Quaternary International 560-561 (2020) 154–178

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

‘It's still the same old story’: The current southern Transdanubian approach to the Neolithisation process of central Europe

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A R T I C L E I N F O

Keywords:
Western Hungary
Neolithisation process
Micro-regional research
Geomagnetic survey
Absolute chronology
aDNA

A B S T R A C T

The pivotal role of the western Carpathian basin in the transmission of key inventions of food production towards central Europe is an accepted fact in Neolithic research. Southern Transdanubia in western Hungary may serve as a unique ‘laboratory’ for targeted investigations, as north Balkan and central European characteristics overlap in the region. Site-based studies of recently excavated late 6th millennium cal BC Neolithic settlements provide insights into possible patterns in the development of longhouse architecture and settlement layout, different combinations of material culture and their alterations, and technology transfer on a regional scale.

In order to gain a more complex view of these themes, three micro-regions have been selected around key sites for further study of different vantage points between Lake Balaton and the Dráva/Drava river. The southernmost one is located in the Southern Baranya Hills, the second along the Danube on the northern fringes of the Tolna Sárköz and in the adjacent section of the Sárvíz valley, while the third lies in the central section of the southern shore of Lake Balaton. Field surveys including the systematic collection of surface finds complemented by geomagnetic prospections can contribute significantly to the reconstruction of settlement clusters.

Absolute chronology has become an important research focus due to larger sets of radiocarbon dates interpreted within a Bayesian framework. The two dominant scenarios for the start of the westward expansion of the LBK are hard to harmonise with each other. An approach that estimates the beginning of the process around 5500 cal BC at the latest gains support from a west-central European perspective. In contrast, recent radiocarbon dating programmes with formal modelling of AMS series within a Bayesian framework estimate the appearance of the LBK west of the Carpathian basin hardly before 5350–5300 cal BC. The latter view provides the potential of harmonising the Neolithisation of central Europe with the emergence of the Vinča culture, at least in its northernmost region. Beyond this debate, ancient DNA analyses have enriched the discussions on migration, demic diffusion and the scale of hunter-gatherer contribution to the process with fresh arguments.

1. Introduction

Almost all studies concerning the dispersal of Neolithic lifeways across central Europe mention the fact as their initial starting point that the process is identical with the appearance of a new-fashioned material culture canonised as the *Linearbandkeramik* (LBK). Another often repeated statement is a reminder of the special attention the subject has constantly received and of its position as one of the most thoroughly investigated prehistoric entities of temperate Europe. Since all cultivated crops and domesticated animals of the region have their roots in a core area in south-west Asia, also called Fertile Crescent, the Near Eastern origin of the Neolithic inventions spread over Europe was never seriously challenged (Whittle, 1996; Bellwood, 2005, 44–84; Shennan, 2018). In contrast, the triggers, ecological aspects and structural questions of the dispersal have long been discussed, as well as the nature of the transition, with massive migration of people and an adoption of farming techniques by Mesolithic population on the opposite ends of the scale, respectively.

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https://doi.org/10.1016/j.quaint.2020.05.049
Received 31 January 2020; Received in revised form 24 May 2020; Accepted 25 May 2020
Available online 27 June 2020

Regarding the Neolithisation of central Europe as the special focus of this study, migratory scenarios were widely accepted from the early twentieth century (Childe, 1929). Central European research has never ignored them completely, not even in periods when they were largely removed from the agenda of relevant theoretical discussions. Most scholars active in the region relied overwhelmingly on evidence derived directly from spatial and typo-chronological patterns of material culture, particularly those of pottery. Far less attention was paid until recently to incorporating achievements from the fields of cultural evolution, anthropology and ecology. Models supporting a population movement rested on varied grounds, and conclusions have been drawn based on a comparative analysis of the excavated features and finds assemblages (Quitta, 1960; Kaufmann, 1991; Lüning, 1991), on demographic estimations (Petrasch, 2001) or even on ancient genetic studies combined with absolute chronology (Ammerman and Cavalli-Sforza, 1973, 1984). David Anthony discussed migration as a well-structured human behaviour and contrasted short-distance relocations with long-distance migrations. In his system, the wave-of-advance model (Ammerman and Cavalli-Sforza, 1973, 1984) proved to be more appropriate to describe a series of short-distance movements. Migrations of farming populations, in contrast, were regarded as long-distance and highly directed processes characterised by leapfrogging in their initial phase (Anthony, 1990). Different mechanisms of contacts between foragers and farmers were summarised by Marek Zvelebil. Those implying the relocation of human groups ranged from directional movements of large masses (folk migration), through sequential colonisation of a region by small groups (demic diffusion), the infiltration of individuals with special skills and leapfrog colonisations of optimal areas and niches by small groups, to small-scale movements of frontier mobility (Zvelebil, 2000, 57–58).

Acculturation of a putative late Mesolithic population in Transdanubia was not completely excluded, even in some migration-driven theories. Following the transition to farming, those groups, and not necessarily the descendants of early 6th millennium cal BC immigrants, would have moved further to the west (Quitta, 1964). Later on, the possible adoption of farming techniques by local hunter-gatherers came to the fore in interpretations with a more north-westerly perspective, often discussing in depth the socio-economic context, the accompanying social shifts and cognitive aspects of the change (Whittle, 1996, 150–153; Thomas, 1996; see also Zvelebil, 2000, 59). Significant Mesolithic contribution to the process was also advocated by some analysts of chipped stone tool assemblages of terminal foragers and early farmers (Kind, 1998; Mateiciucová, 2004). However, argumentation could result in an extremist indigenist position when other aspects remained neglected (Tillmann, 1993). The third substantial approach combines migration with cultural diffusion in order to integrate diverse evidence. According to some of those ideas, leapfrog colonisation, the long-distance move of pioneer groups, was complemented by frontier mobility and contacts driving the transmission of food-producing techniques and the know-how of sedentary life (Gronenborn, 1998, 1999, 182–185; Zvelebil, 2000, 2001).

Integrating evidence from western Hungary into supra-regional systems with a well established theoretical background could not be fulfilled for decades without difficulties. The first recognition of south-east European type Early Neolithic material culture in Transdanubia in the late 1970s was a relatively late achievement from a regional perspective (Kalicz, 1978; Kalicz, 1980b; Kalicz, 1990). This research gap combined with limited research activity on Neolithic sites made assumptions about the formation of the LBK particularly challenging. Notwithstanding numerous less elaborated elements, the region was regarded as an integral part of the LBK distribution even in the interwar period (von Tompa, 1937, 28–32) and its role as the place of LBK origin or at least a part of it was never seriously questioned (Quitta, 1960, 166–167; Gronenborn, 1999, 144–156). Nándor Kalicz, in agreement with other scholars like Hans Quitta and Jens Lüning, concluded that the central European type Neolithic could only emerge in a direct contact zone with south-east Europe (Kalicz, 1993, 1995; Lüning, 1991, 33–37; Quitta, 1960). Nevertheless, conclusions on the period were drawn despite the lack of deeper knowledge of for example architecture and settlement organisation, and thus they concentrated on the relative chronology based on analyses of pottery shapes and particularly decoration (Kalicz, 1988; Gläser, 1993).

The identification of formative LBK communities preceding the earliest LBK in its west-central European guise provided a major argument for further considerations (Bánffy, 2000, 2004). However, the role and chronology of what is called formative LBK in this study are subjects of recurrent disputes. The discussion flared up again recently, some views regarding formative LBK assemblages as merely a variant of developed earliest/early LBK pottery styles and phases and dating them to the same, relatively early horizon from about 5500 cal BC (Strien, 2017, 2018, 2019). As the issue has fundamental implications for models of the entire 6th millennium cal BC cultural and chronological framework of the western Carpathian basin, it is worth pinpointing some arguments in the context of current regional research.

It has been shown in earlier papers that research on late 6th millennium cal BC sites has also followed a different path in western Hungary to that in other parts of central Europe (Bánffy and Oross, 2009; Oross and Bánffy, 2009). Current investigations revealed the decisive role of the development succeeding the formative LBK phase in the unfolding of a dense regional Neolithic settlement network as well as in the spread of farming west of the Carpathian basin. Intensive field activity targeting this period followed by a range of research investigations such as surveys applying non-destructive technologies, radiocarbon dating programmes and projects scrutinising ancient DNA and isotopic studies ended up in an unmatched explosion of available data on early farming communities. Settlement patterns, material culture and the identities of contemporaneous human groups require multi-scalar and complex analyses rather than simply regarding them as peculiarities of one of the numerous provinces of a vast LBK universe (Jakucs et al., 2016; Jakucs, this volume; Marton et al., 2020). This study discusses the impact of recent Transdanubian discoveries on the interpretation of central European developments. Although the research presented is still ongoing, it may help in solving the major contradictions inherent in distinct narratives of the Neolithisation of central Europe.

2. The area of research and a brief look at its geography

The designated core research area comprises 10 798.88 km^2 in southern Transdanubia, more precisely in its central and eastern parts (Fig. 1a). The north to south extension is between Lake Balaton and the Dráva river. Direct geographical contact with the lake is provided by the Somogy Shore Plain (*Somogyi parti sík*), in the central and eastern section of the southern shore. East of the lake, the limit follows the Sió valley and the northern fringes of the Southern Mezőföld (*Dél-Mezőföld*) region. The eastern limit is the Danube along the Tolna Sárköz (*Tolnai-Sárköz*), including the Mohács Island (*Mohácsi-sziget*) in the south. The southernmost triangle of the Baranya region, now part of modern Croatia, was excluded; the limit here follows the international border, and more westerly the Dráva river. The western boundary of the investigated area coincides with the western limits of the Outer Somogy (*Külső-Somogy*) and the Zselic geographical regions, and more southerly with the Fekete-víz Plain (*Fekete-víz síkja*) and the Dráva Plain (*Dráva-sík*), respectively. Hilly landscapes dominate most of the area, with the Mecsek and the Villány Mountains the principal elevations. The macro-region is framed by the alluvial plains along the Danube and Dráva rivers.

The western Balaton region is directly connected to the northern limits of the core research area. In the form taken into account in this research it comprises the Keszthely Riviera (*Keszthelyi-Riviéra*) on the northern shore, the Little Balaton basin (*Kis-Balatoni-medence*) and the southernmost part of the Zalavár Hills (*Zalavári-hát*) west of the lake,

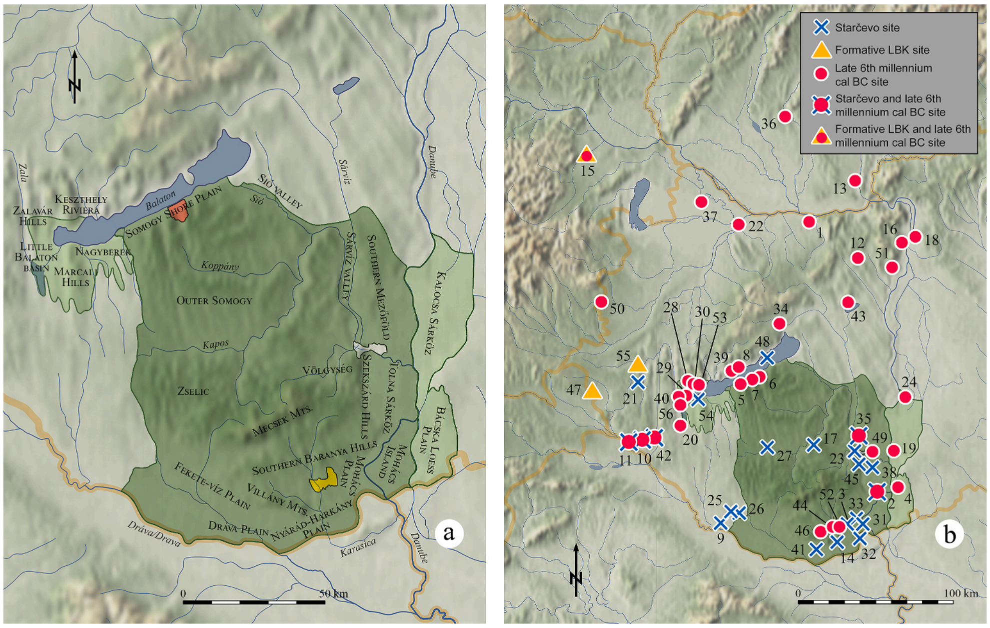

Fig. 1. a, Geographical regions of the research area in southern Transdanubia; b, principal sites in the western Carpathian basin mentioned in the text: **1**, Almásfüzitő-Foktorok; **2**, Alsónyék-Bátaszék; **3**, Babarc-Szabadföldek; **4**, Baja-Bajaszentistván-Szlatina; **5**, Balatonlelle-Lellekúti-dűlő; **6**, Balatonszárszó-Kis-erdei-dűlő; **7**, Balatonszemes-Bagódomb; **8**, Balatonszepezd-Rét feletti erdő-Barackos; **9**, Barcs-Dolec; **10**, Becsehely I-Bükkaljai-dűlő; **11**, Becsehely II-Homokos; **12**, Bicske-Galagonyás; **13**, Bíňa; **14**, Bóly-Sziebert-puszta; **15**, Brunn am Gebirge/Wolfholz; **16**, Budapest-Aranyhegyi út; **17**, Dombóvár-Kapospart; **18**, Dunakeszi-Székesdűlő; **19**, Fajsz-Garadomb; **20**, Garabonc-Ófalu; **21**, Gellénháza-Városrét; **22**, Győr-Pápai-vám; **23**, Harc-Nyanyapuszta; **24**, Harta-Gátőrház; **25**, Istvándi I; **26**, Istvándi II; **27**, Kaposvár-Deseda; **28**, Keszthely-Dobogó; **29**, Keszthely-Fenékpuszta; **30**, Keszthely-Lendl Adolf út; **31**, Lánycsók-Bácsfapuszta; **32**, Lánycsók-Csata-alja; **33**, Lánycsók-Gata Csotola; **34**, Litér-Papvásár-hegy; **35**, Medina-Margitkert; **36**, Milanovce; **37**, Mosonszentmiklós-Egyéni-földek; **38**, Őcsény-Vinca-dűlő; **39**, Révfülöp-49. számú vasúti őrház; **40**, Sármellék-Égenföld-Agyagbánya; **41**, Siklós-Csukma-dűlő; **42**, Sormás-Török-földek; **43**, Sukoró-Tóra-dűlő; **44**, Szederkény-Kukorica-dűlő; **45**, Szekszárd-Bonyhádi út; **46**, Szemely-Irtás; **47**, Szentgyörgyvölgy-Pityerdomb; **48**, Tihany-Apáti; **49**, Tolna-Mözs-Községi-Csádés-földek; **50**, Torony-Nagyrét-dűlő; **51**, Törökbálint-Dulácska; **52**, Versend-Gilencsa; **53**, Vonyarcvashegy-Pintér-villa; **54**, Vörs-Máriaasszony-sziget; **55**, Zalaegerszeg-Andráshida-Gébárti tó; **56**, Zalavár-Keleti József udvara.

and the northern areas of the Marcali Hills (*Marcali-hát*) and the Nagyberek on the southern shore. The investigated area extends to 672.4 km^2.

Another adjacent area in the east is on the left bank of the Danube in the southern part of the Hungarian course of the river. It is formed by the Kalocsa Sárköz (*Kalocsai-Sárköz*) except for its small part on the right Danube bank, the western part of the Bácska Loess Plain (*Bácskai löszös síkság*) and the northernmost edge of the Mohács Island (*Mohácsi-sziget*) east of the modern main bed of the river, a total area of 1390.82 km^2.

3. Prior development of the research context

In a sharp contrast with eastern Hungary, where hundreds of sites of the Körös culture have been discovered since the late 19th century (Anders and Siklósi, 2012), for a long time no equivalent archaeological entity was discovered west of the Danube. As a consequence, identifying the first Neolithic occupation of Transdanubia became one of the most important tasks of Hungarian prehistoric archaeology (Fig. 1b). The site of Medina-Margitkert (mentioned as Medina-Margitsziget in the 1970s) was already known from the 1930s. Apart from some published LBK sherds (Csalogovits, 1936, 15–17, Fig. II), other pieces of the collection with Starčevo traits remained unpublished. Nándor Kalicz and János Makkay investigated the site both through field surveys and excavation between 1969 and 1974. Even the LBK assemblage comprised both Bíňa-Bicske-style early LBK material and finds of a later horizon, the latter called earlier LBK at that time, or what is now known as Keszthely style. The earliest typo-chronological horizon, complemented by some finds from the nearby Harc-Nyanyapuszta, was regarded as the link between Starčevo and LBK and designated as the Medina type (Kalicz and Makkay, 1972a, 1972b; Kalicz, 2009). The discovery of the Lánycsók-Bácsfapuszta (Kalicz, 1978) and the Becsehely I-Bükkaljai-dűlő sites (Kalicz, 1980b) revealed that the early Neolithic of south-east European type had unequivocally appeared in southern Transdanubia as well. Finds assemblages with the same character were finally canonised as the Transdanubian distribution of the Starčevo culture (Kalicz, 1990, 1993).

Since then, early 6th millennium cal BC sites with the same material culture have been recorded up to the Balaton area and to the hilly region directly west of the lake. South of the Mecsek Mountains, in the southernmost part of Transdanubia, some of them lie directly in the southern fringes of the Southern Baranya Hills where one of the micro-regions of our current research activity is also located. In the immediate vicinity of Lánycsók-Bácsfapuszta, Lánycsók-Csata-alja (Vajda-Kiss, 2009, 220–221) and Lánycsók-Gata Csotola (Voicsek, 2010, 23) were discovered prior to a motorway construction. Babarc-Szabadföldek lies within the limits of the Southern Baranya Hills micro-region (Bánffy, 2001), while Bóly-Sziebert-puszta is located just a few kilometres to the south (Kalicz, 1990, 35). Siklós-Csukma-dűlő was discovered at the small Villány Mountains close to the Dráva river. Barcs-Dolec (Barcs-Drávapart) is known from a more westerly section of the Dráva river with Istvándi I and Istvándi II in its hinterland (Kalicz, 2011, 107, Abb. 1,1).

Another distinctive area with Starčevo sites is the Tolna Sárköz with the extended early Neolithic occupation at Alsónyék-Bátaszék in the south (Bánffy et al., 2010; Oross et al., 2016a), and with further sites such as Őcsény-Vinca-dűlő (Kalicz, 2011) and Szekszárd-Bonyhádi út (Kalicz, 1990, 36) more to the north. The already mentioned Medina-Margitkert and Harc-Nyanyapuszta in the Sárvíz valley are directly connected to the Tolna Sárköz. Kaposvár-Deseda (Kalicz, 1990, 36) and Dombóvár-Kapospart (Kalicz, 1990, 35) are known from the valley of the Kapos river, from the internal area (Outer Somogy region) of southern Transdanubia along with some further sites between the Kapos and the Koppány rivers. In south-west Transdanubia, besides Becsehely I-Bükkaljai-dűlő, Starčevo occupation could also be reported from Becsehely II-Homokos (Kalicz, 1980c) and Sormás-Török-földek (Barna, 2005, 17–20, Figs. 1–4). Sites in the westernmost part of the Balaton area and in the Little Balaton basin such as Vörs-Máriaasszony-sziget (Kalicz et al., 2002) already belong to the northernmost distribution along with Tihany-Apáti on the northern shore of the lake (Regenye, 2010) and with Gellénháza-Városrét (Simon, 1996) west of it.

The hilly region west of Balaton hosts sites that are classified as representing the formative phase of the LBK. Szentgyörgyvölgy-

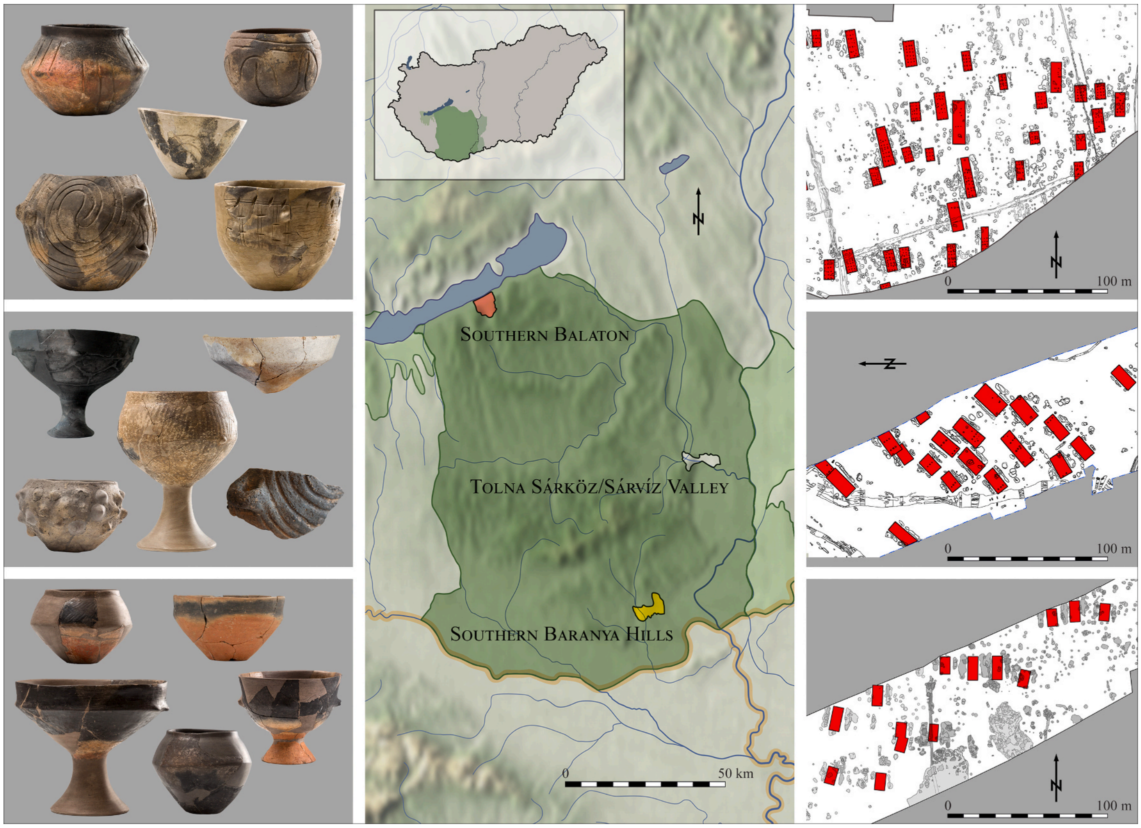

Fig. 2. Variability of late 6th millennium cal BC material culture and settlement layouts across southern Transdanubia.

Pityerdomb, where the pottery assemblage represents overwhelmingly Starčevo traits, is currently the largest excavated site in Hungary (Bánffy, 2000, 2004). Another, but very limited, assemblage was recovered at Zalaegerszeg-Andráshida-Gébárti-tó (Simon, 2002). The pottery shapes and decorations are highly comparable with site 2 at Brunn am Gebirge/Wolfholz in the Vienna basin (Stadler, 2005; Stadler and Kotova, 2010, 2019).

The LBK settlement of the northern shore of Lake Balaton and the Little Balaton basin was profoundly investigated as the first and second volumes of the Archaeological Topography of Hungary (*Magyarország Régészeti Topográfiája*) targeted exactly this area and extensive micro-regional research was carried out in the Little Balaton basin. Due to the significant research focus on the area, a range of sites was published in those two volumes as well as in the first summary of the earliest LBK in western Hungary: among them Balatonszepezd-Rét-feletti erdő-Barackos, Révfülöp-49. számú vasúti őrház, Vonyarcvashegy-Pintér-villa, Keszthely-Fenékpuszta, Sármellék-Égenföld-Agyagbánya, Zalavár-Keleti József udvara, Garabonc-Ófalu and Balatonlelle-Lelle-kúti-dűlő (Bakay et al., 1966; Éri et al., 1969; Kalicz, 1980a; Bánffy et al., 1996). Substantial research was carried out at Bicske-Galagonyás that revealed an assemblage identical with that of the Slovakian Bíňa (Makkay, 1978). Another similar assemblage was discovered in the more northerly section of the Danube at Budapest-Aranyhegyi út (Kalicz-Schreiber and Kalicz, 1992). The two Becsehely sites could be investigated again recently by large-scale excavations, and concerning the early LBK, Becsehely II-Homokos provided valuable further information (Barna, 2004; Kalicz et al., 2012). It must be noted, however, that a detailed relative chronological sequence like that for south-west Slovakia, with the four successive phases of Nitra, Hurbanovo, Bíňa and Milanovce (Pavúk, 1980), was never elaborated for Hungary. Regional results were substantial for research on the later LBK phases. Keszthely-Dobogó, the eponymous site for the Keszthely group, created to distinguish the southern Transdanubian later and late LBK, lies directly on the lake (Kalicz, 1991). Research on the LBK of the Balaton area and the adjacent regions was summarised in detail recently (Oross et al., 2019, 11–20, Fig. 2).

One of the most striking differences in comparison with other central European regions of the LBK distribution was the lack of information on settlement layouts and settlement structures and the very limited knowledge of above-ground timber-framed buildings. The partially excavated tripartite building at Győr-Pápai-vám (Mithay, 1966), that of Almásfüzitő-Foktorok (Vadász, 1971) and the two or three buildings from Sukoró-Tóra-dűlő (Makkay, 1970; Gläser, 1993, 65, Abb. 5b–c) are the few examples. Large-scale excavations of the past twenty-five years have revealed the existence of extended settlements with traces of above-ground timber-framed houses all over western Hungary (Oross, 2013). The early LBK period is still represented by only a few houses such as the two buildings from Dunakeszi-Székesdűlő (Horváth, 2002) and those from Litér-Papvásár-hegy (Regenye, 2008). Representing later and late LBK phases, the site with 20 buildings from Mosonszentmiklós-Egyéni-földek (Egry, 2003), the three tripartite buildings from Torony-Nagyrét-dűlő (Ilon, 2013), eight buildings from different excavations at Törökbálint-Dulácska (Endrődi, 1993, 1994; Horváth, 2004) and probably seven buildings from Harta-Gátőrház (Kustár and Lantos, 2004) should be mentioned. Recent achievements from southern Transdanubia will be discussed below.

4. Variability in late 6th millennium cal BC southern Transdanubia

Large-scale excavations in southern Transdanubia, that is, in the area between the Dráva river and Lake Balaton, started even later than in the northern part of western Hungary. Investigations started in the north, along the planned M7 motorway that connects Budapest with Zagreb and on the short section of the M70 motorway along the Hungarian-Slovenian border. Excavations in the two south-east

Transdanubian counties of Tolna and Baranya were carried out prior to the construction of the M6 and M60 motorways which connect Budapest with Pécs, and with Eastern Slavonia in Croatia. Although research activity started in the north on settlements like Balatonszárszó-Kis-erdei-dűlő (Marton, 2004; Oross, 2004) and Balatonszemes-Bagódomb (Kiss and Sebők, 2007), further discussion follows the direction of the Neolithisation process from the south to the north (Fig. 2).

The Szederkény-Kukorica-dűlő site south of the Mecsek Mountains consists of three separate settlement units. The existence of such spatially separated units has been frequently noticed in late 6th millennium cal BC sites of the region, and they probably reflect semi-autonomous or autonomous, but linked, neighbourhoods or wards (Oross et al., 2019, 46–55; Jakucs, this volume). Ceramic material of the eastern and middle settlement units is dominated by Vinča A type pottery. Early Vinča ceramics had never previously been recognised as the main component of the material culture in a late 6th millennium cal BC settlement north of the Dráva river in Transdanubia, even though recurrent observations were made on Vinča impacts on early LBK sites, mostly along the Danube (Kalicz and Makkay, 1972a, 95; Makkay, 1978, 30–31; Kalicz, 1994). Early LBK shapes and decorations are present but decidedly scarce in the material of those units. In contrast, Ražište-style material dominates the pottery assemblage of the western unit, complemented again by some LBK-style fragments (Jakucs and Voicsek, 2015, 2017; Jakucs et al., 2016). The adjacent Versend-Gilencsa site consist of two distinct neighbourhoods on both sides of the Versend stream. The ceramic material of the eastern one comprises Starčevo, early Vinča and LBK characteristics, although their proportions vary from household to household. The western one resembles the western unit of Szederkény-Kukorica-dűlő as Ražište- and Malo Korenovo-style pottery dominates the assemblages (Jakucs and Voicsek, 2017; Jakucs et al., 2018; Jakucs, this volume).

Ceramic material recovered from the excavated sites of the Tolna Sárköz region can basically be labelled as LBK but intensive Starčevo roots were observed in shapes and decorations as well as in technological aspects of the pottery. Another important component resembles the early Vinča culture, although some fundamental elements of Vinča technology such as black-topped and red-slipped fragments are virtually absent. The late 6th millennium cal BC occupation of Alsónyék-Bátaszék provides an excellent example of those sites. Beside a range of early LBK and Vinča characteristics, *Notenkopf*-style decoration could also be observed (Oross et al., 2016b, 126–130, Figs. 4 and 5). Another principal site of the region is Tolna-Mözs-Községi-Csádés-földek where three distinct wards or neighbourhoods were excavated along the track of the motorway, similarly to Szederkény-Kukorica-dűlő. Starčevo and early Vinča traits were most intensively detected in the southern unit; ceramics of the more northerly one conformed to canonised early LBK assemblages, while later LBK decorations such as *Notenkopf* decorated fragments appeared in the material of the northern unit (Marton and Oross, 2012, 225–233, Abb. 4–9). As other settlements were excavated directly to the south of the site such as Tolna-Mözs-Sági rét-dűlő and Tolna-Mözs-Szarvas-dűlő, we can make the assessment that the appearance of more abundant Zseliz/Želiezovce decoration from the latter site is currently the southernmost example along the Danube.

Balatonszárszó-Kis-erdei-dűlő on the southern shore of Lake Balaton provided a pottery sequence more comparable to other central European assemblages. Pottery of the formative LBK is absent from the site. Five different style groups were distinguished based on the typological analysis of shapes and decorations (Marton, 2008), reinforced later by correspondence analysis (Marton, 2015, 202–214, Figs. 5.108–5.113). Style group 1 and Style group 2 represent the early LBK, broadly equivalent to Bíňa- and Milanovce-style assemblages from south-west Slovakia. Style group 3 pottery combines some early LBK traits with early Keszthely-style material that is complemented with a limited number of *Notenkopf*-style fragments. Keszthely-style pottery is dominant in Style group 4 units but associated with a number of Zseliz/Želiezovce fragments. Style group 5 assemblages are mixed Keszthely and Zseliz/Želiezovce materials where the proportion of the latter reaches 50 per cent in some cases (Marton, 2004, 2008, 2015).

In contrast to the constant recombination of the decorative elements of the pottery assemblages, traces of LBK longhouse architecture were recorded all over the region. Rules for building regarded as the hallmark for the central European early Neolithic appear in a developed form even south of the Mecsek Mountains, associated with predominantly early Vinča- and Ražište-style pottery. In Szederkény-Kukorica-dűlő, 66 buildings were identified mostly based on the long pits flanking the houses. Traces of the post framework could be excavated in exceptional cases only (Jakucs et al., 2016). Similarly, 21 longhouses could be identified because of their long pits in the eastern neighbourhood of Versend-Gilencsa, while later disturbances allowed the recognition of only eight houses in one single row in the western one (Jakucs and Voicsek, 2017, 141–142, Fig. 5; Jakucs et al., 2018, 93, Fig. 2; Jakucs, this volume). Traces of longhouses were also discovered in greater numbers at the more westerly-lying Szemely-Irtás (Jakucs, this volume). Furthermore, structures resembling central European-type longhouses have been discovered on sites even in the Croatian Slavonia, such as at Virovitica-Brekinja and Donji Miholjac-Vrancari, associated with distinct variations of material culture but all dated to the second half of the 6th millennium cal BC (Dizdar and Tonc, 2016; Botić, 2018). The 50 house plans of the Alsónyék-Bátaszék settlement are similar in that they were mostly identified because of the long pits, but there is more frequent evidence for the post framework (Oross et al., 2016b, 124, Figs. 2 and 6). Houses with more than two complete detected cross-rows of load-bearing internal posts are rare among the 47 excavated buildings at Tolna-Mözs-Községi-Csádés-földek (Oross, 2013, 353–360, Figs. 7.7–7.9).

The postholes of the house plans were radically better preserved at Balatonszárszó-Kis-erdei-dűlő. At the current stage of evaluation, 68 prehistoric houses have been identified, of which 63 belonged to the LBK occupation. The buildings correspond with the well known central European LBK architecture in so far as they had five parallel longitudinal rows of posts, the three internal rows serving as the load-bearing elements. Other architectural elements like bedding trenches in the rear section of the houses or the oval postholes in the cross-rows of the front sections are completely absent. These characteristics make local architecture different even in comparison with the closer regions of the north-west Carpathian basin. Despite the lack of traditional elements from which house partition was inferred in LBK houses, traces of possible partition could be observed in some of the buildings (Oross, 2004, 63–66, 2010, 2013, 211–250, Figs. 6.7–6.23). Comparable observations could be made at Keszthely-Lendl Adolf út in the westernmost part of the Balaton area. There, the late LBK settlement provides the first settlement layout for further analysis from the Keszthely bay with its 18 excavated buildings (Oross et al., 2019, 21–37, Figs. 5–14 and 16).

As a general pattern for the investigated region, houses are carefully built side by side, gable walls are aligned in the same direction, and the groups of adjacent houses resemble rows on overall plans of the settlements, even if they were not necessarily contemporaneous. Considerable overlaps between houses are surprisingly rare and even the long pits seldom cut each other. In the case of overlaps, usually the northern short side of a house overlaps with the southern gable wall of another one. This statement is true for all evaluated extended settlements of the region, including Szederkény-Kukorica-dűlő, Versend-Gilencsa, Alsónyék-Bátaszék, Tolna-Mözs-Községi-Csádés-földek and Balatonszárszó-Kis-erdei-dűlő (Oross, 2010; Marton and Oross, 2012, 226; Oross, 2013, 320–345; Jakucs et al., 2016, 273–278, Figs. 3–5; Oross et al., 2016b, 124–126, Figs. 2 and 6; Jakucs et al., 2018, 93, Fig. 2; Oross et al., 2019, 46–53).

5. Micro-regional focus through field surveys: gathering sherds, gathering sites

To evaluate our results at a regional level, the state of late 6th millennium cal BC settlement research in the early 1990s, when Roland Gläser pulled the then available evidence together (Gläser, 1993), seems to be a good basis for a comparison. Gläser could list 102 late 6th millennium cal BC sites from the core research area; if we exclude the Mecsek Mountains with their territory of 328.03 km^2, and the small Villány Mountains of 33.07 km^2, that leaves 10 437.78 km^2. That means on average one site every 102.33 km^2. Early LBK ceramic material could be recorded merely on ten, possibly on 12, sites.

The adjacent territory in the western Balaton basin comprises 672.40 km^2. Due to the intensive field surveys and excavation activity, the number of late 6th millennium cal BC sites has reached 37, one site per 18.17 km^2 on average. The other adjacent territory east of the core research area, along the modern left bank of the Danube, is 1390.82 km^2. The only six late 6th millennium cal BC sites listed by Gläser are equivalent to a single site per 231.80 km^2. Six, probably eight, of the western Balaton region sites, but only two (Baja-Bajaszentistván-Szlatina and Fajsz-Garadomb) on the left Danube bank, were classified as early LBK occupations.

As a substantial part of our research project, three different micro-regions were selected within the core area of the investigated territory. The purpose was a more detailed insight into the wider context of extended, recently excavated sites. The basic units of field walking were 1-ha squares of the Hungarian EOTR (United National Map System) system which uses the so-called EOV (United National Projection), as projected coordinate system (EPSG:23 700) for Hungary. A distance of 25 m was kept between two persons, and the packing units for the collected material were 100 m long. That resulted in 25 × 100 m large cells for the evaluation of the finds. The adopted method was elaborated in the course of exploration works preceding salvage excavations and proved to be a useful tool for detecting all possible sites and to encompass large areas at the same time (Mesterházy and Stibrányi, 2012; Mesterházy, 2013). Archaeological material was collected, cleaned and classified without any selection according to its age, material or function.

The southernmost investigated micro-region is located in the Southern Baranya Hills (Fig. 3). The two extended, excavated sites, Szederkény-Kukorica-dűlő and Versend-Gilencsa, were discovered on the southernmost, warm slopes of the hills. Another goal was to investigate one of the narrow stream valleys that form the geographical hinterland of the large sites in more open areas. For that reason, the Borza stream was selected as it was possible to survey its complete upper course in the framework of the project. The southern limits of the micro-region coincide broadly with the line where the Southern Baranya Hills meet the Nyárád-Harkány Plain (*Nyárád-Harkányi-sík*), a plain directly connected to the alluvial areas along the Dráva river. The main watercourse within the micro-region is the Karasica river, which flows towards the south and joins the Danube on Croatian territory. The highest elevation is 256 m a.s.l., the lowest point at 109 m a.s.l.

Of the complete extent of 3896 ha, 2408 ha area were suitable for survey because of their vegetation. A further 208 ha are covered by vineyards. From that territory, 2183 ha were surveyed up to 1 October 2019, which means that over 90 per cent of accessible territory was investigated.

Even though the two extended sites dominate the micro-region, the Szederkény-Belvárd-dűlő site is located in the same geographical position on the right bank of the Karasica river. The same is valid for the Starčevo settlement of Babarc-Szabadföldek along the Borza stream. Further small sites have been discovered in their hinterland, such as Versend-Mekota in the uppermost part of the Borza valley and Liptód-Bildstock Äcker on a plateau north of the latter.

The Tolna Sárköz/Sárvíz Valley micro-region some 50 km to the north is directly located at the Tolna Danube, an ancient riverbed of the Danube before regulation (Fig. 4). The highest elevation of the micro-region is at 191 m a.s.l., the lowest point at 84 m a.s.l., although the elevations are restricted to two small areas, the larger at the fringes of the Szekszárd Hills, and the smaller one between the Sárvíz valley and the Völgység stream.

The territory of the micro-region comprises 3393 ha, of which 1598 ha were suitable for survey because of their vegetation. Vineyards cover 169 ha within the micro-region. From that territory, 1515 ha were surveyed up to 1 October 2019, so that almost 95 per cent of accessible territory was investigated.

The currently known 15 sites appear to belong to three distinct settlement clusters within the micro-region. One particularly clear example is located directly at the Tolna Danube, which was the main river branch until the regulation works of the 19th century AD. Its most notable settlement is the Tolna-Mözs-Községi-Csádés-földek site where 47 houses were excavated in three different spatial units (Marton and Oross, 2012). As the entire site was investigated by geomagnetic survey, it was securely established that altogether 150 to 186 longhouses were built in the settlement (Rassmann et al., 2015, in press). Another three contemporary sites lie along the Tolna Danube further to the south. Two sites at the Kapszeg lake form the western limits of the settlement cluster. The Kapszeg lake itself is a Pleistocene riverbed that separated naturally from the Danube, and is today a marshy area that receives fresh water only during the biggest floods. The settlement clusters in the Sárvíz river bend and in the Völgység valley serve as connecting links between those riverside communities and the settlements in the internal parts of Transdanubia. None of them seems to be completely investigated yet.

In October and November 2019 a campaign was launched to carry out systematic geomagnetic survey of the late 6th millennium cal BC sites of the micro-region. All three sites along the Tolna Danube south of the Tolna-Mözs-Községi-Csádés-földek site were surveyed. It was impossible to discover traces of Neolithic occupation at Tolna-Mözs-Sági rét-dűlő because of the debris deposited in the course of motorway construction. In contrast, the evidence of excavated longhouses could be complemented by further detected house remains at Tolna-Mözs-Szarvas-dűlő. At Szekszárd-Tószeg-dűlő again, clear signals of long pits belonging to longhouses were detected. In the more westerly Sárvíz Bend and Terminal Völgység clusters, one principal intention was the identification of extended sites and comparison with the Tolna-Mözs-Községi-Csádés-földek occupation. The results of the Szekszárd-Hidaspetre 2 survey are presented below.

Finally, the southern Balaton micro-region is located a further 80 km to the north in a stillwater environment at Lake Balaton (Fig. 5). In the investigated central section of the southern lakeshore, extended sites of different clusters lie at an approximately 4–5 km distance from each other separated by the ancient bays of the lake. That is true for the recorded settlement cluster as well; smaller sites are along the bay and by small creeks in the hinterland of the Balatonszárszó site. The highest elevation of the micro-region is at 263 m a.s.l., while 104 m a.s.l. is the lowest point.

The micro-region comprises a territory of 3704 ha, of which 1533 ha are suitable for survey. The extent of the vineyards is 257 ha. From that area, 970 ha were surveyed up to 1 October 2019, and broadly two thirds of the accessible fields were investigated.

As a result of earlier investigations and our current micro-regional campaigns, five late 6th millennium cal BC sites could be identified within the limits of the Southern Baranya Hills and southern Balaton micro-regions, while the settlement system of the Tolna Sárköz/Sárvíz Valley micro-region comprises 15 sites. Each micro-region was represented by one single site in the catalogue of Gläser; sherds collected on the surface were known from Szederkény-Kukorica-dűlő and Balatonszárszó-Kis-erdei-dűlő, while LBK sherds were discovered in 1st millennium AD graves at Tolna-Mözs-Icsei-dűlő (Gläser, 1993, Site Catalogue, 136, 188, 236). Current micro-regional research provides a substantially closer estimate of the actual settlement network of the late

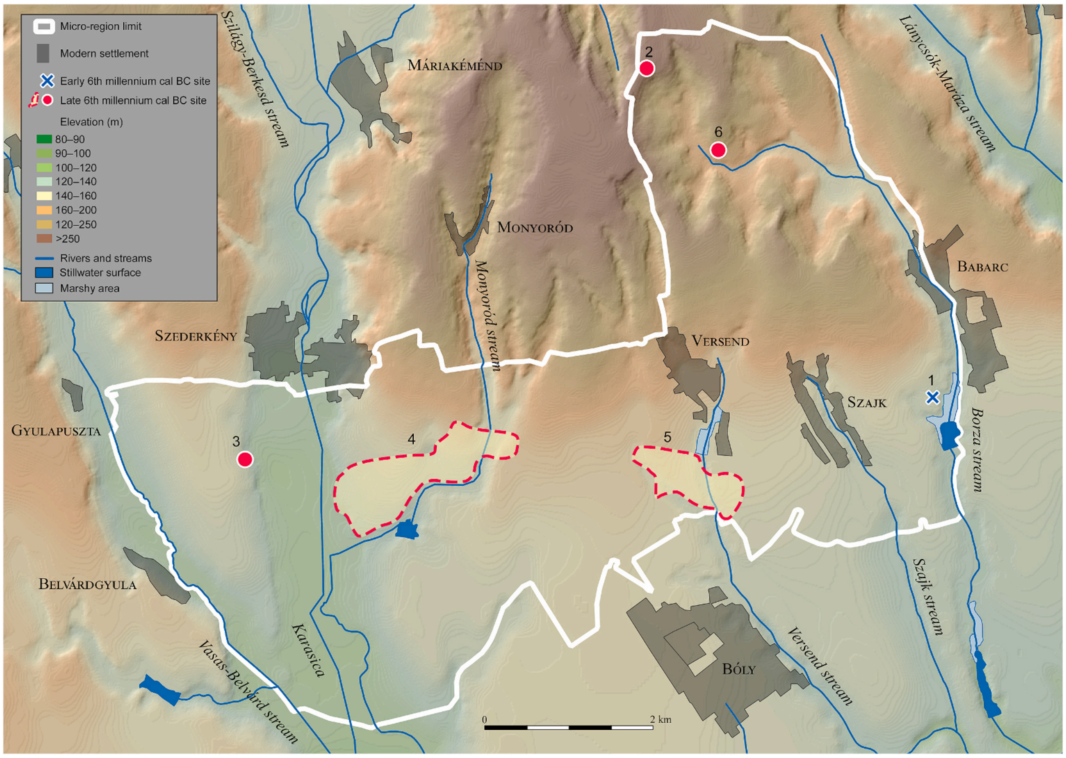

Fig. 3. The Southern Baranya Hills micro-region with 6th millennium cal BC sites: **1**, Babarc-Szabadföldek; **2**, Liptód-Bildstock Äcker; **3**, Szederkény-Belvárd-dűlő; **4**, Szederkény-Kukorica-dűlő; **5**, Versend-Gilencsa; **6**, Versend-Mekota.

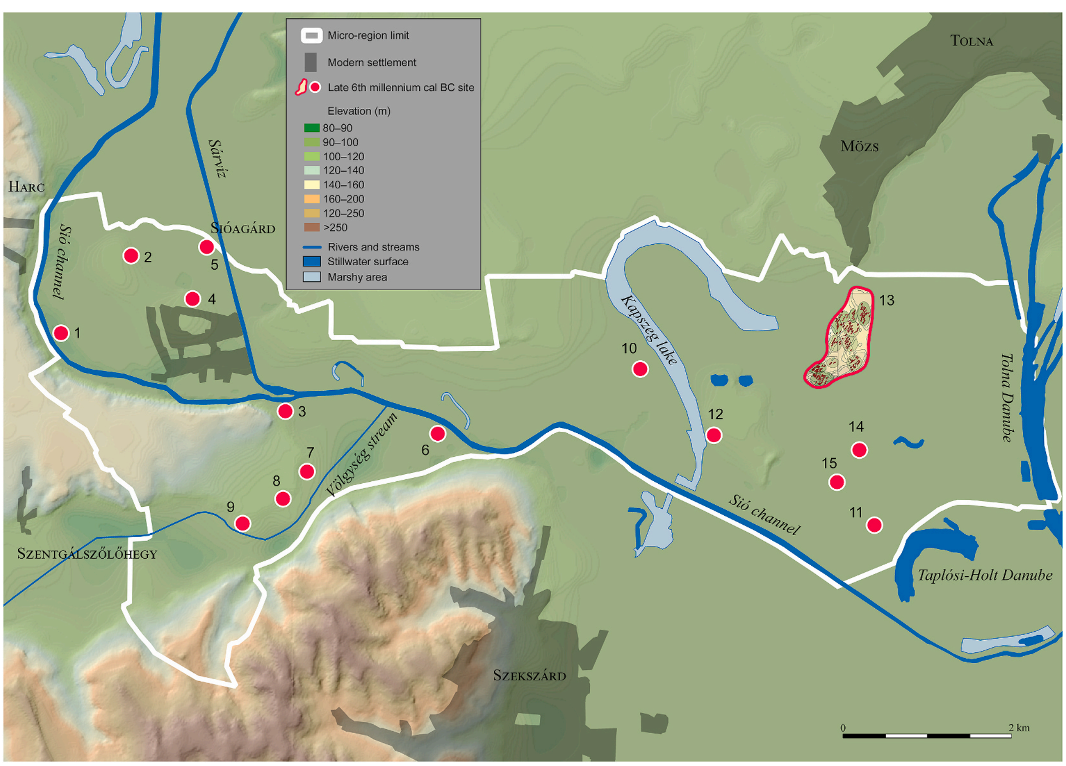

Fig. 4. The Tolna Sárköz/Sárvíz Valley micro-region with late 6th millennium cal BC sites: **1**, Sióagárd-Bikalegelő; **2**, Sióagárd-Harci-útra-dűlő; **3**, Sióagárd-Leányvár-dűlő; **4**, Sióagárd-Vermes-hegy; **5**, Sióagárd-Tüskés-sziget; **6**, Szekszárd-Belső Hidas-sziget; **7**, Szekszárd-Hidas-dűlő; **8**, Szekszárd-Hidas-dűlő-dél; **9**, Szekszárd-Hidaspetre 2; **10**, Szekszárd-Palánki-dűlő 1; **11**, Szekszárd-Tószeg-dűlő; **12**, Tolna-Mözs-Icsei-dűlő; **13**, Tolna-Mözs-Községi-Csádés-földek; **14**, Tolna-Mözs-Sági rét-dűlő; **15**, Tolna-Mözs-Szarvas-dűlő.

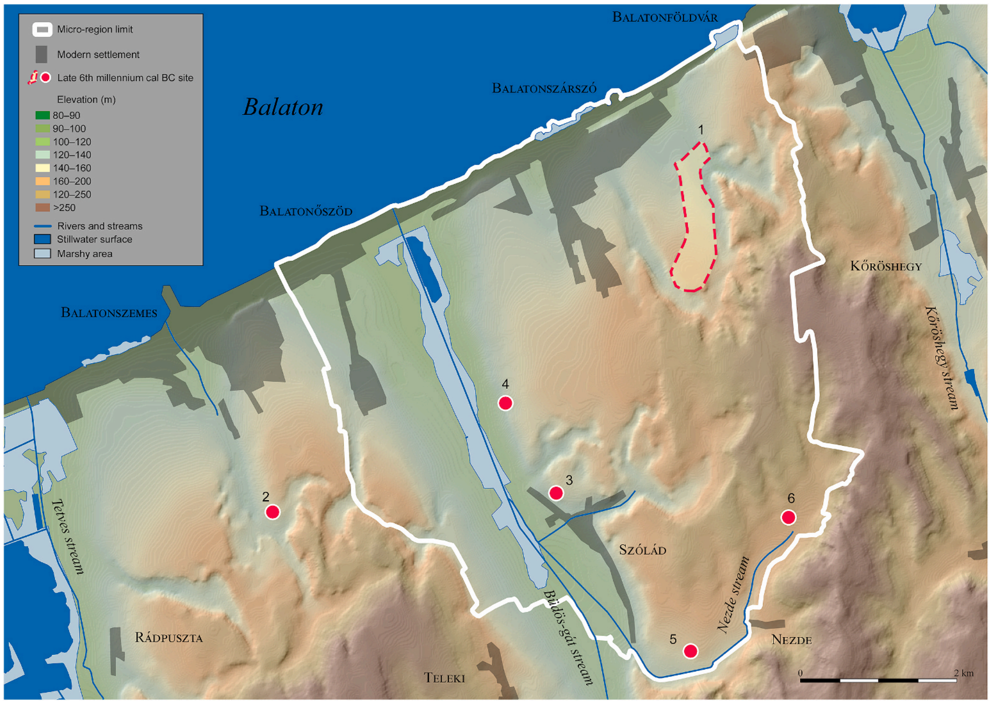

Fig. 5. The southern Balaton micro-region with late 6th millennium cal BC sites: **1**, Balatonszárszó-Kis-erdei-dűlő; **2**, Balatonszemes-Bagódomb; **3**, Szólád-Kertek mögött; **4**, Szólád-Szőlőhegy; **5**, Szólád-Tölösi-dűlő; **6**, Szólád-Tüszküs.

6th millennium cal BC and projects a much denser occupation than previously assumed. The evaluation of the finds has been completed from the Tolna Sárköz/Sárvíz Valley micro-region, but is still in progress from the other two, which is why the extended sites of the Southern Baranya Hills and southern Balaton micro-regions are marked with dashed outlines.

6. Geomagnetic survey: gathering houses

To gain a more precise picture of the extent of the settlements and settlement patterns beyond surface find distributions, geomagnetic surveys were carried out on several sites in the research area. The first category consists of the excavated extended sites. The Balatonszárszó-Kis-erdei-dűlő and Tolna-Mözs-Községi-Csádés-földek sites were surveyed in an international collaboration with the DAI Römisch-Germanische Kommission in Frankfurt am Main and with further German colleagues from various institutions. The data on the Tolna-Mözs-Községi-Csádés-földek settlement had already been evaluated (Rassmann et al., 2015, in press). Geomagnetic survey of the Szederkény-Kukorica-dűlő site started in autumn 2018. The second group of surveyed sites comprises further, predominantly smaller occupations within the limits of the three micro-regions investigated earlier by excavations or field surveys, or discovered in course of the field surveys during the recent project. The third group of surveyed sites consists of iconic settlements of the entire research area discovered earlier, which had played a substantial role in former debate. The three case studies representing the second and third categories are discussed below.

Geomagnetic prospections were conducted by a SENSYS MXPDA five-channel Fluxgate gradiometer, with continuous GPS orientation and RTK correction. The probes were set at 0.5 m intervals in a perpendicular line to direction of the prospection. The accuracy of the data acquisition was approximately 0.1 m along the measuring line. The raw data obtained from the survey were filtered in several different ways for the further archaeological analysis and interpretation.

6.1. Case study 1: Versend-Mekota

Versend-Mekota is located within the Southern Baranya Hills micro-region in the valley of the Borza stream which had been selected for investigation of the hinterland of the extended sites. The remote site was already known before the micro-regional field survey, as a handful of prehistoric sherds were collected earlier. A series of drone photographs were taken in different seasons. Winter-time pictures from February 2018 demonstrate how different the micro-environment of the site is in comparison to the large sites of Szederkény-Kukorica-dűlő and Versend-Gilencsa (Fig. 6). Another series was the basis of a digital surface model completed by photogrammetry that serves as precise background for the visualisation of the results of the surface find collections by field walking and those of the geomagnetic survey.

Current fieldwork started with an extensive survey, and late 6th millennium cal BC Neolithic and Middle Bronze Age sherds were collected (Fig. 7a and b). The field survey was repeated using a 20 × 20 m grid as packing units for the sherds. In contrast to the 2500 m^2

Fig. 6. Versend-Mekota. Winter-time drone photo, view from the west.

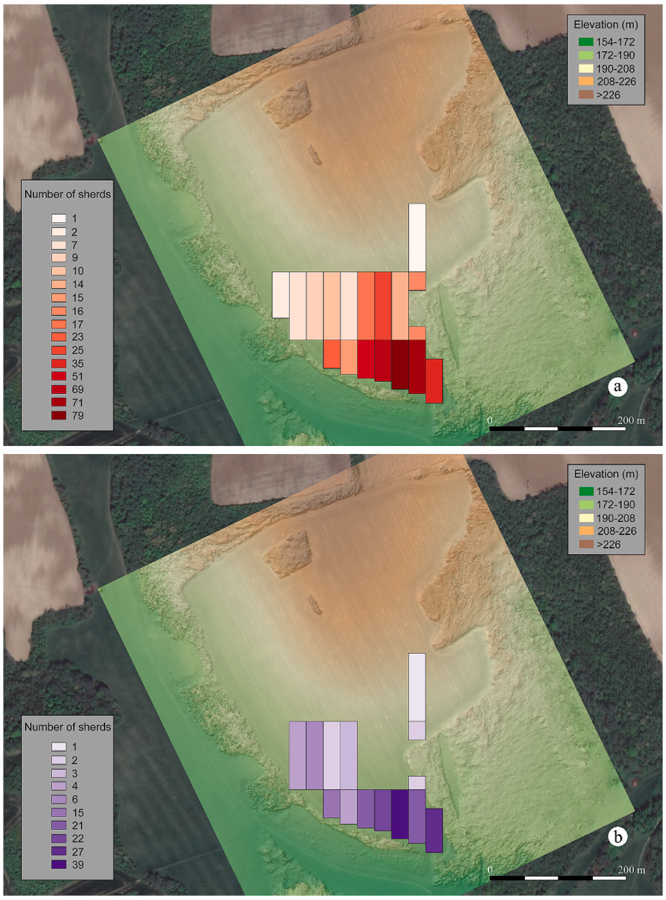

Fig. 7. Extensive field survey at Versend-Mekota: a, distribution of the entire pottery material; b, late 6th millennium cal BC sherd distribution.

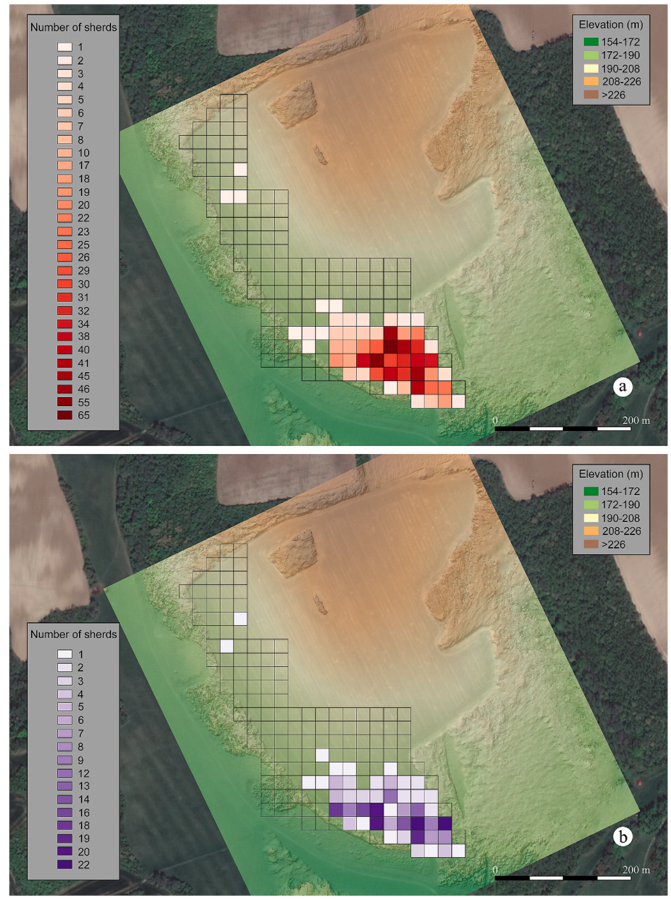

Fig. 8. Intensive field survey at Versend-Mekota: a, distribution of the entire pottery material; b, late 6th millennium cal BC sherd distribution.

resolution of the extensive field surveys, the intensive survey enables a more precise, 400 m^2 resolution in the course of the evaluation. The overall distribution of sherds indicates an occupation in the southern part of the western terrace both during the Neolithic and the Bronze Age (Fig. 8a). The late 6th millennium cal BC ceramic material, that features both LBK and Vinča characteristics, accumulated particularly in the southernmost part of the terrace (Fig. 8b and 9). It is worth noting that a small number of late 6th millennium cal BC sherds were also collected in the northern area of the terrace.

Geomagnetic prospection was carried out on the southern part of the terrace first, resulting in a very clear signal for long pits belonging to late 6th millennium cal BC longhouses. As the distribution of longhouses continued towards the west and north, the survey was extended to the entire surface of the terrace and to the lower parts of the adjacent slope. The investigated surface of the prospection comprises 4.8 ha. Due to the bias caused by erosion, a much wider area had houses than the area of the sherd distribution. The extended pits of the Bronze Age occupation are clearly visible as well, and broadly coincide with the distribution of Bronze Age pottery. Bronze Age features are also responsible for some gaps in the reconstructed settlement layout as they have probably destroyed the remains of Neolithic houses (Fig. 10a).

Altogether, 41 longhouses were discovered aligned into at least five different rows on the terrace (Fig. 10b). The area covered with houses comprises 1.7 ha; its lowest point is at 166.7 m a.s.l., while the highest elevation of that zone is at 185.4 m a.s.l. Some pits were discovered right at the northern part of the terrace, marking activity that was carried out outside the zone of the houses, more than 50 m away.

The Versend-Mekota site was established in a by no means wholly favourable environment. The only strategic advantage is that the community could control the source of the Borza stream which is directly opposite the terrace. Further investigations could successfully target the possible differences in the subsistence strategy of the community in comparison with the more southerly located extended sites. It is also a plausible explanation that the traces of a group were discovered that was displaced by the robust occupation at Szederkény-Kukorica-dűlő and at Versend-Gilencsa.

6.2. Case study 2: Szekszárd-Hidaspetre 2

Szekszárd-Hidaspetre 2 is one of the three closely located sites on the left bank of the Völgység stream in the Terminal Völgység cluster of the Tolna Sárköz/Sárvíz Valley micro-region. The two adjacent contemporaneous occupations are Szekszárd-Hidas-dűlő and Szekszárd-Hidas-dűlő-dél. One important purpose of the survey was the investigation of the settlement west of the densely occupied cluster at the Tolna Danube. The three sites could possibly form distinct neighbourhoods such as at Tolna-Mözs-Községi-Csádés-földek or even in a less coherent fashion as at Szederkény-Kukorica-dűlő. The prospection of 1.6 ha at Szekszárd-Hidas-dűlő, however, yielded no traces of longhouses, while the Szekszárd-Hidas-dűlő-dél site has not yet been investigated.

Based on the extensive field survey (Fig. 11a), the survey of the Szekszárd-Hidaspetre 2 site over a total of 5.7 ha proved to be successful (Fig. 11b). Traces of 53 late 6th millennium cal BC longhouses have been discovered over an area of 1.8 ha (Fig. 11c). The lowest point covered by houses is at 98.2 m a.s.l., while the highest elevation of that zone is at 100.9 m a.s.l., which means that the distribution of the buildings is restricted to a well-defined terrace of the stream. The settlement provided good evidence for the establishment of settlements relatively close to clusters with at least hundreds of houses, on a scale

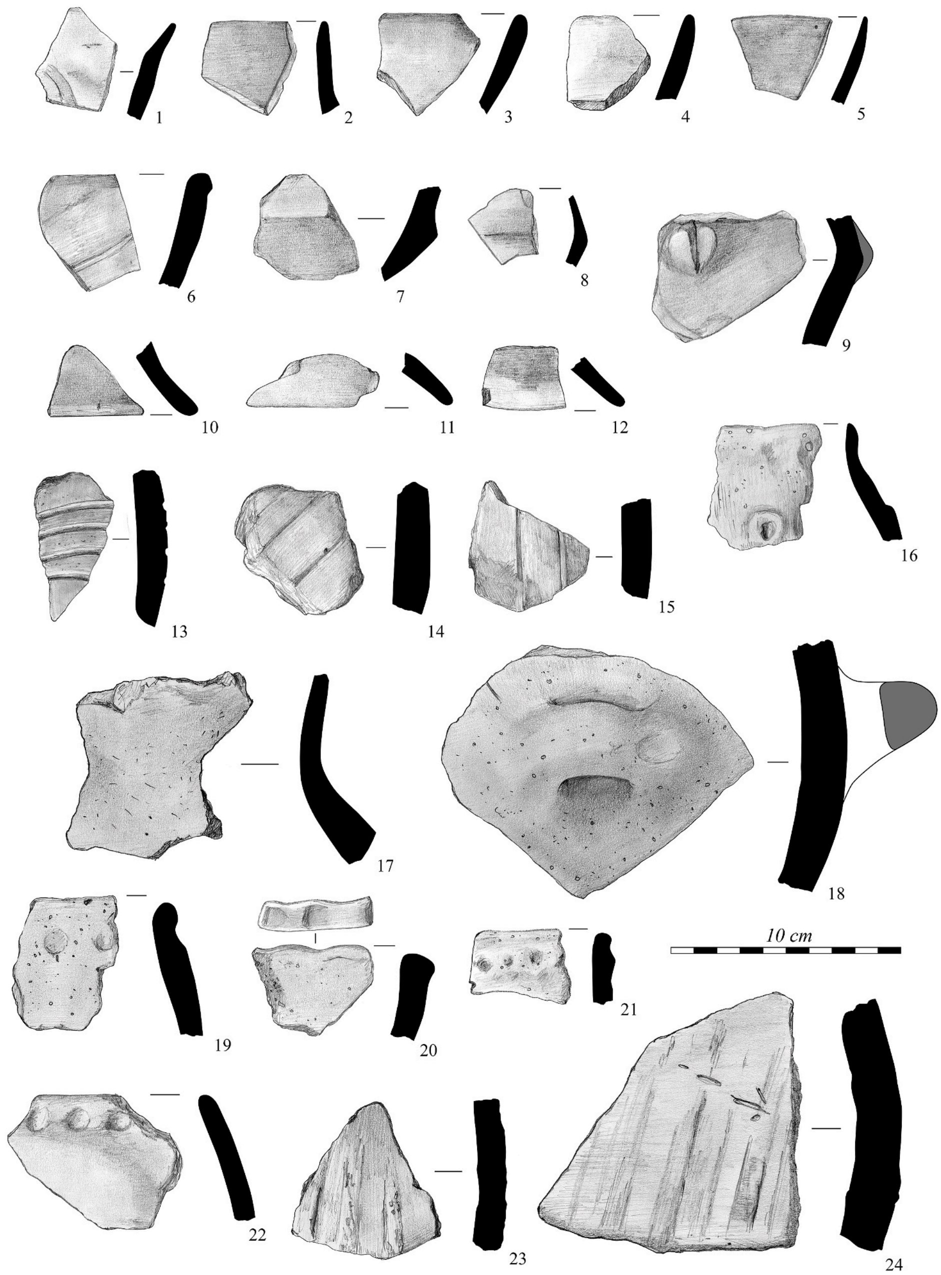

Fig. 9. Late 6th millennium cal BC pottery finds from Versend-Mekota. Surface collection.

comparable with the LBK occupation of Alsónyék-Bátaszék.

6.3. *Case study 3: Medina-Margitkert*

The emblematic site of Medina-Margitkert in the Sió/Sárvíz valley belongs to the limited group of 6th millennium cal BC occupations of the region where the pottery assemblage comprises Starčevo-, as well as early LBK- and later LBK-style (Keszthely) sherds.

After the collection in field survey of a limited number of Neolithic finds, our current geomagnetic prospection aimed to answer the question whether the site has some further research potential. A total of 2.2 ha were surveyed between the ancient river bed and the modern channel. The lowest point of the investigated area is at 93.5 m a.s.l., while the highest elevation is at 95.8 m a.s.l. The results show that most of the traces of the subsequent Neolithic occupations were destroyed by the regulation works in the 1930s, except one single longhouse suitable for a possible excavation in the future (Fig. 12).

7. Absolute chronology of 6th millennium cal BC southern Transdanubia

The absolute chronology of early farming communities, that of particular sites and activities as well as estimated time spans for archaeological cultures, was exclusively defined by informal analyses of individual dates in western Hungary until the end of the first decade of the 21st century. In the course of an aDNA project investigating Neolithic and Chalcolithic populations of the Carpathian basin, further 6th millennium cal BC burials were dated to ensure the chronological position of bioarchaeological samples (Szécsényi-Nagy et al., 2015; Oross et al., 2016a, 2016b). The potential of further progress was not only the AMS dating of carefully selected samples but the application of Bayesian statistics in the course of the interpretation of the data (Bayliss, 2009; Bronk Ramsey, 2009). In a Bayesian approach, the analysis of new data incorporates all existing experience and knowledge on the targeted problem resulting in an improved level of

Fig. 10. Versend-Mekota: a, geomagnetic survey; b, reconstructed late 6th millennium cal BC settlement.

understanding when combining prior beliefs and new information (Buck et al., 1996; Bayliss et al., 2016, 25–27, Fig. 2). At the moment of the start of recent dating programmes in Transdanubia, there were numerous available examples for the successful application of the method in European Neolithic research (Bayliss et al., 2007; Whittle et al., 2011). Another important point was an appropriate sample selection. The reliability of different sampled materials and the certainty of the association of samples with contexts and material intended to be dated were on the agenda from quite an early stage of radiocarbon dating (Waterbolk, 1971). Sampling strategy with particular attention to distinct categories of bone samples was summarised recently (Bayliss et al., 2016, 31–50) along with comparison of different sampled materials in another study (Bánffy et al., 2018). All models referred to below were completed with different versions of the OxCal calibration software (Bronk Ramsey, 2001, 2009).

7.1. Results of the Times of Their Lives project

The *Times of Their Lives* project opened up the way for a formal modelling of large series of radiocarbon dates from AMS measurements in the region and their discussion in a European context between 2013 and 2017. The formal model for the early Neolithic Starčevo occupation at Alsónyék estimates the beginning of the early Neolithic occupation in *5800*–5730 cal BC (*95% probability*; *start: Alsónyék Starčevo*), probably in *5775*–5740 cal BC (*68% probability*), and its end in *5575*–5505 cal BC (*95% probability*; *end: Alsónyék Starčevo*) probably in *5560*–5525 cal BC (*68% probability*) (Oross et al., 2016a, 103–105; Fig. 8).

In the course of a wider modelling of the spread of the Neolithic into central Europe, the formative LBK was also modelled based on results from Szentgyörgyvölgy-Pityerdomb and Brunn am Gebirge/Wolfholz,

Fig. 11. Szekszárd-Hidaspetre 2: a, extensive field survey with the distribution of late 6th millennium cal BC sherds; b, geomagnetic survey; c, the reconstruction of the late 6th millennium cal BC settlement.

site 2. According to Model 3, the formative LBK started in *5610*–5475 cal BC (*95% probability*; *start formative*), probably in *5545*–5485 cal BC (*68% probability*), and ended in *5445*–5340 cal BC (*95% probability*; *end formative*), probably in *5420*–5360 cal BC (*68% probability*) (Jakucs et al., 2016, 323, Figs. 22 and 23).

Concerning late 6th millennium cal BC sites, a substantial series of dates were obtained from Szederkény-Kukorica-dűlő. From different alternative models, Model 1 was regarded as providing the most plausible chronology for the site. This estimates the beginning of the settlement in *5360*–5305 cal BC (*95% probability*; *start Szederkény*), probably in *5340*–5315 cal BC (*68% probability*), and its end in *5210*–5165 cal BC (*95% probability*; *end Szederkény*), probably in the *5190s* or 5180s cal BC (*68% probability*). The three different

Fig. 12. Medina-Margitkert: a, geomagnetic survey; b, reconstructed late 6th millennium cal BC house plan.

neighbourhoods with distinctive material culture were revealed to be broadly contemporaneous, with the middle unit starting some decades later than the eastern and the western ones, and being abandoned first. The Highest Posterior Density interval for the first dated event in the eastern unit was *5350*–5300 cal BC (*95% probability*), probably *5330*–5310 cal BC (*68% probability*); *5325*–5260 cal BC (*95% probability*) and *5320*–5285 cal BC (*68% probability*) in the middle unit; and *5350*–5290 cal BC (*95% probability*) and *5330*–5305 cal BC (*68% probability*) in the western one, respectively (Jakucs et al., 2016, 292–296, Figs. 11 and 13, Table 3). The modelled series of the Versend-Gilencsa site has less relevance in the current discussions as it started considerably later (Jakucs et al., 2018).

Only two burials recovered from western long pits of houses are radiocarbon dated from Tolna-Mözs-Községi-Csádés-földek, but 23 radiocarbon results from 21 samples are available from the broadly contemporaneous occupation of the Alsónyék-Bátaszék complex, another site of the Tolna Sárköz region about 20 km to the south. Despite obvious Vinča-style elements in the ceramic assemblage, the latter was simply labelled as LBK occupation in the course of the dating programme for the Alsónyék-Bátaszék complex as a heuristic term. The main model for the late 6th millennium cal BC settlement at Alsónyék estimates the beginning of the LBK activity in *5365*–5230 cal BC (*95% probability*; *start: Alsónyék LBK settlement*), probably in *5335*–5280 cal BC (*68% probability*). The LBK activity ended in *5195*–5145 cal BC (*8% probability*; *end: Alsónyék LBK settlement*) or *5040*–4860 cal BC (*87% probability*), probably in *5010*–4915 cal BC (*68% probability*), suggesting that the settlement was used until the end of the regional LBK occupation (Oross et al., 2016b, 138, Figs. 7–9).

7.2. The Balatonszárszó dating programme

The Balaton area can provide further information, as the pottery sequence of the Balatonszárszó-Kis-erdei-dűlő site is appropriate for a comparison both with northern and southern Transdanubian canonised LBK pottery styles as well as with those of more distant regions. As already mentioned, Style group 1 units (Fig. 13) are virtually identical with Bíňa-Bicske-type assemblages (Makkay, 1978; Pavúk, 1980), while Style group 2 assemblages (Fig. 14) can be correlated with Milanovce-style material (Pavúk, 1980). The occurrence of those pottery styles is restricted to the north-east part of the Balatonszárszó site where houses were built at a greater distance from each other, and the settlement has a scattered layout in contrast to the densely built-up southern settlement part (Marton, 2008, 2015; Oross, 2013). Beyond their distinctive character because of their shape and decoration, the technology of pottery production also changes over time and across style groups, reinforcing the distinctive character of the early LBK assemblage (Kreiter et al., 2017, 2019).

The radiocarbon dating of the Balatonszárszó site was carried out in two rounds. The first round was completed in a collaboration between the University of Oxford, Cardiff University and the Archaeological Institute of the Hungarian Academy of Sciences. The programme was supported by the Natural Environment Research Council, United Kingdom. All 47 samples were dated in the Oxford Radiocarbon Accelerator Unit (ORAU). One measurement failed from Pit 1052, while another from Posthole 5713 (OxA-13784) dates a Copper Age context. Among the 45 results dating the Neolithic occupation, 17 human bone samples dated burials and 28 disarticulated faunal samples derived from other settlement features, such as pits and an enclosure. Round two dating was supported by the National Research, Development and Innovation Office (NKFIH/NRDIO), Hungary. Twenty-one successful measurements were carried out in the Scottish Universities Environmental Research Centre (SUERC), all of them on articulating and refitting faunal samples. Ten samples from articulating and refitting faunal samples were submitted to the Oxford Radiocarbon Accelerator Unit (ORAU). One measurement failed, but another one was successfully replicated, resulting in a series of ten measurements from the laboratory. Burial 278 (MAMS-14139) was dated in the course of a human aDNA project, while a sample dating a medieval horse (Beta-468260) was part of a faunal aDNA research programme. A total of 79 radiocarbon results are available from the site, of which 77 date late 6th millennium cal BC Neolithic contexts. Current modelling targets the early LBK occupation of the site.

Burial 792, a left-crouched, 40–59-year-old male, is dated (OxA-13650) by a long bone, a femur or a tibia (Table 1) and Burial 793, a left-crouched, 23–39-year-old male, is dated (OxA-13651) by a metacarpal from the northernmost part of the excavated surface where contexts are associated with Style group 1 (Bíňa-Bicske-type) pottery (Cramp, 2004; Jakucs et al., 2016, Table 5). Burial 796, a left-crouched, 15–16-year-old female, is dated (OxA-13652) by a rib from the southern part of the north-east surface where contexts are associated with Style group 2 (Milanovce-type) pottery. The burial was cut into a pit complex of Pits 5340, 5411, 5412, 5467 and 5468. First observations suggested it has sealed Pit 5411, but the burial is actually in a more southern part of the complex. Radiocarbon dating has reinforced the possibility that the burial predates Pit 5411.

Pit 4950, the westernmost pit of an extended pit complex, was dated (OxA-13640) by a sample from a *Bos taurus* disarticulated left femur, associated with moderately diagnostic early LBK ceramic material. Pit 4953 (SUERC-78052), an individual oval settlement pit west of House 41, was dated by a sample from a *Bos taurus* radius, articulating with humerus and ulna. Pit 4960, an individual oval settlement pit directly east of Burial 793 was dated (OxA-36839) by a sample from a *Bos taurus* lumbar vertebra with a refitting unfused epiphysis. Pit 5356, an individual oval settlement pit south-west of House 68 with particularly diagnostic Style group 2 ceramic material, was dated (SUERC-78059) by a sample from *Bos taurus* articulating carpal bones. Pit 5411, a pit of an extended pit complex with moderately diagnostic early LBK ceramic material, was dated (OxA-13799) by a sample from a *Bos taurus*

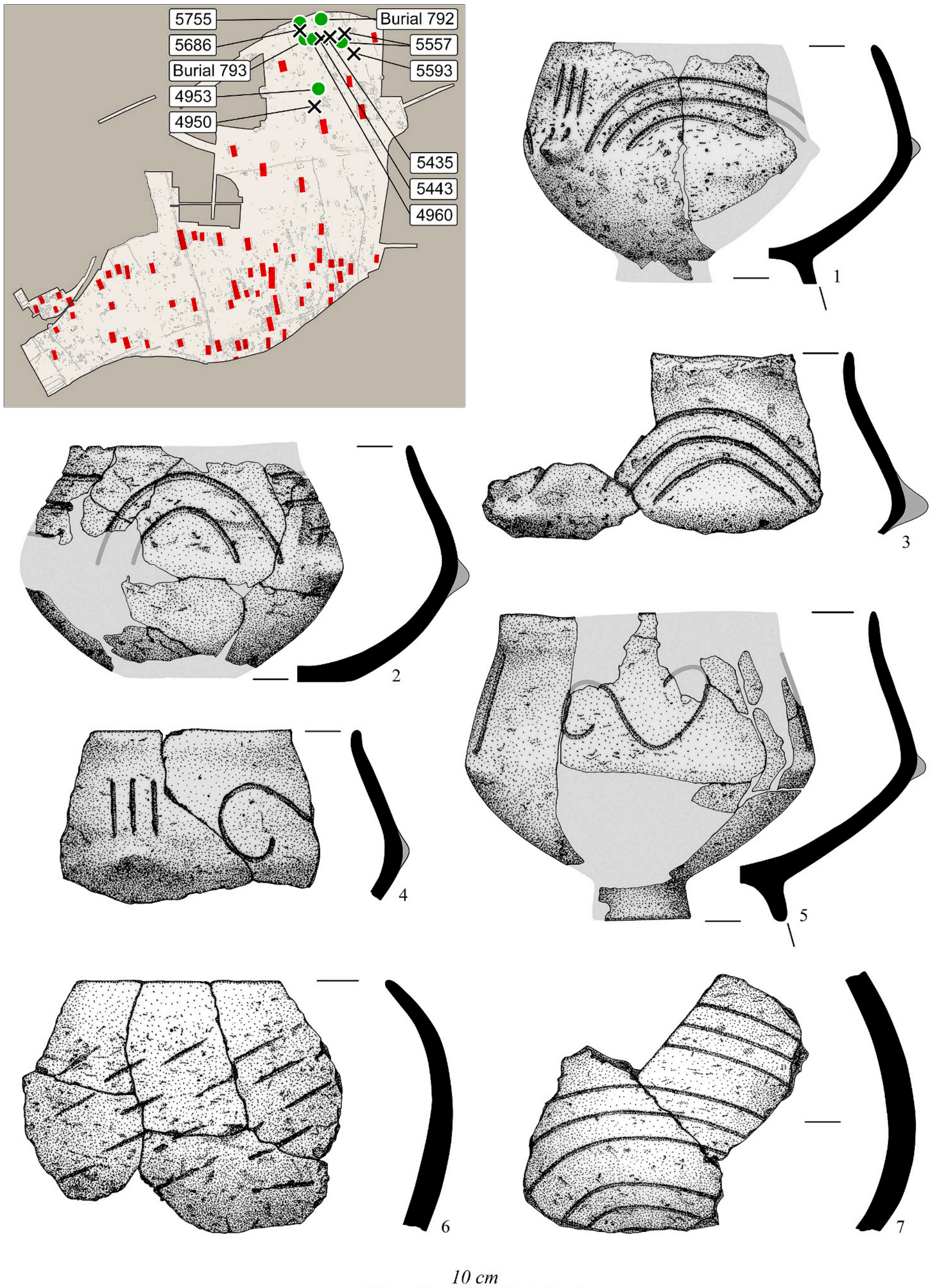

Fig. 13. Style group 1 early LBK-style pottery from sampled contexts at Balatonszárszó-Kis-erdei-dűlő: Pit 5435 (1); Pit 5557 (2–4, 6–7); Pit 5686 (5). Relevant radiocarbon samples from burials, articulating and refitting faunal samples are shown with dots, and those from disarticulated faunal samples with crosses on the site map.

disarticulated metapodium. Pit 5435, a pit of a pit complex was dated (OxA-13642) by a sample from an *Ovis aries/Capra hircus* disarticulated right humerus, associated with particularly diagnostic Style group 1 ceramic material. Pit 5443, a pit of a pit complex, was dated (OxA-13795) by a sample from a *Bos taurus* disarticulated right metatarsal, associated with particularly diagnostic Style group 1 ceramic material. Pit 5557, an individual oval settlement pit west of House 42, was dated first (OxA-13653) by a sample from an *Ovis aries/Capra hircus* disarticulated right radius. The dating of the context was repeated (SUERC-78056) by a sample from a different bone, from a *Bos taurus* thoracic vertebra with a refitting unfused epiphysis. A particularly diagnostic Style group 1 ceramic assemblage was recovered from the pit. Pit 5593, an individual oval settlement pit, was dated (OxA-13654) by a sample from a *Bos taurus* disarticulated right metatarsal, associated with moderately diagnostic Style group 1 ceramic material. Pit 5686, the largest pit of a pit complex, was dated (OxA-13655) by a sample from a *Bos taurus* disarticulated radius, associated with particularly diagnostic Style group 1 ceramic material. Pit 5755, the northern pit of a settlement pit complex that consists of Pits 5686, 5754, 5755 and 5833, was dated (SUERC-78057) by a sample from *Bos taurus* articulating carpal bones, associated with moderately diagnostic early LBK ceramic material.

Pit 5856, the western long pit of House 45, was dated first (OxA-13783) by a sample from a *Bos taurus* disarticulated rib, and the dating of the long pit was repeated (SUERC-78058) by a sample from a *Bos taurus* proximal phalanx articulating with the intermediate phalanx. The context yielded particularly diagnostic Style group 2 ceramic material. Pit 6005, an oval settlement pit, the so-called western pit of

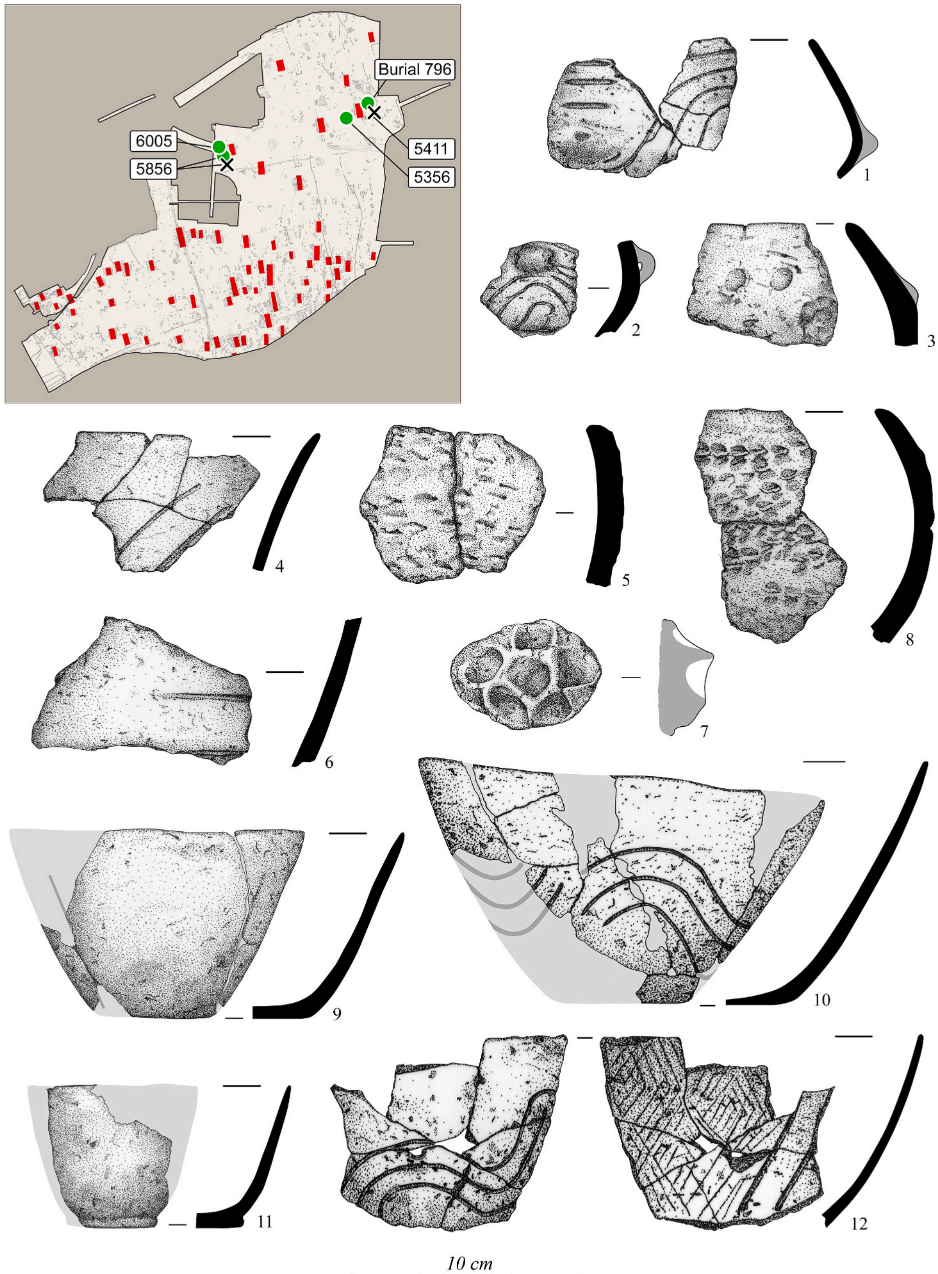

Fig. 14. Style group 2 early LBK-style pottery from sampled contexts at Balatonszárszó-Kis-erdei-dűlő: Pit 5856 (1–11); Pit 5356 (12). Relevant radiocarbon samples from burials, articulating and refitting faunal samples are shown with dots, and those from disarticulated faunal samples with crosses on the site map.

House 45, was dated (OxA-36840) by a sample from a *Bos taurus* metacarpal with a refitting unfused epiphysis, associated with particularly diagnostic Style group 2 ceramic material.

Four different alternative models were completed for the dating of the early LBK occupation at Balatonszárszó-Kis-erdei-dűlő using the program OxCal v4.3.2 (Bronk Ramsey, 2009; Reimer et al., 2013). The first model presents Style group 1 (Bíňa-Bicske) and Style group 2 (Milanovce) as two successive typo-chronological phases, that incorporates the assumption that all three house units (Houses 41, 42 and 44) of the former were used earlier than the four houses (45, 66, 67 and 68) representing the latter one. Ten dates are included in this model. SUERC-78057 from Pit 5755 was programmed as an outlier as it was recovered from a pit of a pit complex at the northernmost limit of the excavated surface. Pit 5755 yielded only moderately diagnostic ceramic material but provided an articulating faunal radiocarbon sample, while the associated Pit 5686 with particularly diagnostic Style group 1 material and with the earliest radiocarbon result (OxA-13655) of the entire dating programme contained disarticulated faunal samples only.

Model 1 (Fig. 15) for the early LBK occupation of Balatonszárszó has good overall agreement (Amodel = 96). The early LBK activity started in *5340*–5215 cal BC (*95% probability*; *Start Balatonszárszó early LBK*), probably in *5310*–5245 cal BC (*66% probability*) or in *5235*–5225 cal BC *(2% probability)*. The early LBK activity ended in *5285*–5235 cal BC (*3% probability*; *End Balatonszárszó early LBK*) or in *5230*–5045 cal BC (*92% probability*), probably in *5220*–5160 cal BC (*68% probability*). The transition from Style group 1 to Style group 2 occurred in *5290*–5210 cal BC (*95% probability*; *Balatonszárszó Style group 1/Style group 2*), probably in *5260*–5215 cal BC (*68% probability*) (Fig. 16).

The second model presents the early LBK occupation of Balatonszárszó as one single phase of activity and deals with its different components as forming one coherent and linked occupation. Features associated with Style group 1 pottery material on the

Table 1
Radiocarbon results from the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő. The results are presented in ascending order by context number.

Lab ID	Context no.	Context description [Sample ID]	Material	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N$ (‰)	C:N	Radiocarbon age (BP)	*Modelled date (95% probability)*	*References*
OxA-13650	Burial 792	Burial of left-crouched, east-northeast–west-southwest oriented 40–59-year-old male cut into the shallow Pit 4969 in the northernmost part of the excavated area. No grave goods uncovered. [36a]	Human bone: long bone, femur or tibia	−19.55 ± 0.3	9.9 ± 0.4	3.2	6292 ± 33	*5300*–5215 cal BC	Cramp (2004); Jakucs et al. (2016), Tables 5, 304
OxA-13651	Burial 793	Burial of left-crouched, east-southeast–west-northwest oriented 23–39-year-old male. It was probably cut into the uppermost part of a shallow feature that could not be identified in the northernmost part of the excavated area. No grave goods uncovered. [37a]	Human bone: metacarpal	−19.7 ± 0.3	9.7 ± 0.4	3.2	6330 ± 33	*5315*–5215 cal BC	Cramp (2004); Jakucs et al. (2016), Tables 5, 304
OxA-13652	Burial 796	Burial of left-crouched, south–north oriented 15–16-year-old female. It was cut into the central part of a pit complex that contains Pits 5340, 5411, 5412, 5467 and 5468 directly east of House 68. No grave goods uncovered. [38c]	Human bone: rib	−19.5 ± 0.3	9.5 ± 0.4	3.2	6242 ± 31	*5295*–5205 cal BC	Cramp (2004)
OxA-13640	Pit 4950	Westernmost pit of an extended pit complex in the northernmost part of the excavated area south-west of House 41, north of House 67. Further parts of the pit complex are Pits 4949, 5019, 5049, 5250, 5251, 5252, 5390, 5428, 5429, 5437, 5445 and 5446. Moderately diagnostic early LBK-style ceramic material with 41 sherds, diagnostic Style group 1 ceramic material with 229 sherds but without suitable samples from Pit 5019. [24a]	Animal bone: cattle; left femur; disarticulated	−19.45 ± 0.3	6.65 ± 0.4	3.3	6221 ± 32		Cramp (2004)
SUERC-78052	Pit 4953	Individual oval settlement pit west of House 41. Particularly diagnostic Style group 1 ceramic material with 480 sherds. [BSZ 801]	Animal bone: cattle; radius; articulating with humerus and ulna	−20.3 ± 0.2	6.4 ± 0.3	3.3	6240 ± 29		unpublished
OxA-36839	Pit 4960	Individual oval settlement pit directly east of Burial 793 in the northernmost part of the excavated area. Diagnostic Style group 1 ceramic material with 193 sherds. [BSZ 803]	Animal bone: cattle; lumbar vertebra; refitting unfused epiphysis	−21.4 ± 0.2	6.3 ± 0.3	3.2	6257 ± 34		unpublished
SUERC-78059	Pit 5356	Individual oval settlement pit south-west of House 68. Particularly diagnostic Style group 2 ceramic material with 547 sherds. [BSZ 807]	Animal bone: cattle; articulating carpal bones	−20.2 ± 0.2	7.6 ± 0.3	3.3	6157 ± 29		unpublished
OxA-13799	Pit 5411	Northwestern pit of a settlement pit complex. Further parts of the pit complex are Pits 5340, 5412, 5467, 5468. Burial 796 is cut into the central part of the pit complex. Moderately diagnostic early LBK-style ceramic material with 68 sherds. [147]	Animal bone: cattle; metapodium; disarticulated	−20.6 ± 0.3	7.75 ± 0.4	3.3	6161 ± 35		Cramp (2004)
OxA-13642	Pit 5435	Pit of a pit complex in the northernmost surface of the excavated area. Further parts of the pit complex are Pits 5287, 5439, 5441, 5442 and 5443. Particularly diagnostic Style group 1 ceramic material with 64 sherds. [26b]	Animal bone: sheep/goat; right humerus; disarticulated	−19.45 ± 0.3	6.45 ± 0.4	3.1	6229 ± 35		Cramp (2004)
OxA-13795	Pit 5443	Pit of a pit complex in the northernmost surface of the excavated area. Further parts of the pit complex are Pits 5287, 5435, 5439, 5441 and 5442. Particularly diagnostic Style group 1 ceramic material with 168 sherds. [27b]	Animal bone: cattle; right metatarsal; disarticulated	−21.6 ± 0.3	6.9 ± 0.4	3.2	6216 ± 36		Cramp (2004)
OxA-13653	Pit 5557	Individual oval settlement pit west of House 42 in the northernmost part of the excavated area. Particularly diagnostic Style group 1 ceramic material with 337 sherds. [39a]	Animal bone: sheep/goat; right radius; disarticulated	−19.65 ± 0.3	6.5 ± 0.4	3.2	6234 ± 33		Cramp (2004)
SUERC-78056	Pit 5557	Individual oval settlement pit west of House 42 in the northernmost part of the excavated area. Particularly diagnostic Style group 1 ceramic material with 337 sherds. [BSZ 802]	Animal bone: cattle; thoracic vertebra; refitting unfused epiphysis	−22.9 ± 0.2	9.4 ± 0.3	3.2	6221 ± 29		unpublished
Combine Pit 5557		Acomb = 119.3% (An = 50.0%); n = 2							
OxA-13654	Pit 5593	Individual oval settlement pit south-west of House 42. Moderately diagnostic Style group 1 ceramic material with 38 sherds. [40b]	Animal bone: cattle; right metatarsal; disarticulated	−20.25 ± 0.3	6.65 ± 0.4	3.2	6280 ± 32		Cramp (2004)

(*continued on next page*)

Table 1 (*continued*)

Lab ID	Context no.	Context description [Sample ID]	Material	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N$ (‰)	C:N	Radiocarbon age (BP)	Modelled date (95% probability)	References
OxA-13655	Pit 5686	Largest pit of the settlement pit complex that consists of Pits 5686, 5754, 5755 and 5833 at the northern limit of the excavated surface. Particularly diagnostic Style group 1 ceramic material with 195 sherds. [41a]	Animal bone: cattle; radius; disarticulated	−21.45 ± 0.3	7.1 ± 0.4	3.3	6339 ± 32		Cramp (2004); Jakucs et al., (2016), Tables 5, 304
SUERC-78057	Pit 5755	Northern pit of a settlement pit complex that consists of Pits 5686, 5754, 5755 and 5833 at the northern limit of the excavated surface. Moderately diagnostic early LBK ceramic material with 22 sherds but with articulated bone sample. [BSZ 804]	Animal bone: cattle; articulating carpal bones	−20.2 ± 0.2	8.1 ± 0.3	3.3	6143 ± 29		unpublished
OxA-13783	Pit 5856	Western long pit of House 45. Particularly diagnostic Style group 2 ceramic material with 547 sherds. [42a]	Animal bone: cattle; rib; disarticulated	−20.25 ± 0.3	7.35 ± 0.4	3.2	6227 ± 38		Cramp (2004)
SUERC-78058	Pit 5856	Western long pit of House 45. Particularly diagnostic Style group 2 ceramic material with 547 sherds. [BSZ 805]	Animal bone: cattle; proximal phalanx; articulating intermediate phalanx	−20.3 ± 0.2	8.1 ± 0.3	3.3	6261 ± 29		unpublished
Combine Pit 5856		Acomb = 113.4% (An = 50.0%); n = 2							
OxA-36840	Pit 6005	Individual oval pit, so called western pit of House 45, directly west of the western long pit (5856) of the house. Particularly diagnostic Style group 2 ceramic material with 652 sherds. [BSZ 806]	Animal bone: cattle; metacarpal; refitting unfused epiphysis	−19.6 ± 0.2	7.2 ± 0.3	3.2	6235 ± 34		unpublished

northernmost excavated surface and those with Style group 2 material forming a belt in the southern part of the north-east area between the former and the late LBK settlement part reveal a clear spatial pattern. That makes the calculation of the first and last dated events for both surfaces possible. The same ten results were included in the second model as well, and SUERC-78057 from Pit 5755 was programmed as an outlier again.

Model 2 (Fig. 17) has a good overall agreement as well (Amodel = 110). The early LBK activity started in *5355*–5220 cal BC (*95% probability*; *Start Balatonszárszó early LBK*), probably in *5320*–5245 cal BC (*68% probability*). The early LBK activity ended in *5285*–5095 cal BC (*95% probability*; *End Balatonszárszó early LBK*), probably in *5220*–5165 cal BC (*68% probability*). The Highest Posterior Density interval (Fig. 18) for the first dated event on the northernmost surface (associated with Style group 1/Bíňa-Bicske-style material) is *5320*–5220 cal BC (*95% probability*; *First BSZ northernmost surface*), probably *5305*–5240 cal BC (*68% probability*), and that for the last one is *5285*–5190 cal BC (*90% probability*; *Last BSZ northernmost surface*) or *5180*–5135 cal BC (*5% probability*), probably *5235*–5200 cal BC (*68% probability*). The Highest Posterior Density interval for the first dated event in the southern part of the north-east surface (associated with Style group 2/Milanovce style material) is *5305*–5215 cal BC (*95% probability*; *First BSZ S part of NE surface*), probably *5295*–5245 cal BC (*62% probability*) or *5230*–5220 cal BC (*6% probability*), and that for the last one is *5285*–5135 cal BC (*95% probability*; *Last BSZ S part of NE surface*), probably *5225*–5185 cal BC (*68% probability*).

The third model presents Style group 1 (Bíňa-Bicske) and Style group 2 (Milanovce) as two successive typo-chronological phases similarly to Model 1, but all disarticulated faunal samples were also included in the model that comprises 18 radiocarbon results. SUERC-78057 from Pit 5755 was programmed as an outlier.

Model 3 (Fig. 19) has good overall agreement (Amodel = 89). The early LBK activity started in *5325*–5220 cal BC (*95% probability*; *Start Balatonszárszó early LBK*), probably in *5305*–5250 cal BC (*51% probability*) or in *5240*–5220 cal BC *(17% probability)*. The early LBK activity ended in *5220*–5045 cal BC (*95% probability*; *End Balatonszárszó early LBK*), probably in *5220*–5155 cal BC (*68% probability*). The transition from Style group 1 to Style group 2 occurred in *5285*–5210 cal BC (*95% probability*; *Balatonszárszó Style group 1/Style group 2*), probably in *5250*–5210 cal BC (*68% probability*) (Fig. 20).

The fourth model was developed from Model 2, and presents the early LBK occupation of Balatonszárszó as one single phase of activity. Disarticulated faunal samples were included in the model that comprises 18 radiocarbon results. SUERC-78057 from Pit 5755 was programmed as an outlier.

Model 4 (Fig. 21) has good overall agreement (Amodel = 119). The early LBK activity started in *5335*–5220 cal BC (*95% probability*; *Start Balatonszárszó early LBK*), probably in *5310*–5270 cal BC (*35% probability*) or in *5265*–5225 cal BC (*33% probability*). The early LBK activity ended in *5225*–5105 cal BC (*95% probability*; *End Balatonszárszó early LBK*), probably in *5215*–5180 cal BC (*68% probability*). The Highest Posterior Density interval (Fig. 22) for the first dated event on the northernmost surface (associated with Style group 1/Bíňa-Bicske-style material) is *5320*–5220 cal BC (*95% probability*; *First BSZ northernmost surface*), probably *5295*–5225 cal BC (*68% probability*), and that for the last one is *5240*–5130 cal BC (*95% probability*; *Last BSZ northernmost surface*), probably *5220*–5200 cal BC (*68% probability*). The Highest Posterior Density interval for the first dated event on the southern part of the north-east surface (associated with Style group 2/Milanovce style material) is *5300*–5215 cal BC (*95% probability*; *First BSZ S part of NE surface*), probably *5290*–5265 cal BC (*24% probability*) or *5260*–5215 cal BC (*44% probability*), while that for the last one is *5225*–5130 cal BC (*95% probability*; *Last BSZ S part of NE surface*), probably *5220*–5190 cal BC (*68% probability*).

All four models estimate the beginning of the early LBK occupation of Balatonszárszó not earlier than the mid-54th century cal BC,

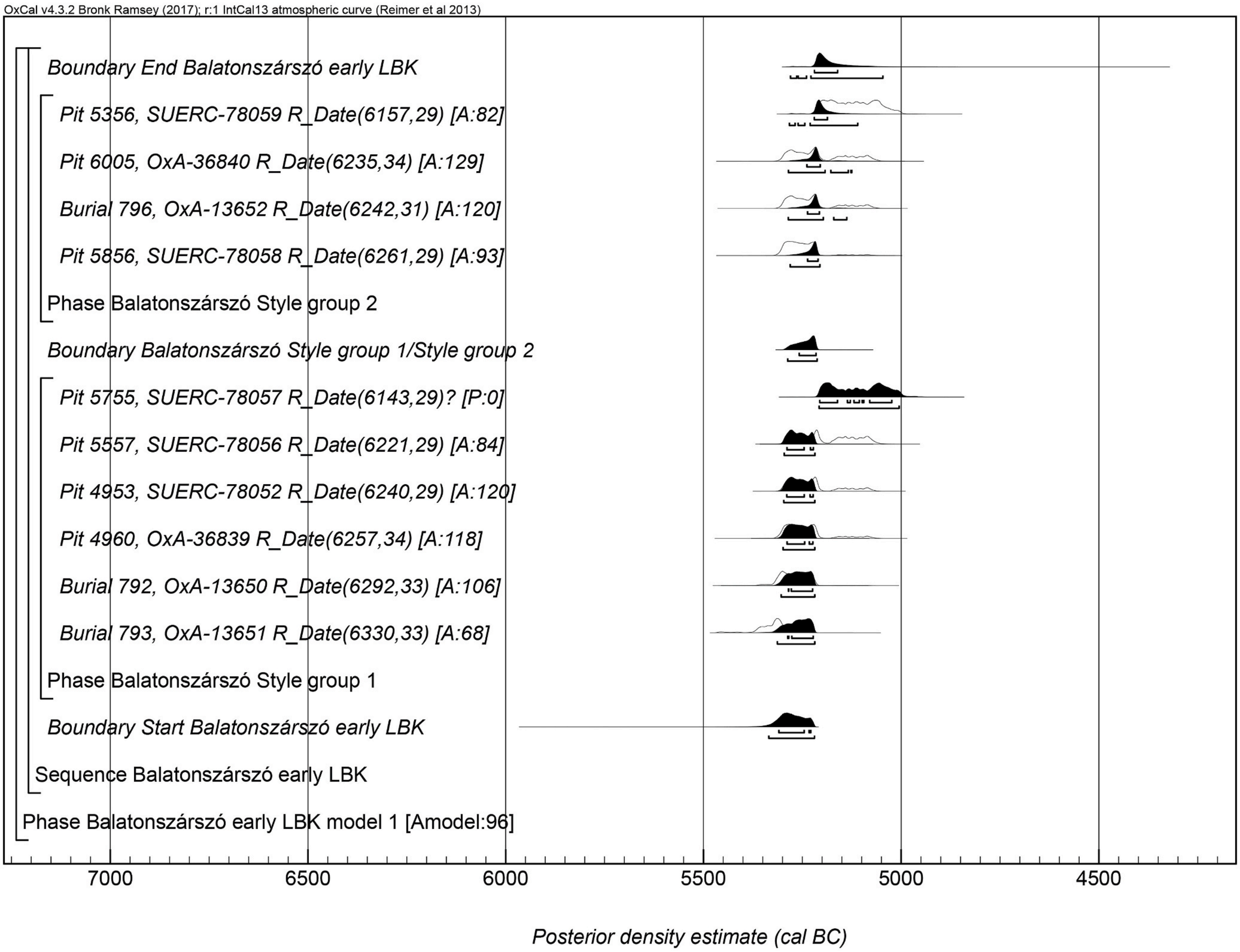

Fig. 15. Probability distributions of radiocarbon dates from the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő (Model 1). Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the result of simple radiocarbon calibration, and a solid one, based on the chronological model used. Distributions other than those relating to particular samples correspond to aspects of the model. For example, the distribution 'Start Balatonszárszó early LBK' is the estimated date of the establishment of the early LBK occupation. The large square brackets down the left-hand side, along with the OxCal keywords, define the overall model exactly.

probably not earlier than its last two decades with only 5–30 years difference in the start of the intervals in the different models. The results are all the more plausible, as an individual calibration of the earliest result from Pit 5686 (OxA-13655) shows the beginning not earlier than the middle third of the 54th century cal BC, even with a 95% probability. Generally, models suggesting a more flexible occupation of the northernmost surface and that of the south part of the north-east surface (Models 2 and 4) estimate a slightly earlier start than those ones (Models 1 and 3) that support a rigid sequence of Style group 1 (Bíňa-Bicske) and Style group 2 (Milanovce) assemblages. The latter ones estimate broader intervals for the end of the early LBK occupation in the 51st century cal BC, or possibly in the 52nd century cal BC. The accuracy of these estimations is limited by the effect of the nature of the calibration curve for the last three centuries of the 6th millennium cal BC and by the limited number of samples.

As the inclusion of disarticulated faunal samples (Models 3 and 4) did not cause significant changes in the posterior density estimates for the start of the early LBK occupation and resulted even in more precise estimations for its end, we can assume that there was no earlier occupation on the site that could have provided residual samples substantially predating the excavated early LBK units.

If house units associated with Style group 1 (Bíňa-Bicske-style) material are at least partially earlier than those with Style group 2 (Milanovce-style) assemblages, the occurrence of residual samples in pits of the latter from the northernmost surface cannot be excluded. The transition between Style group 1 and Style group 2 is estimated in the

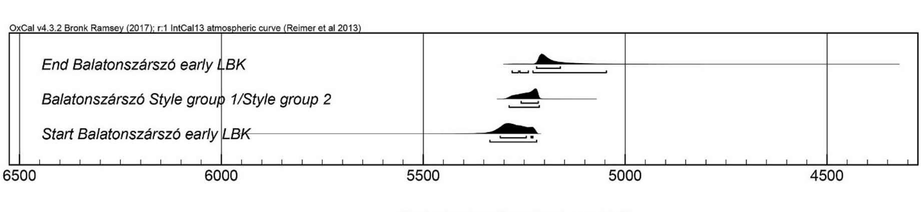

Fig. 16. Probability distributions of key parameters for the start and the end of the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő and for the transition between Style group 1/Style group 2 (Model 1), derived from the model shown in Fig. 15.

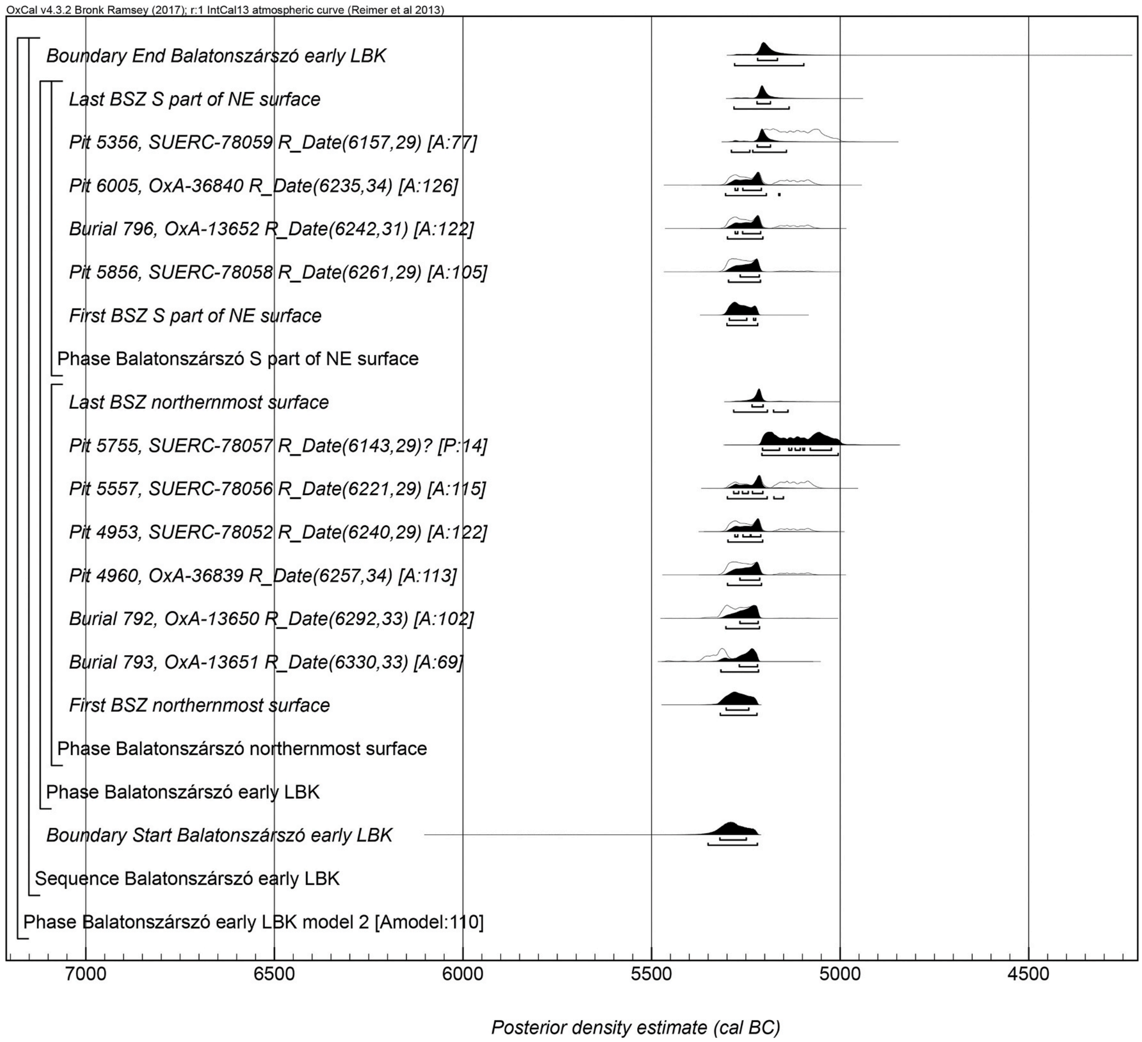

Fig. 17. Probability distributions of radiocarbon dates from the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő (Model 2). The format is as Fig. 15. The large square brackets down the left-hand side, along with the OxCal keywords, define the overall model exactly.

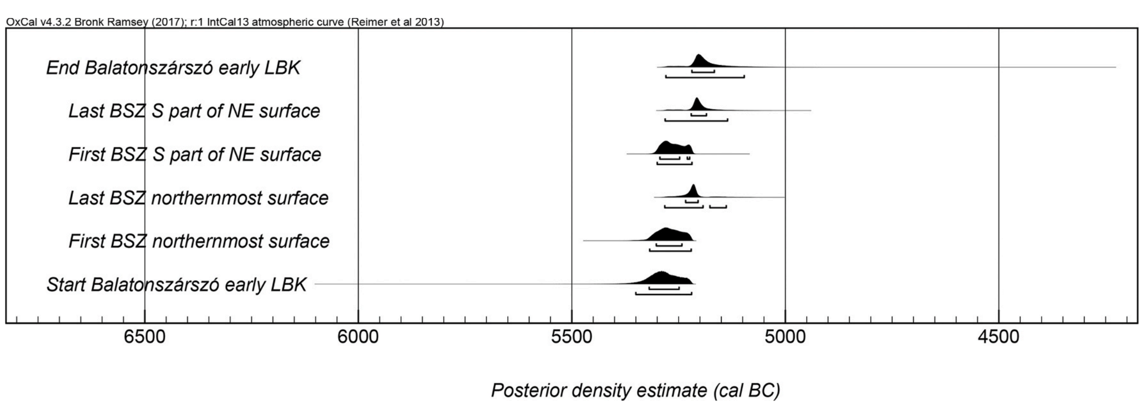

Fig. 18. Probability distributions of key parameters for the early LBK occupation from Balatonszárszó-Kis-erdei-dűlő (Model 2), derived from the model shown in Fig. 17.

53rd century cal BC, probably between 5260 cal BC and the last two decades of the century according to Models 1 and 3.

Generally, Model 2 and Model 4 provide the most plausible chronology for the early LBK occupation of Balatonszárszó, but the estimates for the start of the occupation and some parameters are slightly more constrained in Model 4 because of the larger number of results dating early LBK contexts.

8. 'Play it again': people, sites and time between the Balkans and central Europe

The aDNA and the genomic revolutions of the past two decades have enriched discussions of the Neolithisation process of central Europe with substantial arguments. Even on the level of mtDNA, obvious affinity was revealed concerning the first farmers of central Europe with

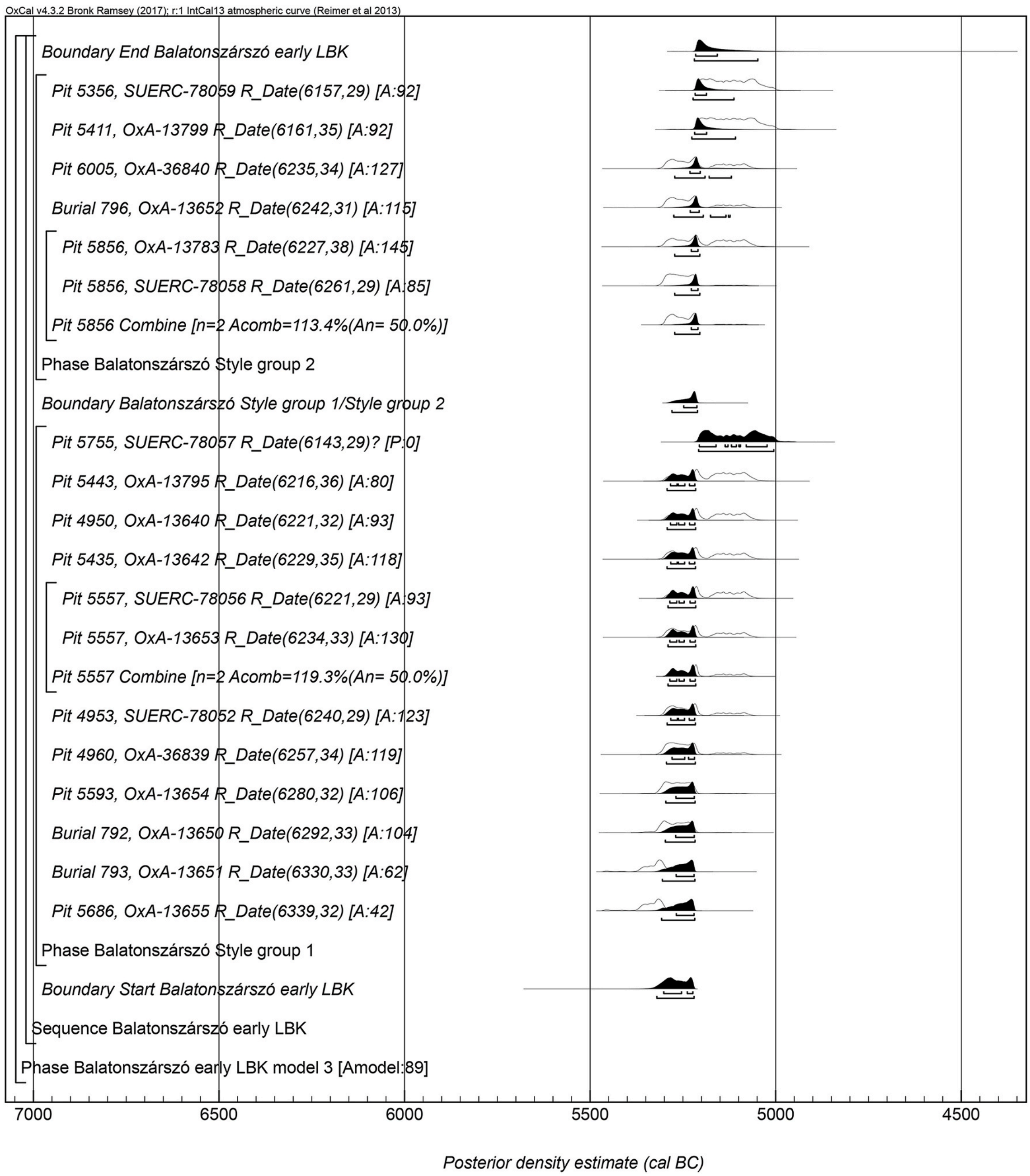

Fig. 19. Probability distributions of radiocarbon dates from the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő (Model 3). The format is as Fig. 15. The large square brackets down the left-hand side, along with the OxCal keywords, define the overall model exactly.

Near Eastern populations (Haak et al., 2005). At the same time, mtDNA level studies also suggested discontinuity between hunter-gatherers and the early farmers of central Europe (Bramanti et al., 2009). Further investigations could firmly reinforce both conclusions (Haak et al., 2010; Brandt et al., 2013). The first extended genetic research targeting 6th millennium cal BC western Carpathian basin populations directly published mtDNA and Y chromosomal data from Mesolithic, Starčevo and LBK contexts. High variability was identified among the 6th millennium cal BC farmers of the area including mtDNA haplogroups (Szécsényi-Nagy et al., 2015); some of the detected mtDNA haplogroups form the so-called mitochondrial 'Neolithic package' (Szécsényi-Nagy et al., 2015). Concerning ancestral hunter-gatherer lineages, they proved to be exceedingly rare in the Starčevo (2.27%) and totally absent in the LBK (0%) mtDNA datasets from Transdanubia, as well as in the LBK (1.85%) west of the Carpathian basin (Szécsényi-Nagy et al., 2015).

Later investigations applying genome-wide sequencing obtained further information on the admixture of early farming populations with hunter-gatherers: 2.3 ± 1.0% in case of the Starčevo, the astonishingly low value of 0.8 ± 0.9% among individuals associated with the Transdanubian LBK entity, and 4.2 ± 0.6% in LBK datasets from Germany (Lipson et al., 2017, Extended Data, Table 3). More substantial hunter-gatherer admixture, which means over 10 per cent, was recorded first in late 5th millennium and 4th millennium cal BC cultural entities of the Carpathian basin and in central Europe (Lipson et al., 2017, Extended Data, Table 3). The latter presumably does not represent the signal of a hunter-gatherer population that survived over a millennium after the initial Neolithisation of the region. The phenomenon probably refers rather to the absorption of groups at least partially with acculturated ancestors. Even though genomic evidence from

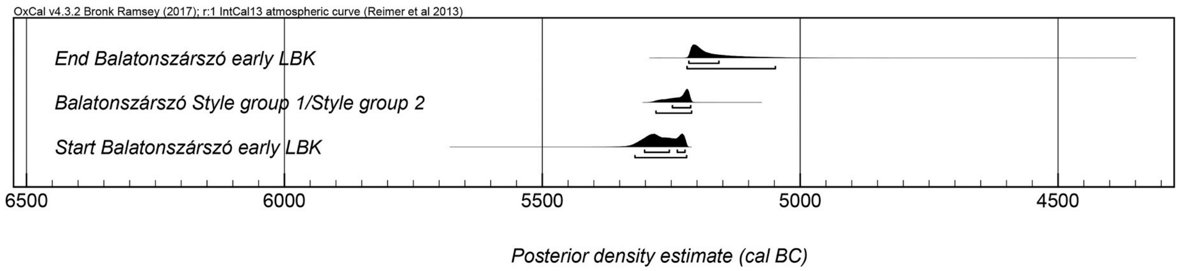

Fig. 20. Probability distributions of key parameters for the start and the end of the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő and for the transition between Style group 1/Style group 2 (Model 3), derived from the model shown in Fig. 19.

Brunn am Gebirge/Wolfholz reveals that further research can provide additional information on interactions between the earliest farmers and hunter-gatherers (Nikitin et al., 2019), it is hard in the light of current bioarchaeological discoveries to give any explanation for the process of initial Neolithisation other than a massive population movement.

The earliest Neolithic occupation of southern Transdanubia is proved between 5800 and 5500 cal BC (Fig. 23), although only the Starčevo site of Alsónyék-Bátaszék has been formally modelled. Alsónyék-Bátaszék is located north of the Mecsek Mountains and an earlier appearance of early Neolithic sites cannot be excluded in the southernmost part of Transdanubia, close to the Danube-Dráva confluence. The establishment of the earliest Neolithic sites in the latter area around 6000 cal BC would correspond with the results from the Tisza-Maros confluence in eastern Hungary (Whittle et al., 2002; Oross and Siklósi, 2012). After the rapid expansion across the Balkans (Shennan, 2018, 71–76), the frontier line was probably not completely frozen but advanced slowly towards the Balaton area during the early 6th millennium cal BC, similarly to that demonstrated previously on the Great Hungarian Plain (Whittle et al., 2002; Domboróczki, 2010, Fig. 11). In contrast to earlier visualisations of the Starčevo distribution in southern Transdanubia as a coherent cultural province (Kalicz, 1990, Taf. 1–3, 1993; Oross and Bánffy, 2009, Fig. 1), the depiction of the actual sites shows smaller preferred regions across the area and territories avoided by the earliest farmers.

Formative LBK sites are broadly dated to the interval between the 56th and mid-54th centuries cal BC (Jakucs et al., 2016; Bánffy et al., 2018). Excavated evidence for the period is available from a narrow pre-Alpine zone of the westernmost Carpathian basin and from the Vienna basin. Surprisingly, contemporaneous material culture could not be discovered from other regions of Transdanubia resulting in a gap lasting for one and a half centuries. The single gap in the more than one millennium-long site biography of Alsónyék was proved between the Starčevo and the LBK occupations, actually between 5500 cal BC and about 5350 cal BC (Bánffy et al., 2016, 288, Figs. 1 and 3). Similar conclusions could be drawn in the course of the radiocarbon dating programme for Vinča-Belo Brdo and for the Vinča culture in general as part of the *Times of Their Lives* project (Tasić et al., 2015; Whittle et al., 2016).

These results coincide with the demographic estimations based on the somewhat controversial method (because of worries that it reflects research activity rather than past activity patterns and that it may simply reproduce the patterns of the calibration curve: Contreras and Meadows, 2014; Whittle, 2018) that uses summed calibrated radiocarbon probability distributions as a population proxy for the central Balkans, according to which a considerable population decrease is projected shortly after 5500 cal BC followed by a wave of population increase around 5300 cal BC (Porčić et al., 2016; Shennan, 2018). It is impossible to explain the historical processes of those one and a half centuries in detail yet, as well as to estimate the scale of a possible depopulation and the nature of a potential bottleneck in the demographic development of the communities concerning southern Transdanubia. Despite the absence of sites from the 55th and early 54th centuries cal BC, some preferred niches of the Starčevo population were reoccupied by the late 54th century settlers such as on the southern edge of the Southern Baranya Hills, at Alsónyék-Bátaszék, in the Little Balaton basin and around Becsehely in south-west Hungary. These observations provide a strong argument against a sharp discontinuity even beyond aDNA results.

Extended late 6th millennium cal BC sites investigated by large-scale excavations such as Szederkény-Kukorica-dűlő, Alsónyék-Bátaszék and Balatonszárszó-Kis-erdei-dűlő all started around 5350 cal BC or some decades later during the 54th century cal BC, but obviously not earlier, independently from the associated material culture. Even the formal modelling of very heterogeneous sets of radiocarbon results assigns the Neolithisation of central Europe to this period (Jakucs et al., 2016, 315–324, Figs. 18–24, Table 5). It is also worth noting that the significance of the early LBK horizon was underestimated in earlier studies, both in the formation of the regional settlement system and in the Neolithisation process, due to the lack of information (Oross and Bánffy, 2009, 179–182, Figs. 4–6). Current evidence suggests that late 54th century cal BC settlements already represent at least an early stage of an infilling phase in the most favourable areas already occupied by early 6th millennium cal BC farmers and even beyond. One of the best examples for the latter are the sites of Balatonszárszó-Kis-erdei-dűlő and Balatonszemes-Bagódomb close to one another in two adjacent settlement clusters on the southern shore of Lake Balaton, both characterised by early LBK-style pottery in their early horizon.

The presented model has received some severe critiques, one point being not only chronology, but even more so the lack of critical mass for a demic diffusion towards western central Europe (Strien, 2017). The more canonised approach supports a start date for the LBK expansion around 5500 cal BC. Based on correspondence analysis of pottery assemblages, formative LBK and Bíňa-Bicske as typo-chronological phases are regarded as contemporaneous and as regional variants both predating the central European Neolithisation process that is assumed to start along with the appearance of Milanovce-style ceramic assemblages (Strien, 2018, 2019). However, the idea of connecting Milanovce-style pottery with the LBK dispersal has a longer tradition in central European Neolithic archaeology (Gronenborn, 1999, 182–183, Fig. 7c and d). It is also suggested that results from bone collagen samples are generally younger than botanical samples, and that bone samples should thus be largely omitted (Strien, 2018, 2019).

As demonstrated above, the period specifically between 5500 and 5350 cal BC is particularly problematic because of the lack of sites for providing a proper demographic basis for the process (see also Bánffy et al., 2018, 129). In contrast, extensive sites in all three investigated micro-regions of southern Transdanubia started around 5350 cal BC. Their territory is 109.93 km^2 altogether, which slightly exceeds one per cent of the entire core research area between the Dráva river and Lake Balaton excluding mountainous areas. In other words, it would be possible to form 285 micro-regions of the average size of the investigated ones within this area. At least one site per micro-region was established during the late 54th century cal BC. Extrapolating the evidence of our current survey to the core research area in southern

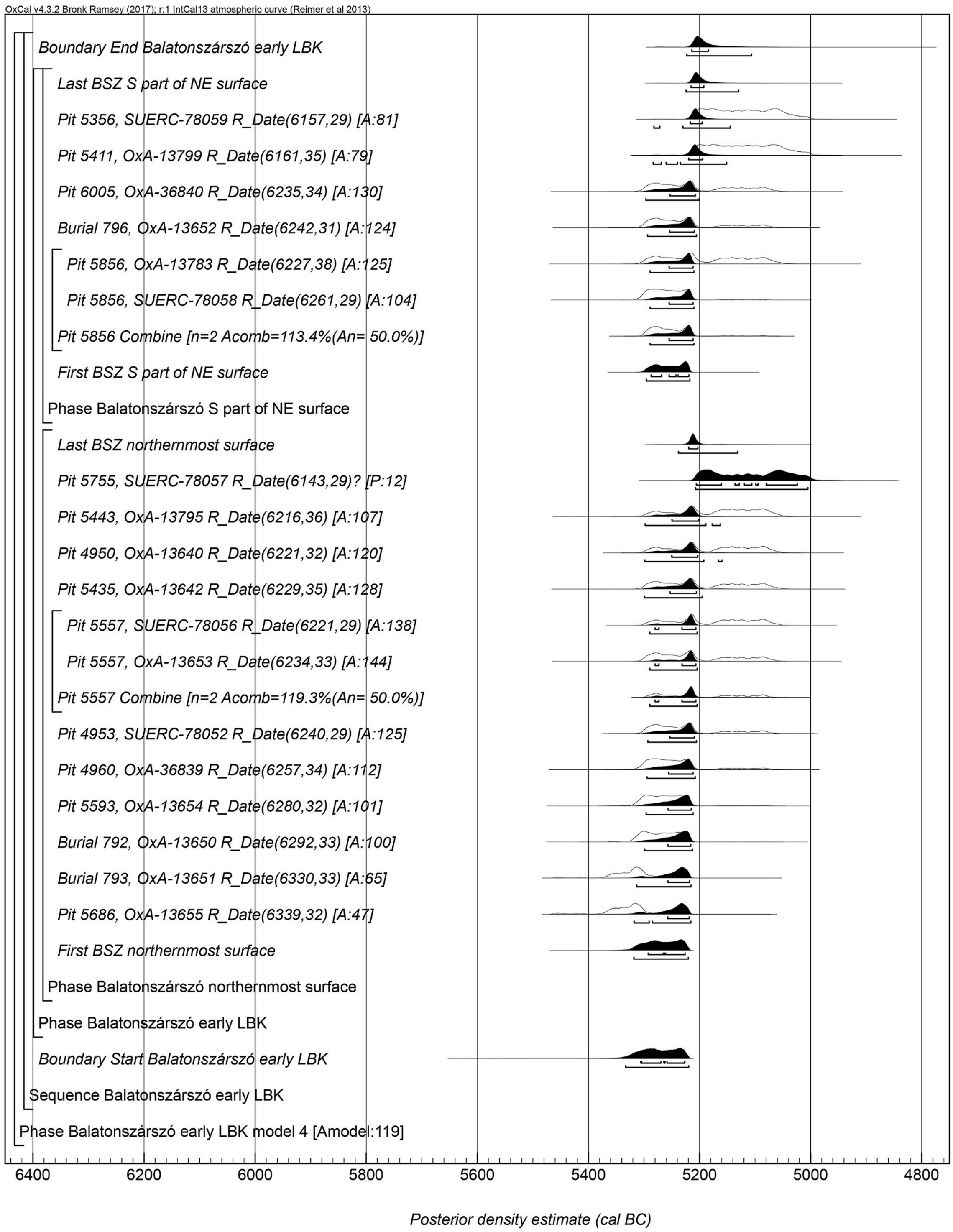

Fig. 21. Probability distributions of radiocarbon dates from the early LBK occupation of Balatonszárszó-Kis-erdei-dűlő (Model 4). The format is as Fig. 15. The large square brackets down the left-hand side, along with the OxCal keywords, define the overall model exactly.

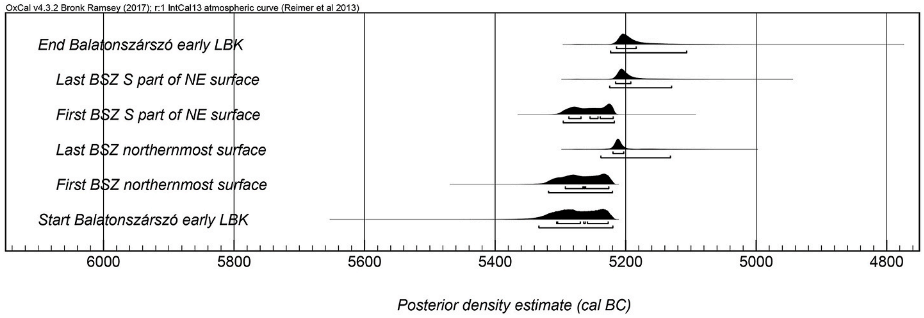

Fig. 22. Probability distributions of key parameters for the early LBK occupation from Balatonszárszó-Kis-erdei-dűlő (Model 4), derived from the model shown in Fig. 21.

Transdanubia results in 285 sites as a minimum from the 54th century cal BC and 2373 late 6th millennium BC sites altogether (excluding Sopot ones). Settlement density can be considerably above average in a favourable environment as demonstrated by the Tolna Sárköz/Sárvíz Valley micro-region, but the investigated micro-regions can also represent distinctive, above-averagely populated areas in general. Taking into account the hilly environment of the extended parts of Transdaubia, the actual number of sites can be more moderate. Nevertheless, sites such as Versend-Mekota reveal the adaptive power of late 6th millennium cal BC farmers in the geographic and climatic circumstances of southern Transdanubia.

Despite all the uncertainties, the two to four human generations-long period from about 5350 cal BC can provide a dense and appropriate settlement system with a range of sites to have served as parent communities for the first Neolithic groups of central Europe west of the Carpathian basin and the Vienna basin. Current research has paved the way for a more detailed reconstruction of the settlement network on a regional scale, comparable to other regions of early Neolithic central and western Europe such as the Rhineland (Zimmermann, 2002) and southern Bavaria (Pechtl, 2012), as well as for plausible demographic estimates (Zimmermann et al., 2009; Shennan, 2018).

9. Concluding remarks

Southern Transdanubia is a particular, south-eastern corner of Neolithic central Europe both in terms of geography and cultural phenomena. Some canonised central European characteristics are identical, while other elements show strong south-east European affinities. Moreover, the area is a cradle of a range of transformations with substantial implications far beyond the region. To get a comprehensive, supra-regional overview on processes, combining different approaches and fixing temporal relations are inevitable steps.

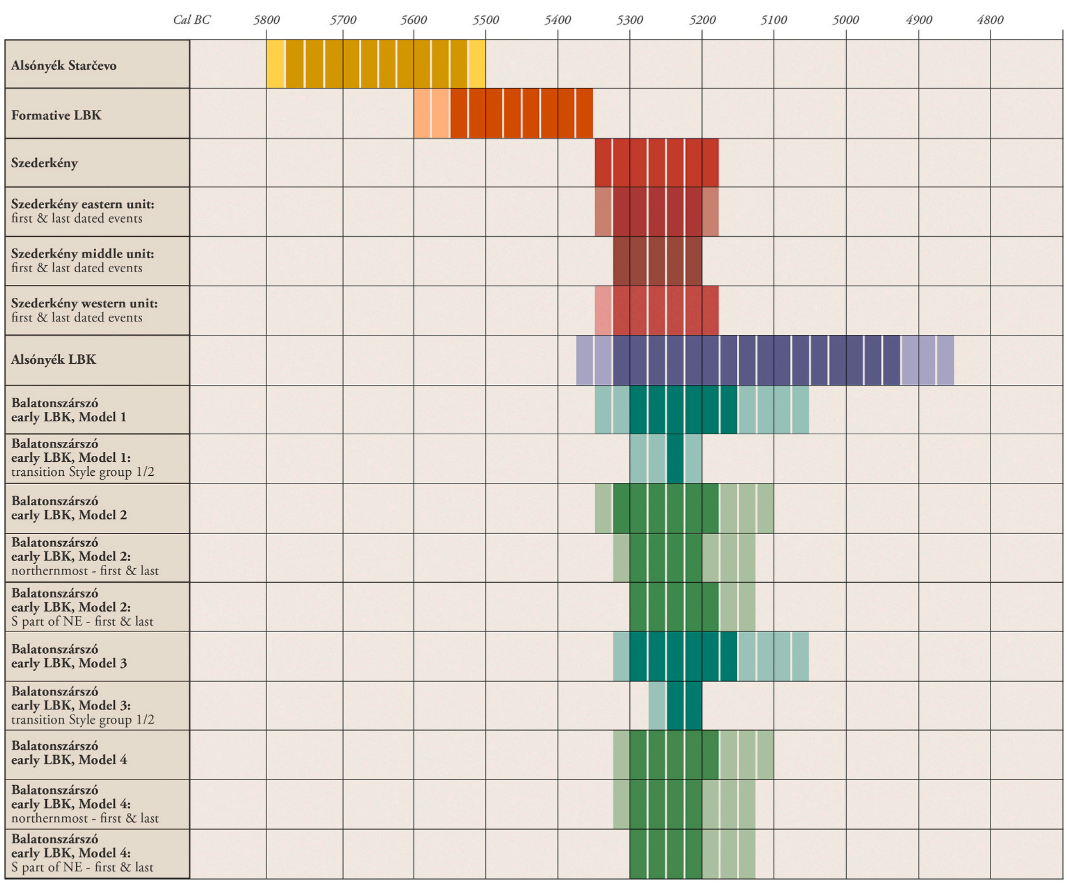

Fig. 23. Overview of 6th millennium cal BC absolute chronology of western Hungary. Intervals are rounded by 25 years, and dark and light colours together represent the 95% probability intervals, while 68% probability intervals are represented by dark colours exclusively.

Based on all available evidence, a rapid central European Neolithisation scenario can be suggested which relies on demic diffusion to a substantial extent within two–four human generations from about 5350 cal BC. Although the fact of population movement cannot be questioned any more, our site- and regional-scale knowledge of the social aspects and drivers of the process (Hofmann, 2016) is still decidedly modest. Intensive recent research activity, however, comprising site-based studies, micro-regional research including non-invasive surveys, achievements in the absolute chronology of the region and the results of bioarchaeological investigations, has detected the principal elements of a settlement network, the biological background and the timeframe for such a kind of movement.

Acknowledgements

Grateful thanks are due to NKFIH/NRDIO (formerly OTKA) for funding our project, *Neolithic communities in the contact zone between the Balkans and Central Europe in the second half of the sixth millennium BC* (*Újkőkori közösségek a Balkán és Közép-Európa érintkezési övezetében a Kr. e. 6. évezred második felében*, grant code: K 112366, led by Krisztián Oross); and the National Cultural Fund of Hungary (NKA), for funding the project, *Non-destructive survey of Neolithic settlements in southern Transdanubia and in the Balaton area* (*Újkőkori települések roncsolásmentes műszeres felmérése a Dél-Dunántúlon és a Balaton vidékén*, grant code: 207134/349, led by Gábor Serlegi). Thanks are also due to the Natural Environment Research Council, UK, for supporting the first round of dating of Balatonszárszó-Kis-erdei-dűlő; Professor Robert Hedges for his role in that first round; István Vörös in the Hungarian National Museum; and the European Research Council for funding the *Times of Their Lives* project (Advanced Investigator Grant 295412, 2012–2017, led by Alasdair Whittle and Alex Bayliss). Local museums, the Janus Pannonius Museum in Pécs (Csilla Gáti and Gergely Kovaliczky), the Wosinsky Mór Museum in Szekszárd (Attila Czövek and János Gábor Ódor) and the Rippl-Rónai Museum in Kaposvár, provided invaluable help during the project. Our research gained local support from Irén and József Rikker in Tolna-Mözs, as well as from Antal Márton and János Scheidler Jr., representing the Mözs Agricultural Ltd. We could constantly rely on the help of Renáta Ulbert and Zoltán Hendinger in Baranya. We are indebted to Zsolt Réti and Viktor Szinyei for managing the figures of the contribution; and Magda Éber and Zsuzsanna Ba for drawing the pottery.

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