lenneis, 2017; Barna et al., 2016).

western Slovakia, they are found everywhere where Lengyel settlement clusters occur. Interestingly, here they are always close to clusters, but never in the centre of them. The concentration of rondels in south-eastern western Hungary coincides with the settlement territories. Similar to the situation in south-western Slovakia, they do not occur in the centres of the clusters but on the periphery.

However, in western Hungary we observe many settlement areas without rondels nearby. This concerns especially the settlement areas south and south-east of the Balaton and those north and north-east of the Balaton. Here, people apparently managed without rondels. The lack of rondels north of the Balaton is interesting, as most of the known prehistoric mines or quarries are located here. It seems plausible that there is a connection between the lack of rondels and the high frequency of mines. Perhaps, these settlements were specifically related to the use of the flint sources and were thus not permanently inhabited and that, accordingly, there was no need for the special activities carried out in the rondels here, as people undertook these activities there at other locations. Or it could be that the communal work carried out here – extraction, production and transport of silicites – was communally meaningful, similar to the rituals in the rondels and that the rondels would therefore be obsolete here.

Conclusion

As part of our approach to investigating settlement densities in order to reconstruct and analyse settlement areas, we investigated several spatial aspects and uncovered a few interesting patterns. In Lower Austria and in south-western Slovakia, roughly 5000 km² were covered by 30 and 20 LBK settlement territories, respectively, while in western Hungary it was 7400 km² covered by 50 LBK territories, which roughly corresponds to a similar mean territory size. In the Lengyel period, the overall settled region increases in western Hungary and decreases in the two other regions. While we detect differences in the location of the settlements, from a broader viewpoint, the same territories were inhabited. People stayed in the same regions but not on the same sites.

A significant difference is the huge number of isolated, single settlements in western Hungary during both phases. This suggests a different spatial organisation in western Hungary, which probably indicates a link to south-eastern European patterns. However, the large number of settlement areas shows that there may have been a dualistic form of organisation, both territorial-decentralised and centralised around large, individual sites.

We also see, and for the first time confirm with spatial statistics, that the shift from LBK to Lengyel is accompanied by a shift towards increasingly higher elevation and stronger slope of the territory, thus indicating an overall shift to different or more diverse activities. For example, these activities include focusing more on cattle breeding and, probably, flint procurement. This development is most pronounced in western Hungary – the region where at the same time the settled area markedly increases.

According to the elevation and slope, during the LBK and Lengyel periods preferences for different zones – what we might term ‘comfort zones’ – are discernible. Within these zones, in both periods, a maximum of c. 50 per cent of the potential land in the comfort zones was inhabited. Thus, the land was far from being overexploited. This, however, accounts for the broad, macro point of view only. At the local, micro level, single settlements or settlement areas may have overexploited their direct environment or specific niches of it. Müller *et al.* argue that the carrying capacity in the Upper Žitava Valley probably reached its limit in the late 6th millennium BCE (2020, 498–501). However, the dense network of collaborating settlements probably facilitated the resilience of individual units in the cluster. This we see in western Hungary, where the number of united settlement areas increases significantly during the Lengyel period. Probably, a process of specialisation and increased inter-region collaboration during the Lengyel period facilitated this system: each settlement in a settlement area had its special tasks, and together, the areas functioned as connecting cogs. This is visible in the Bakony Mountains, where a few newly established settlement agglomerations appear during Lengyel in a region not well suited for ‘classic Neolithic economies’ (Biró and Regénye, 2003: 266; Neubauer, 2017: 294f.).

The fact that settlement territories across the regions (western Hungary, Lower Austria and south-western Slovakia), and indeed across the entire LBK area (our study regions compared with Germany, see Zimmermann *et al.*, 2009; Herzog, 2010), are best characterised by the same density value (the 4 km isoline), indicates a common underlying socio-spatial pattern. This pattern probably reflects the dispersed, extensive settlement of mostly smaller sites with strong, trans-spatial inter-site links (Furholt 2018), the latter being upheld by the possibility to easily reach the next settlement within an easy, less than 1 hour walk. The sizes of those settlement areas differ greatly, probably due to their respective geographical conditions. Yet, patterns of social organisation could also be responsible for area size.

The rather uniform settlement area sizes in the Early LBK period and the relative persistence in size in some regions indicate that there is something like a preferred group size, which – if our parameters for calculation are somewhat close to reality –

would be somewhere around a median of 1600 inhabitants. Perhaps a group of this size could have easily organised itself through trans-spatial contacts, local and regional councils or assemblies. The latter could be reached by everyone living in such an area within a day's walk. In other words, our median values as well as the main spectrum of area sizes allow for frequent inter-site encounters and even central gatherings without the need for longer travel.

The fact that the trajectories of settlement territory sizes over time differ in different regions indicates that the character of inter-site relations may have developed in different ways. Different trajectories of territory sizes in combination with constant density cut-off values (4 km) would indicate that the inter-site relations of everyday encounters and interaction between sites – the trans-spatial-social system – seems to have remained rather stable. In contrast, other aspects, such as the political organisation, in the form of general assemblies or regional councils, may have taken different paths, something that is underscored by the strikingly different locational patterns of roundels at the end of our study period. In Lower Austria, where they are located close to the centre of settlement territories, they are likely to have been gathering places of those areas' inhabitants. In south-western Slovakia as well as in western Hungary, their location at the edges of territories indicates that they served for encounters between territories – for connections between people with much fewer opportunities for everyday encounters. This shows that we can expect diversity both in the size of political units – those focused on a settlement territory vs those uniting several of them – and different social functions of roundels in different regions. A general dynamics and fluidity in Neolithic social and political organisation are to be expected and are also very compatible with the data we presented here.

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5.3 Prehistoric communities in the Upper Žitava Valley, south-western Slovakia: Integrating scales

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Abstract

Early traces of settlement in the Upper Žitava Valley provide us with an insight into a system of cohabitation practices and interaction between settlements of various size and character in a regional framework. Ongoing research on settlement traces of the LBK and Želiezovce groups provides us with an impression of the environment and the economic, social and political structures during this time. The extensive data available on material culture, feature types, and environmental and socio-economic practices that was collected and analysed during now more than a decade of research provides a basis for the comparison and reconstruction of Early Neolithic lifeways in the Upper Žitava Valley. With the additional integration of models from socio-anthropological research, we can discuss possible forms of settlement organisation and the network of communities living at this time.

Keywords: Settlement organisation, settlement patterns, communality, socio-economic structures

Introduction

Continuous research on the LBK and Želiezovce sites in the Upper Žitava Valley has provided us with a solid idea of the distribution, location and outline of different settlement sites in the timespan between 5300 and 4900 BCE. In addition to apparent preferences with regard to the natural habitat, we were also able to clarify chronological questions, as well as habitation structures and features. The wide range of new data presented in this book, which covers all relevant fields of inquiry and analyses carried out, also provides us with the possibility to talk about the entanglement, interaction and differentiation of the communities present in the chronological phases of the LBK and Želiezovce groups in the Upper Žitava Valley.

In many regards, the Early Neolithic sites in the Upper Žitava Valley exhibit multiple parallels to other contemporaneous settlement sites and areas in central Europe during the LBK phases. Apart from the typical layout of the houses and the presence of the defining fine ceramic ware, the typical reliance on cattle that is documented for various sites of the LBK in central Europe was encountered as well (cf. Hofmann *et al.*, 2016). All these patterns have also been observed in the different sites in the Upper Žitava Valley and have been confirmed in the material that was recovered and subsequently analysed from the excavations at Úlany nad Žitavou and Vlkaš 'Do hulského chotára'. A rather homogenous, or standardised, practice of subsistence economy is recorded with regard to both animal husbandry (Chapter 3.3) and crop cultivation (Chapter 3.4). The food economies are based on emmer and einkorn as staple crops, as well as cattle as the main domesticated animal. Additionally, the pottery found in the context of the younger LBK shows many more parallels and uniformity in comparison to the wider distribution area of LBK communities than does that of the later phases. In the youngest period, the LBK differentiates into various regional groups – in the case of our region, including in the Upper Žitava Valley, the Želiezovce group. Although there is continuity in practice or tradition of pottery making in many regards (such as continuously used motifs and forms), some form of localisation seems to take place (Chapter 3.2). Even the socially rather disruptive end of the LBK is distinctly evidenced in the Upper Žitava Valley (cf. Furholt *et al.*, 2023). The site of Vráble 'Velké Lehemby' exhibits signs of conflict at the end of the settlement, with a number of regular and irregular burials, as well as a mass burial within the double-ditch system surrounding one of the neighbourhoods of the site (cf. Müller-Scheeßel *et al.*, 2021; Furholt *et al.*, 2020).

It seems that the development of the younger and youngest LBK can be told using the example of the Upper Žitava Valley. Yet, apart from these observations, more insights may be gained regarding the actual organisation and patterns of cohabitation within the Upper Žitava Valley in the timeframe between 5300 and 4900 BCE.

How was cohabitation in Early Neolithic communities organized?

Apart from referring to economic factors, such as subsistence practices, aspects of materiality and the locations in which settlements are chosen to be built, cohabitation mostly refers to the social processes and institutions that constitute ways of living together. Depending solely on archaeologically preserved data, these are hard to reconstruct, thus a cultural anthropological perspective must be included in order to develop a possible scenario of cohabitation in LBK and Želiezovce communities. In the following, a brief synthesis on the results presented in this volume will be given, as well as an interpretation of the early Neolithic settlement system in the Upper Žitava Valley.

Economy and land use

The economic parameters as indicated by the spectra of animal bones, macro-remains and phytoliths support the idea of a rather typical LBK subsistence model, with largely independent or autonomous farmsteads as the basis of habitation and production. Analyses of the faunal material from Úlany nad Žitavou and Vlkaš 'Do hulského chotára' indicate a strong reliance on domestic animals, with meat production as the main goal of animal husbandry. The spectrum includes cattle, sheep/goat, pig and dog, with the dominance of cattle that is typical for the LBK (Chapter 3.3).

The subsistence practices are similar to those recorded for various central European sites, and they also seem to have been shared to a large degree within

the Upper Žitava Valley. This holds true not only for the general range of crops and animals found – or not found, in the case of the low proportion of bones from game animals indicated by the zooarchaeological analyses – but also for other subsistence practices. The fuel economy relies on oak and ash in all of the settlements that could be examined in detail, indicating a use of ecological niches surrounding the settlement sites, consisting of areas of thick and rather dry forest, as well as areas with conditions that were moister, as indicated by the presence of elm and ash. Varying degrees of land openness may well be connected to practices of herding and land openings due to the temporary use of smaller plots as fields (Chapter 3.4). The analyses of isotope values in animal bones do indeed indicate only little contribution from densely forested environments in the fodder of the herbivores from Vlkaš ‘Do hľského chotára’ and Úľany nad Žitavou (Chapter 3.5). This preference for rather small distances for various economic practices is indirectly supported by the model of land use at Vráble (Chapter 5.1). The different scenarios developed in the model show that, even if the maximum values of the demographic reconstructions are used (Müller *et al.*, 2020), the resources and land required for subsistence activities are within a short walking distance from the village.

Also, with regard to the question of manure, the overall results from Vlkaš ‘Do hľského chotára’ and Úľany nad Žitavou are similar to each other, indicating a long moderate to intensive manuring regime based on a comparison of the results of isotope analyses of cereals from both sites (Chapter 3.5) with the results from experimental studies (cf. Fraser *et al.*, 2011; Bogaard *et al.*, 2013). Despite the overall presence of shared economic practices, there are indications of differences in the intensity of manuring among the individual houses (Chapter 3.5), thus pointing towards an autonomy of single households regarding their subsistence practices and strategies.

Despite these similarities, there are some interesting differentiations between practices observed in Vlkaš ‘Do hľského chotára’ and Úľany nad Žitavou, as representatives of hamlets, and Vráble, as an agglomerated village. At Vráble, an integrated plant-animal management strategy was observed that was based on the use of open environments; there was not any clear evidence of woodland grazing (Chapter 3.4). That this rather distinct practice is not visible as such at Vlkaš ‘Do hľského chotára’ or Úľany nad Žitavou sheds light on possibly differentiated economic practices under the umbrella of a seemingly uniform Early Neolithic economy.

A network of actors?

The documented sites in the Upper Žitava Valley indicate a system of rather independent settlement sites that may be seen as single hamlets clustered in favourable spots within the landscape. Here, we follow the definition of hamlets as being marked by the absence of communal features, a high degree of economic independence, as well as a great flexibility in terms of the number of houses occupied simultaneously at the site (cf. Uhlig and Lienau, 1972). These hamlets all start around 5300 cal BCE, as indicated by the dates derived from excavation activities, the orientation of the houses, and the typochronology of the pottery (Chapter 2.3; Chapter 3.2; Müller-Scheeßel *et al.*, 2020). Typochronologically, the pottery represents the phases of the younger LBK, most notably represented by the ‘*Notenkopfkeramik*’, as well as Želiezovce, represented by the typical double lines with notches. Some of the sites also exhibit material that can be assigned to the Lengyel and Baden periods, indicating some degree of continuous settlement activities (Chapter 2.3; Chapter 3.2).

Within the area that was surveyed and can be included in the site area due to the find distribution, the size of the settlements ranges between 3.8 ha, in the case of Nevidzany ‘Dolné urbáre’, and 9 ha, in the case of Čifáre ‘Nad trístím’. Naturally, the size of the settlements does not equal the area of the find distribution. In three of the

cases, the number of houses that could be documented geophysically is around 30 (Čifáre 'Nad trístím': min. 30; Veľka Maňa 'Za hlbokou cestou': 29; Úľany nad Žitavou 'Dolné diely': 34), whereas at Vlkaš 'Do hľského chotára', a total of 61 houses could be recorded. Apart from the house structures, which are represented by the elongated pits and partly by postholes, further pit features were documented at all of the sites. At Čifáre 'Nad trístím', some more distinct empty spaces were documented as well, although it remains unclear for now how these spaces were used (Chapter 2.3). It is clear that not all of the houses in the different sites are contemporaneous, and the temporality and rhythm of settlement growth and decline are therefore of special interest. Using the exact orientation of the houses as a chronological marker (cf. Müller-Scheeßel *et al.*, 2020), a rough estimation can be given for all the settlements that were surveyed. The oldest settlement that was recorded is Vlkaš 'Do hľského chotára'. While a few houses were already extant around 5300 BCE, most of the houses belong to the phase between 5250 and 5150 BCE. Around 5250/5200 BCE is indeed when most of the hamlets in the Žitava Valley seem to have been founded. In the case of both Čifáre 'Nad trístím' and Nevidzany 'Dolné urbáre', a gradual growth between 5250/5200 and 5100 BCE can be seen, which is then followed by a decline. At Veľka Maňa 'Za hlbokou cestou', a different trajectory is visible; in this case, the early phase of the settlement is already marked by the highest density of houses, which is then again followed by a decline (Chapter 2.3; Müller-Scheeßel *et al.*, 2020).

A closer look into the presence of features, their spatial relationship, and the find distributions (Chapter 3.1) reveals further information on the established settlement sites in the Žitava Valley. At Úľany, *Schlitzgruben* (V-shaped pits) are the only feature type present that is not linked to the construction and maintenance of the LBK and Želiezovce long houses. Most of the features are represented by postholes and the typical elongated long pits accompanying the houses laterally. Especially the long pits are characterised by repeated cuts and in-filling. The situation at Vlkaš was more complex due to the presence of postholes, pits of indeterminate character, elongated long pits, as well as beehive-shaped pits dating to either the LBK or Želiezovce, as well the later, Bronze Age occupation of the site area. The long pits especially were characterised by overlaps, thus showing successive construction of several houses in very close proximity. The situation encountered at Vlkaš is very different from the occupation sequence in Úľany and points towards an intensive sequence of spatial occupation. Phases of construction and abandonment of single houses probably followed each other at least in the central part of the settlement area. This process was marked by a continuous reference to the location of the former houses by seemingly slightly realigned construction of houses in close proximity to their predecessors.

While economic independence and/or autonomy seems reasonable and well supported by the available data in the case of LBK and Želiezovce settlements in the Upper Žitava Valley, the nature of social entanglements is an entirely different discussion. As already mentioned, the absence of communal structures, such as wells or ditches, as well as the relatively small size of the settlements in terms of the number of houses, seems to indicate a local network of hamlets. Due to the defining absence of communal features, which are highly relevant for decision making processes and socio-political institutions in general (cf. Henkel, 2004), a certain dependence on other sites, such as villages, can be assumed. As the basic unit responsible for decisions concerning cohabitating groups of people, as well as the subsistence strategies of the very same, households formed the social, political and also economic backbone of hamlets. Yet, instead of imagining a steady presence of (extended) nuclear families per house, we have to assume a certain fluidity, mobility and flexibility when thinking about the composition of these households. Especially in small-scale societies, houses usually constitute social groups, of which single house structures are only a small part. The social house may encompass different roles and responsibilities for

each of its members and is a political unit as much as a social and economic one. Therefore, movements of individuals between house structures, the sharing of one house structure by several households, and the adoption of children or adults as a political strategy have to be taken into consideration as well. In these cases, house structures are defined by complex character traits, such as their role in memory culture (cf. Gillespie, 2007; Fox, 2006: esp. 16–20). Thus, households exist not simply by themselves, but always as part of a much larger institution, most notably of course larger kinship units, such as lineages. Houses as potential actors do usually depend on one kind of network or the other, not only for daily affairs and social security, but also for more overarching matters and affairs (Bender, 1967: 494–499). Commonly, these networks and institutions are visible in one way or the other, be it in the context of specific spots within a settlement (such as gathering places; *e.g.* Wunderlich, 2019), in the context of specific houses or house decorations (such as lineage houses; *e.g.* Adler and Wilshusen, 1990), or in the context of external places.

While specific material, economic or ritual practices are certainly a means to show allegiances in a performative way, these are not clearly present in the context of LBK and Želiezovce settlements in the Upper Žitava Valley. No clear differentiation can be detected in the archaeologically documented choice of husbandry practices, crop cultivation, or raw materials that would bind together and define either certain hamlets or certain houses. This leads to the idea that an external, central place was actually the context in which maybe also other hamlets chose to interact with each other, as well as show their position and belonging within their socio-political institutions and networks.

A central site and its satellites?

One of the central questions emerging from the research on the extraordinary site of Vráble ‘Veľké Lehembý’ and the location’s continued importance as indicated by the Bronze Age site of Vráble ‘Fidvár’ (cf. Bátorá *et al.*, 2012), as well as later use of the location (Chapter 1), is: How did this spot gain its importance? This question is not solely about chronology, but also about how the social, economic and political parameters of the settlement system in the Upper Žitava Valley were organised. With the presence of communal structures in the form of the double-ditch system, the indicated importance of sharing practices, and the distinct neighbourhoods, Vráble certainly is characterised by interactive and collective features as well as exclusive features (cf. Furholt *et al.*, 2020; Wunderlich *et al.*, 2020). As a village, Vráble seems to have had a potentially integrating function for the other settlements in the area, which certainly may have been at least partly differentiated within a hierarchical system.

The relationship between Vráble, as a village with a central communal importance, and the hamlets in the surrounding areas is a rather interesting one. While many parallels are discernible that hint at rather similar and shared economic practices, including the reliance on ecological niches and the general outline of husbandry and crop cultivation, all of which are rather typical for LBK contexts, there are also some differences. First and foremost, the differentiated economic system within the neighbourhoods of Vráble indicates a deliberate emphasis on the autonomy of or distinction among the three spatial units represented in the village that goes way beyond the smaller differences detectable between the hamlets, such as Vlkaš and Úľany. The overall dominance of pig that is seen in the faunal record of Vráble is atypical both for contemporaneous settlements in the regional context of the Žitava Valley and for the wider context of central Europe. Even more interesting is the neighbourhood-specific preference for either pig, goat/sheep or cattle, which is paralleled in differences in the preference for either einkorn or emmer, and either flint or obsidian (cf. Furholt *et al.*, 2020; Wunderlich *et al.*, 2020). Despite the existence of similar research results from other LBK contexts (*e.g.* Cuiry-les-Chaudaires; cf.

Hachem, 2018), this can hardly be seen as a standard for LBK settlements. Of course, these intra-site differences may be interpreted as a result of existing division of labour or simply differing preferences. Yet, economic practices can always serve as a means to form, (re)enforce and display differentiation and perform socio-political structures within a given community or society (cf. Martin, 2003: 365), and they should therefore not be underestimated.

Apart from the economic aspects of cohabitation in either houses, neighbourhoods, hamlets, villages or networks of settlements, architectural practices with regard to house construction are another factor of interest in the Upper Žitava Valley (Chapter 3.1). In the entire Upper Žitava Valley, there is a low presence of large houses, which have been interpreted as potential communal structures in the context of other central European LBK sites (cf. Hofmann and Lenneis, 2017). There are also no particularly small structures present whatsoever, thus delimiting the usual range of houses sizes in the Žitava Valley and maybe also signalling the absence of specialised house forms due to a simple lack of need, in an economic as well as a social sense. In the local context of the Upper Žitava Valley, the larger settlements (both in terms of number of houses and area), tend to display a larger range when it comes to the size of the houses reconstructed based on the postholes and elongated long pits discernible in the magnetic plans (Fig. 3.1.24). Three classes or groupings of house sizes can be reconstructed in the valley for the period of LBK and Želiezovce groups, each of which may have been connected to a distinct social group that could have been based on, for example, kinship structures and ties, such as lineages. Just as there are differences between Vráble and other, contemporaneous sites in economic practices, there are differences regarding the houses as well. The differences among house sizes are greater at Vráble than at the other settlements, as are the differences in the house inventories (Chapter 3.1; Wunderlich *et al.*, 2020). Thus, it seems that the distinct and autonomous character of both single houses and their households, as well as house groups and the socio-political entities that these represented, was much more pronounced in the village of Vráble than in the network of hamlets in the Upper Žitava Valley. As houses are a specific materialisation not only of a given household, but also of inter-communal relations, as well as at least aspects of the social structure of the community and society associated with these (cf. Bender, 1967), these differences seem highly relevant.

It cannot be stressed enough that the material and spatial aspects are certainly not all there is to neighbourhoods. On the contrary, it is the political and social agency of a neighbourhood that makes it distinct in the first place, without necessitating a clear spatial setup or distinction (cf. Forrest and Kearns, 2001). The fact that at Vráble the three neighbourhoods actually do exhibit a distinct spatial setup, one that is even more pronounced by the construction of the ditch system at the end of the village's history, may emphasize the separate and independent agency of the three neighbourhoods. The layout of the entire village is not necessarily of an integrative character but, rather, marked by open space and boundaries of one sort or the other. As clans and also lineages, due to their size, usually stretch across various spatial sites, such as villages, farmhouses or hamlets, there is no reason to directly assume that these units are the main actors behind the neighbourhoods at Vráble. Bearing the apparent conformity of LBK and Želiezovce communities in mind, we suggest that it may be that those socio-political actors that cross the boundaries of specific lineages are what are spatially represented at Vráble. Certain groups with shared interest, allegiances or any other factor binding segments of communities together independently from kinship structures could have found an expression in the neighbourhoods of Vráble as well. In this sense, Vráble as a central place in the Upper Žitava Valley could at the time have served to enhance social cohesion within the regional networks of settlements, and as an important means to express the overall autonomy of both kinship groups and other relevant collectives.

Due to internal and/or external factors and influences, this system disintegrated at the beginning of the 5th millennium BCE. With the mass burial in the double-ditch system (Furholt *et al.*, 2023), the village of Vráble exhibits signs of a conflict-ridden ending and of a rise in social tensions during this time (cf. Furholt *et al.*, 2023; Wunderlich *et al.*, 2020). Although the central site was abandoned, the situation in the hamlets is partly different. Some of the sites were abandoned, but others were probably continuously used as a settlement location or reused after some time (cf. Wunderlich *et al.*, 2024). This indicates that it was not necessarily the entire community living in the Upper Žitava Valley that collapsed but, rather, the overarching socio-political institutions and networks.

The wider context: Late LBK communities in central Europe

The end of the LBK phenomenon in central Europe and the transition to the subsequent archaeological entities has been intensively discussed, especially following the discovery of such sites as Talheim, Asparn-Schletz, Herxheim and now Vráble. Apart from these extraordinary sites, which indicate that the end of the LBK, at least in some local contexts, was accompanied by social disruption and conflict (cf. Meyer *et al.*, 2014), the transition from the LBK to later periods is of considerable interest. The situation that we encountered at Vráble is surely one that reflects the rise of social tension among the neighbourhoods of the village, indicated by the construction of the ditch system around the southwestern neighbourhood, with entrances through the ditch system facing away from the other segments of the village. Beyond this, the mass burial and irregular burial rites encountered in this ditch shed light on radically transformed burial and ritual practices (e.g. Zeeb-Lanz, 2009; but also Link, 2014). If we look into the settlement structures, we can again see similarities on the macro scale and dissimilarities at the micro scale. The situation in the regions of Transdanubia, Slovakia and Lower Austria exhibits these similarities and dissimilarities (Chapter 5.2). The overall choice of settlement location remains the same across this entire study area from LBK to the succeeding Middle Neolithic groups, with roughly the same preference for the areas in the river valleys that were also settled by LBK communities. Yet, changes in territorial settlement patterns are detectable, thus indicating a much more differentiated situation when we zoom in to the micro scale. For example, the density of settlements per settlement territory is changing, with a generally decreasing density in the subsequent Lengyel and Stroke-Ornamented Ware phases. Lengyel settlements also tend to be found at higher elevations, a preference that has repeatedly been connected to the rising importance of cattle and slight adjustments in subsistence strategies (cf. Neubauer, 2017; Kadrow, 2017). The analyses conducted by Schultrich and colleagues (Chapter 5.2) do show interesting differences between Transdanubia and Slovakia, as well as with Austria, despite the overall parallels between all three regions, which are materialised by the presence of rondels, among other things.

While discontinuities, especially with regard to the settlement locations after the LBK phases, have long been the focus of attention, other studies show a high degree of continuity, not only in settlement patterns (e.g. Link, 2015), for example, but also with regard to exchange networks (e.g. Scharl, 2015), among others. Yet, this situation seems to be rather variable and probably also dependant on local factors (cf. Hofmann *et al.*, 2016). It seems that the variation that is masked by the supposed uniformity of LBK societies also exists during the shift from LBK to the subsequent communities. To understand the dynamics influencing this transition, it is therefore vital to take a closer look at regional and also local contexts and developments.

Conclusion: a reconfiguration of a settlement system

The end of the LBK and Želiezovce settlement system leads into a transformative phase in the lifeways of the communities living in the Upper Žitava Valley, in which not only the organisation of cohabitation, but also the organisation of collective and communal matters changed drastically. Surveys and geophysical prospections of both previously known and previously unknown sites with surface find distributions indicate a restructured and locally differentiated settlement system in the subsequent Lengyel phases. Within the framework of magnetic prospections and field walking, several sites with Lengyel features, consisting of either houses or pit structures, could be documented. In addition, the previously unknown rondel of Podhájska was discovered and partly excavated, thus providing new data to better understand Lengyel communities in the Upper Žitava Valley (cf. Wunderlich *et al.*, 2024).

Especially in the area around Vráble, several sites with continuous or renewed habitation from LBK to Lengyel contexts were documented (e.g. Čifáre). While there is not necessarily a clear break when it comes to the choice of and reference to settlement locations, the settlement structure itself is quite different from that of the previous phases. Within Lengyel contexts, cohabitation communities seem to have been very small, with only a few houses constituting a small hamlet. The house construction changes as well, with the disappearance of houses with accompanying elongated pits in favour of archaeo-magnetically less visible houses or the house type with clearly discernible wall ditches and central posts (cf. Wunderlich *et al.*, 2024). While we cannot say much about the subsistence economy or household autonomy yet, as the necessary data are still missing, it is clear that at least the chipped stone economy changes considerably. The use of obsidian becomes much more frequent in comparison to the use of flint and radiolarite, especially in the context of the rondels. Obsidian is represented by a comparatively high frequency of cores and tools, thus indicating production on these sites.

The rondels themselves seem to have been established as a new form of communally used places fairly shortly after the dispersed system of Lengyel hamlets was established. The rondels themselves are usually surrounded by numerous pit structures, which are at least partly contemporaneous with the rondels. These pit features may have constituted settlement sites as well, although magnetically visible house features in direct relation to the rondels are thus far missing in the Upper Žitava Valley (in contrast with Bučany; Pažinová 2012). Yet, these structures represent a different layout of the settlement system than the above-described hamlet structures. As both outlines are to be found within the same micro region, we have to assume a rather diversified settlement system in Lengyel contexts that at least potentially seems to have been much more flexible and certainly more decentralised than the LBK and Želiezovce system. This newly established settlement system included clearly recognisable communal places that were connected to collective action from early on. Although a convincing interpretation of these structures remains difficult (cf. Vondrovský *et al.*, 2022), we have to take into account their collective and communal character as built monuments, as well as their suitability for a wide range of activities. Yet, these circular enclosures occur at rather regular distances from each other, implying that we may have to account for a number of local centres rather than regional or even supra-regional central places. This again points towards a growing decentralisation, which is quite in contrast to the earlier focus on the agglomerated site of Vráble, which represents a central site without any kind of parallel in the entire region and beyond. It remains an open question to which degree the social tension and conflict-filled ending of Vráble was responsible for this clear break with the previously established settlement system, but it seems likely that the nature of

the ending played a role, also in light of other, comparable situations, such as the aforementioned findings at Asparn-Schletz and Herxheim.

Future research will undoubtedly shed further light on the development of communities in the Upper Žitava Valley in the various prehistoric periods. Yet, the existing data already show us how this rather unremarkable environmental context was witness to a dynamic of interaction, cohabitation, conflict and reconfiguration of the communities inhabiting the Žitava Valley at this time. It seems that Vrábľe gained and lost its function as a place providing a framework for social cohesion and communality during and after the Early Neolithic period. Nevertheless, the continued use of the older settlement locations and the later establishment of the Early Bronze Age site of Vrábľe 'Fidvár' hint at a continued relevance for this location. The complex dynamics of settlement organisation, economic practices and socio-political organisation shed a light on a simultaneously high degree of autonomy among not only households, but also single communities that enacted their relations with each other in varying material ways.

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