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By Alex Bayliss, Nancy Beavan, Derek Hamilton, Kitti Köhler, Éva Ágnes Nyerges, Christopher Bronk Ramsey, Elaine Dunbar, Marc Fecher, Tomasz Goslar, Bernd Kromer, Paula Reimer, Eszter Bánffy, Tibor Marton, Krisztián Oross, Anett Osztás, István Zalai-Gaál, and Alasdair Whittle

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Fuzzy prehistory

For most regions and for most sequences around the world, prehistorians until now have only been able to assign the past people whom they study to rather imprecise times. Such imperfect chronology is the result of our reliance on radiocarbon dating and a conventional approach to the interpretation of radiocarbon results which relies, basically, on the visual

inspection of calibrated dates. Thus, typically, a radiocarbon sample from a few thousand years ago will calibrate to a date spanning 100–200 years (at 2σ). A group of such samples will not produce identical calibrated dates, even when they derive from the same event, and archaeologists visually inspecting a graph of such dates tend to include the extremes of the timespan indicated, and thus considerably exaggerate the duration of a given phenomenon as well as accepting the relative imprecision of its dating (Bayliss et al. 2007). In the European Neolithic there has been a long-standing tradition of inferring chronology by summing, first uncalibrated (Ottaway 1973; Geyh / Maret 1982; Breunig 1987), and then calibrated (Aitchison et al. 1991) radiocarbon dates. This method similarly tends to produce inaccurate chronologies of exaggerated duration (Bayliss et al. 2007, 9–11). For the fortunate few, in regions with favourable conditions in which timbers are preserved, dendrochronology can provide dates precise to a calendar year and even to a season within a given year, for example among the Pueblo settlements of the American Southwest or the Neolithic and Bronze Age settlements on the fringes of the Alps in west and central Europe (e. g. Herr 2001; Menotti 2004). In most regions, however, such preservation and such chronologies are exceptional.

Relative chronological schemes, which have been a particular strength of archaeology in continental Europe, exploit the entanglement of people and things (Hodder 2012). The rich materiality of past lives provides the basis for its chronological analysis by typology and seriation, both exploiting principles of similarity and difference. Chrono-typology identifies stylistic similarities across a background of difference, using also association, context and stratigraphy (Adams / Adams 1991). Seriation formally orders a matrix of types and units (such as artefact-types in graves or decorative motifs on pottery vessels). Such orderings may or may not be chronologically successive, although in practice they can be shown often to be so (Greenacre 2007). The resolution of relative dating provided by material culture depends on the pace of change within the artefacts selected for study. Where this is swift, typological phases may cover just a few decades (e. g. Stehli 1989a), although where change in the studied material is very slow, phases may cover several centuries (e. g. Kalicz 1991). Normally, however, prehistorians seem content with radiocarbon-backed culture history chronologies which employ successive units of 200 years or more in duration; the familiar chronological tables chart these units *(fig. 1)*.

It is no surprise that slow change over the long term has been the dominant, if not the unthinking default, chronological perspective. A further, perhaps unavoidable, consequence of the dating methods which are usually available, and the imprecise chronologies which result, has been that many prehistorians have been content to write accounts of the past which have been very generalised. On the one hand, they normally lump together in broadly defined phases, often of several centuries or more, events, constructions and other phenomena, which might well not be coeval, and on the other, they tend to emphasise the long-term development of change, in a search for long-running or underlying processes, at the expense of shorter-term events and successions. Recently, much more theoretical attention has been directed to individuals, personhood and agency – the latter the nexus of action, practice, choice, memory, values and emotion which constitutes human subjects, and is often combined with structure, the web of rules, tradition, habits, taken-for-granteds and unconscious knowledge of how to go on (Barrett 2001). This has been an attempt to get closer to people in the past, rather than just notions of the structures within which they operated or the processes to which they were subject (Dobres / Robb 2000; Fowler 2004). Even this approach, however, has not come to terms with the limitations of current dating, and agents and individuals tend to float timelessly in a kind of pseudo-ethnographic present. Imprecise chronology has entailed a fuzzy kind of prehistory.

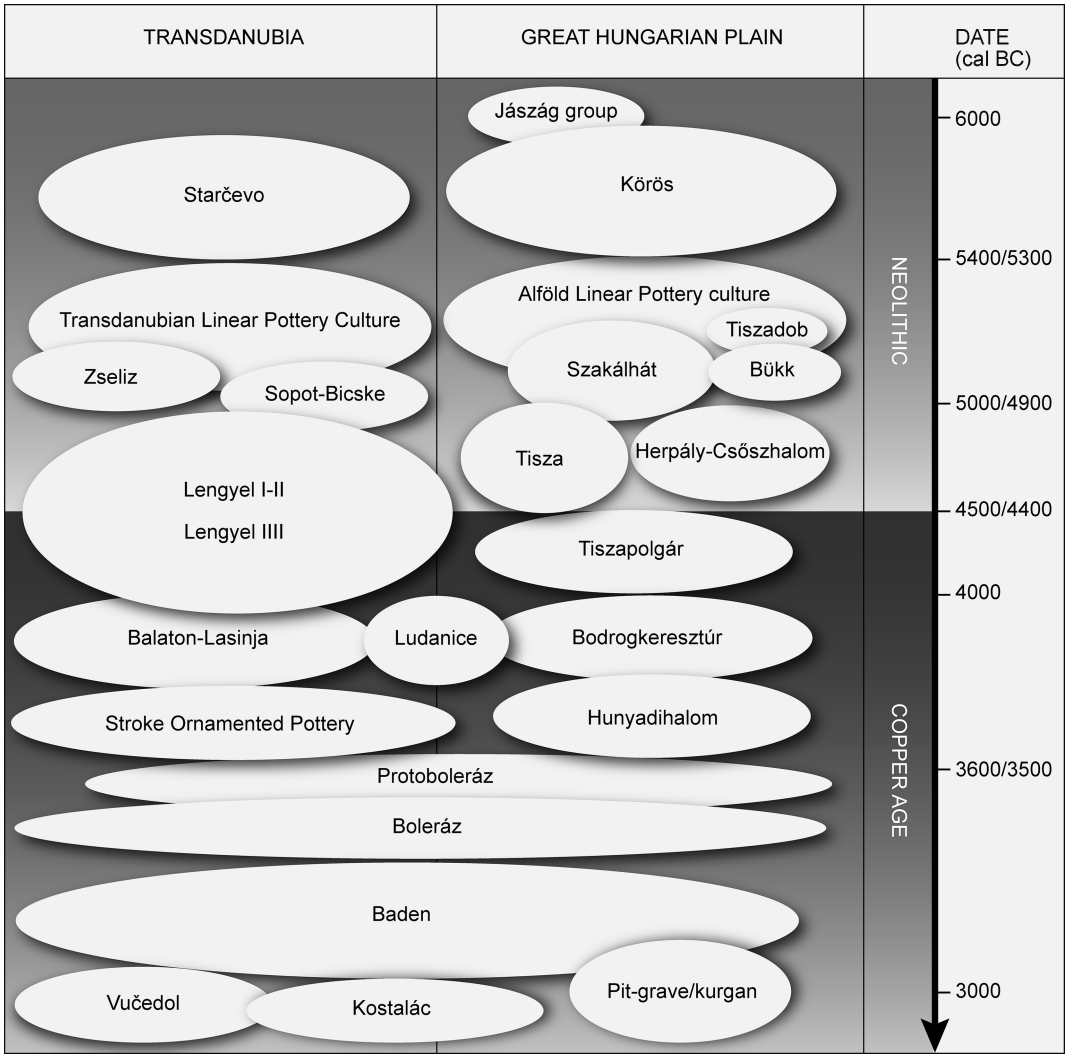

Fig. 1. A culture-historically based regional chronology for the Hungarian Neolithic (after Visy 2003, 485).

Bayesian chronological modelling

The application of Bayesian statistics for the interpretation of radiocarbon dates allows chronologies that are precise within a scale of human lifetimes and generations to be constructed routinely (Bayliss 2009). This makes fuzzy prehistory a choice rather than a necessity and opens up new avenues of interpretation for archaeologists (Bayliss / Whittle 2007; Whittle et al. 2011, Chapter 14).

The basic idea behind the Bayesian approach to the interpretation of data is encapsulated by Bayes' theorem (Bayes 1763) *(fig. 2)*. This simply means that we analyse the new data we have collected about a problem ('the standardised likelihoods') in the context of our existing experience and knowledge about that problem (our 'prior beliefs'). This enables us to arrive at a new understanding of the problem which incorporates both our previously existing knowledge and our new data (our 'posterior belief'). We do this by the use of formal probability theory, where all three elements of our model (that is, existing

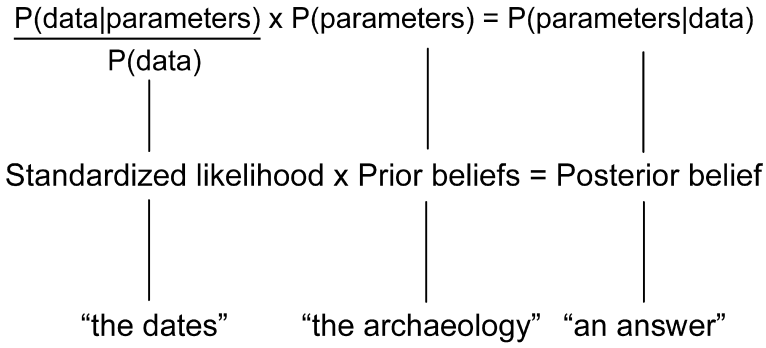

Fig. 2. Bayes' theorem applied to archaeological chronologies.

beliefs, new information, and revised interpretations) are expressed as probability density functions. These give us a quantitative measure of our state of knowledge of each component of the model. Bayesian models are thus interpretative constructions which rely on multiple lines of evidence (Buck et al. 1996). An accessible general introduction to the principles of Bayesian statistics is provided by Lindley (1985), and to its history by Bertsch McGrayne (2011).

Alison Wylie (2002, 162–163) has suggested that 'scientific arguments are more like cables than chains'. In this view, individual lines of argument that are insufficient on their own can make a cumulatively persuasive case when woven together, although the strands that make up a cable of comparative, evaluative argument may conflict with one another and thus may require dynamic judgements and revisions. In the construction of archaeological chronologies, Bayesian statistics provide a formal and explicit methodology for weaving together different strands of evidence to form the cable. The approach combines calibrated radiocarbon dates with knowledge of the archaeological contexts from which they are derived to produce a series of formal, probabilistic date estimates. Stringent demands are made of both the radiocarbon dates and our archaeological understanding of stratigraphy, associations, sample taphonomy and context in general, but the combined chronology should be more reliable than its individual components, since it is reliant on multiple strands of reinforcing evidence. To return to Wylie's metaphor, the resultant cable should be both stronger (more robust) and tighter (more precise).

Our models incorporate archaeological prior beliefs of various kinds. We need to be clear about the basis of these beliefs. Some may be comparatively unequivocal – the stratigraphic succession of a sequence of articulated animal bone samples, for example. In other cases the stratigraphic sequence may be open to alternative interpretations, or there may be doubt about the taphonomy of the dated material. In other situations, our prior beliefs may themselves derive from other methods which bring with them their own set of presuppositions and structure. For example, correspondence analysis will place a closed context according to the average position of each of the artefact types it contains, and so in a chronological sequence it will be located at the average time when all the artefacts in the assemblage were manufactured, not at the point of burial. The fundamental point is that Bayesian statistics, being a formal methodology, force archaeologists to be explicit about their strands of reasoning.

Once the elements of a model have been defined, millions of calculations are undertaken in order to reconcile the probability distributions of the individual calibrated radiocarbon dates with the other available information, using Markov Chain Monte Carlo methods.

Each distribution is repeatedly sampled to build up a set of solutions consistent with the model structure. Statistical checks are available to check the stability of a solution (its convergence) and the compatibility of the radiocarbon dates and the archaeological information included in the model (its agreement; Bronk Ramsey 1995, 429; 2009a, 356–357). These diagnostic statistical tools aid us in ensuring internal consistency within our cable (see also Wylie 2002, 176–177).

The chronological models presented in all the papers in this volume have been constructed using the program OxCal v4.2 (Bronk Ramsey 2009a; 2009b; Bronk Ramsey / Lee 2013) and the atmospheric calibration curve for the northern hemisphere published by Reimer et al. (2013). The algorithms used are defined exactly by the brackets and OxCal CQL2 keywords on the left-hand side of the technical graphs (e. g. Oross et al. this volume [a], fig. 6 http://c14.arch.ox.ac.uk/). The posterior density estimates output by the model are shown in black, with the unconstrained calibrated radiocarbon dates shown in outline. The other distributions correspond to aspects of the model. For example, '*start: Alsónyék Starčevo'* is the estimated date that the activity at Alsónyék began in this period (Oross et al. this volume [a], fig. 6). In the text and tables, the Highest Posterior Density intervals of the posterior density estimates are given *in italics*. So, for example, we estimate that Starčevo occupation on subsite 5603 began in *5800–5730 cal BC* (*95% probability*; *start: Alsónyék Starčevo*; Oross et al. this volume [a], fig. 6), probably in *5775–5740 cal BC (68% probability)*. Where unmodelled radiocarbon dates are given, they have been calibrated using the probability method (Stuiver / Reimer 1993) and IntCal 13. All ranges have been rounded outwards to the nearest five years.

The Bayesian process at Alsónyék

Over the past two decades, an iterative process for the routine implementation of Bayesian modelling for the construction of chronologies for archaeological sites has been forged from the body of applications undertaken by English Heritage (now Historic England) (Bayliss / Bronk Ramsey 2004; Bayliss 2009). This process, summarised in *figure 3*, was followed for the construction of the chronological models for Neolithic settlement and burial at Alsónyék.

Existing knowledge

The dating programmes described in this volume were undertaken between 2012 and 2015, during the post-excavation analysis of the Alsónyék complex (Osztás et al. this volume [a]). Our understanding of different elements of the landscape and assemblages during this process thus differed depending on how much research had been undertaken on a particular aspect of the site at the time when samples were submitted for radiocarbon dating. For example, the analysis of the Starčevo pottery was much further advanced than that of the Lengyel pottery.

The settlements, and many of the excavated features, however, could be placed reliably within the overarching typo-chronological sequence of Neolithic ceramics in central and south-eastern Europe (Simon 2003; Biró 2003). The existing radiocarbon dating for the occurrence of these ceramic groups within Transdanubia is limited, in terms of both the number of measurements available and the quality of the samples submitted for dating (for example, in most cases the fragments of charcoal submitted for dating were not identified to age and species). The quality of the reporting of these results (Bayliss 2015) is also often

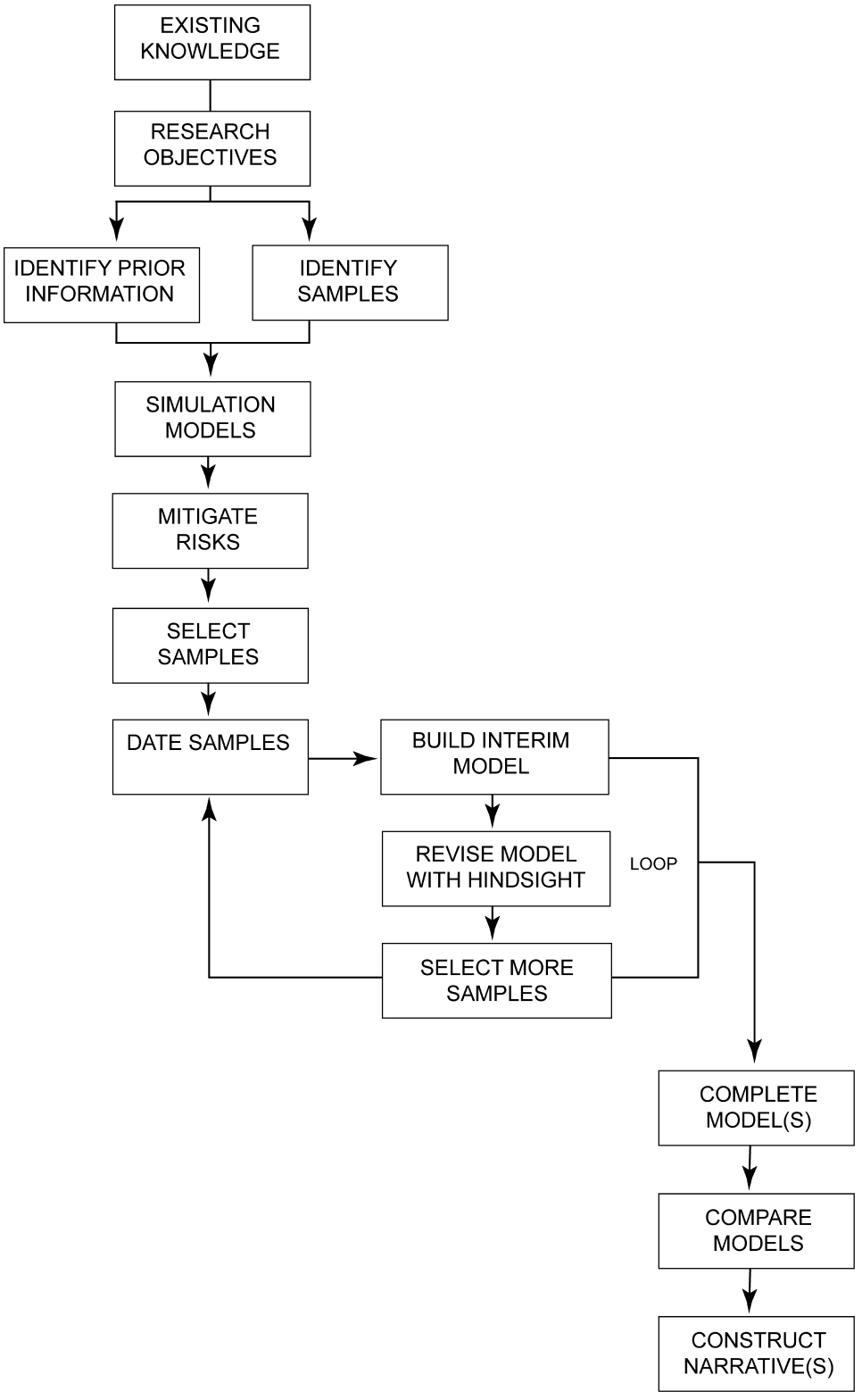

Fig. 3. The Bayesian process.

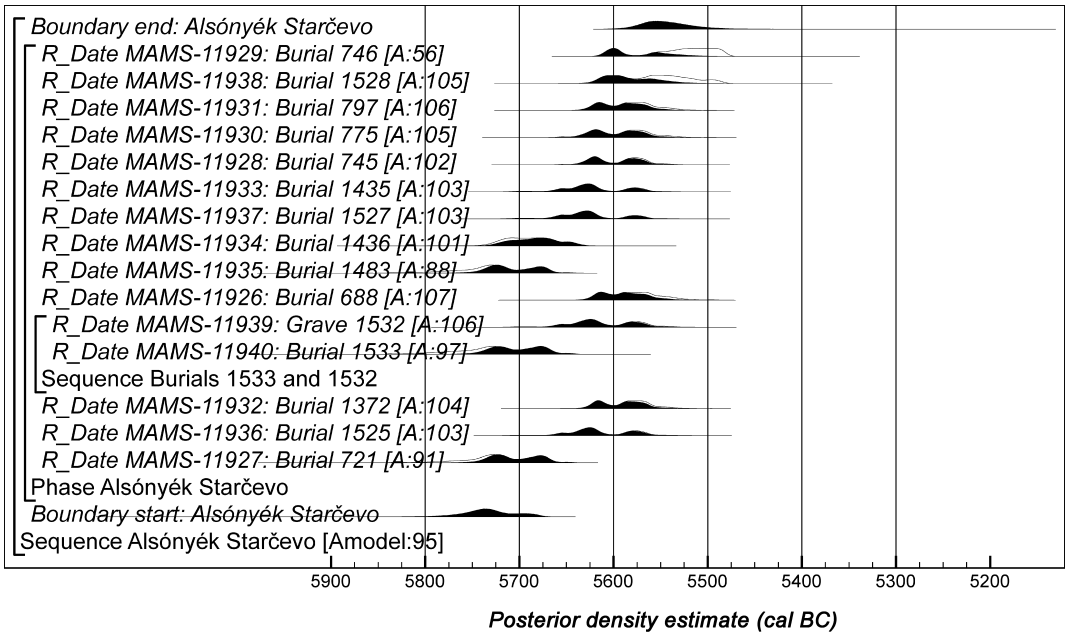

Fig. 4. Probability distributions of dates from the Starčevo settlement in site 5603 at Alsónyék available in 2012. Each distribution represents the relative probability that an event occurs at a particular time. For each of the dates two distributions have been plotted: one in outline, which is the 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: Alsónyék Starčevo*' is the estimated date when the settlement was established. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly.

insufficient for them to contribute to more than an outline chronology for the associated ceramics.

Fortunately, as part of the aDNA and stable isotope study undertaken between 2009 and 2013 (Szécsenyi-Nagy et al. 2015), 21 radiocarbon dates were obtained on human skeletons selected for aDNA analysis from Alsónyék. These results, along with the carbon and nitrogen stable isotope measurements on the dated burials, were kindly made available to us in advance of full publication.

Fifteen of these dates came from the Starčevo settlement on subsite 5603 (Oross et al. this volume [a], tab. 1). A preliminary chronological model was constructed incorporating the single stratigraphic relationship between graves 1532 and 1533 with these dates *(fig. 4)*, which clearly indicated that activity on this site probably fell in the second quarter of the sixth millennium cal BC. The first typological analysis of the Starčevo pottery assemblage had already demonstrated its exceptional variety (e. g. in terms of painted pottery; Bánffy et al. 2010). In the course of the current dating programme, three style groups were identified. Many of their components are comparable with diagnostic traits of Starčevo typo-chronological phases in Slavonia (to the south), although it was not known if these were of chronological significance at Alsónyék (Bánffy et al. 2010; Oross et al. this volume [a], 97).

No radiocarbon dates were available from the LBK site at Alsónyék before this study, and so our existing assessment of the chronology of the site was based on the overall chronology for the presence of LBK ceramics in Transdanubia (Oross et al. this volume [b], 129)

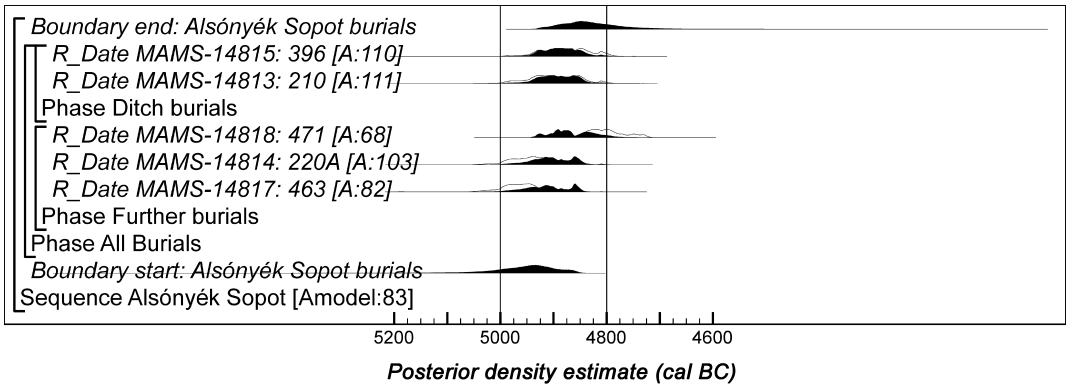

Fig. 5. Probability distributions of dates from Sopot burials at Alsónyék available in 2012. The format is identical to that of *fig. 4*. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly.

and the rather scant parallels for the Alsónyék LBK pottery assemblage from elsewhere in south-east Transdanubia (Oross et al. this volume [b], 131). Little could be said other than that the earliest, and probably the latest, LBK pottery types to occur in Transdanubia do not appear to be present, and that the site probably dates to the later sixth millennium cal BC.

Five radiocarbon dates were available from the aDNA and stable isotope project for the Sopot burial ground in subsite 5603-2 (Oross et al. this volume [c], tab. 1), preliminary modelling of which suggested that the cemetery might have endured for a relatively restricted period sometime within the first two centuries of the fifth millennium cal BC *(fig. 5)*.

We inherited a single radiocarbon date from the aDNA and stable isotope project for the Lengyel cemetery (MAMS-11941; Osztás et al. this volume [b], tab. 1), which calibrates to 4730–4540 cal BC (95% probability). The initial review of the ceramics suggested that the earliest forms of Lengyel pottery (which are not known to occur in Transdanubia) were not present. The scale of occupation in this period was taken to indicate that the Lengyel site was in use for most of the currency of this ceramic type in Transdanubia (c. 4900–4300 cal BC).

Objectives

The explicit definition of the archaeological problems to be addressed by a programme of scientific dating is an essential step in the Bayesian process. The aims of the project determine the precision of dating that is required to answer specific questions and consequently the sampling strategy that is necessary to achieve that precision.

The radiocarbon dating programme at Alsónyék was a joint initiative between the *Times of Their Lives* project (funded by the European Research Council), which concentrated on the Lengyel and Sopot sites, and the Alsónyék post-excavation project (funded by the Hungarian Scientific Fund, OTKA), which concentrated on the Starčevo and LBK sites. Both projects also benefited from radiocarbon dates that had been previously obtained by the aDNA and stable isotope project *Bevölkerungsgeschichte des Karpatenbeckens in der Jungsteinzeit und ihr Einfluss auf die Besiedlung Mitteleuropas* (funded by the Deutsche Forschungsgemeinschaft [Al 287/10-1]) and took a joint approach to the design of the new radiocarbon dating programme.

The overall programme aimed to address the following issues:
– to provide calendar dating for the establishment and demise of each settlement, thus estimating the duration of use of each site
– to determine whether occupation of the complex was continuous, or whether there were periods of abandonment, or times when settlements of different cultural traditions were occupied contemporaneously
– to estimate changes in the intensity of occupation of the complex through time.

Additionally, each component of the dating project addressed specific issues of relevance to a particular site or period.

Starčevo ceramics mark the first appearance of Neolithic lifeways in Transdanubia, and so dating the establishment of this settlement was a priority. Establishing whether the pottery style groups identified were of chronological significance and, if so, determining the chronology and duration of each style group, were also important.

Given the difficulties in finding any grouping within the LBK ceramics from Alsónyék, calendar dating for this site was needed to place it within the wider LBK typo-chronology for the western Carpathian basin. It was also hoped to explore how the layout of the settlement developed through time, both through determining the sequence of longhouses within a particular cluster, and through determining the sequence of house clusters. Finally, we wished to estimate the interval between the filling of the house long pits and the burials that were cut into them.

As outlined by Oross et al. (this volume [c], 152), the position of Sopot occupation within the Neolithic sequence of Transdanubia is currently a matter of active debate. It was hoped to establish the chronology of the Sopot burial ground relative to both the LBK and Lengyel settlements, and in particular to determine whether the late LBK and early Sopot communities may have overlapped.

The objectives of the Lengyel dating programme were modified during the course of the dating project (as described below). Initially, however, our sampling focused on:
– placing the occupation within the regional sequence for Lengyel ceramics
– determining whether groups of burials and settlement activity in the same location were contemporary
– revealing the timing and tempo of settlement activity, answering questions such as: was there a single concentrated horizon of activity or did the site grow over time? Which areas were in use at which time? Did the settlement shift? How big was the settlement at any one time?
– refining our understanding of the typo-chronology of Lengyel ceramics by providing precise calendar dating for the sequence under construction through the seriation of pottery vessels in graves at Alsónyék
– determining the duration and contemporaneity of different burial groups
– determining the times when tuberculosis was present in the community

Sampling

There are a number of steps in constructing an efficient and effective sampling strategy to achieve a series of archaeological objectives through a programme of radiocarbon dating and chronological modelling. The identification and selection of suitable material for scientific dating form only one of those steps. It is also necessary to identify archaeological information that can be included in the model as prior information, and to determine the

most effective combination of that prior information with the available pool of potential samples through a series of realistic simulation models. Finally, measures must be designed to mitigate the risks inherent in the identified sampling strategy.

Prior information

The archaeological information that is included in a chronological model is as important as the radiocarbon dates and must be subject to the same degree of rigorous assessment.

The first kind of archaeological knowledge which we have included in all the models presented in the papers contained in this volume relates to place. People tend to repeat themselves, and often activity is concentrated in particular places that archaeologists call sites. This means that the radiocarbon dates from a site are related – the samples do not derive randomly from anywhere within the span of the radiocarbon calibration curve (currently AD 1950 to 48,050 BC), but randomly from within the period when that site was occupied. At Alsónyék, we can further refine our understanding of this relatedness, as occupation in different places can be associated with distinctive ceramic traditions. We can thus model chronologies for four different sites: one associated with Starčevo ceramics (Oross et al. this volume [a]), one associated with LBK ceramics (Oross et al. this volume [b]), one associated with Sopot ceramics (Oross et al. this volume [c]), and one associated with Lengyel ceramics (Osztás et al. this volume [b]).

This archaeological information is not sophisticated, but it is critical that it is included in a Bayesian chronological model if accurate chronologies are to be produced (Steier / Rom 2000; Bronk Ramsey 2000). Most often this has been done using the uniform phase model proposed by Buck et al. (1992), which interprets the samples as coming randomly from a phase of occupation which starts and then continues more or less constantly until it ends. (Since the radiocarbon calibration curve in this period is interpolated at 5-year intervals from measurements on tree-ring samples that are generally decadal or bi-decadal in range [Reimer et al. 2013; Niu et al. 2013], minor deviations from constant occupation [for example, seasonal variations] will not matter in practice.) For the Lengyel settlement, the robustness of this approach is assessed using the trapezium phase model proposed by Karlsberg (2006), as implemented in OxCal v4.2 (Lee / Bronk Ramsey 2012). This approach interprets samples as coming randomly from a phase of occupation that begins gradually, and reaches a height of intensity that continues more or less constantly, until it gradually declines and then ends.

The second type of archaeological information that is included in all the models presented in this volume is the relative sequence of deposits provided by stratigraphy. The sites have no great depth of stratigraphy, but features frequently intercut, and most often we selected samples from settlement features that had been cut by later burials. Stratigraphy, of course, provides a relative sequence of excavated deposits, and radiocarbon dating provides dates for samples. Consequently, for it to be valid to use a sequence derived from stratigraphy to constrain the calibration of radiocarbon dates in a Bayesian model, it is essential that the carbon in the sampled material was in equilibrium with the atmosphere at the time the deposit was formed. This has significant implications for what constitutes suitable material for sampling (see below).

At Alsónyék, constraints provided by stratigraphy add precision to the model without the need for additional radiocarbon dates. This is true of many sites, although in some instances, for example when a site falls on a plateau in the radiocarbon calibration curve, stratigraphy is essential in obtaining precise chronologies (see Bayliss et al. 2014). Incorporating as many such relationships as possible into the models is thus cost-effective. It is

even more so if samples can be selected to constrain the calibration of existing dates (as was done in selecting samples from Starčevo features stratigraphically related to burials that had already been dated by the aDNA project) or to contribute towards more than one objective (as was done when samples from Lengyel settlement features were cut by graves containing diagnostic Lengyel ceramics).

The third type of archaeological information is that derived from the typological sequence of things. In the case of the Starčevo ceramics, this was a series of typological style groups whose chronological significance was uncertain at the time of sample submission (Oross et al. this volume [a], 97). In the case of the Lengyel cemetery, this was the seriation by correspondence analysis of the occurrence of pottery types in grave-assemblages. At the time of sample submission, work on this correspondence analysis was just beginning but, based on the success of previous work on similar material (Zalai-Gaál 2002; 2010), it was anticipated that a seriation of selected Lengyel grave-assemblages at Alsónyék, including those sampled for radiocarbon dating, would be available by the time the first round of radiocarbon results were due to be reported.

Potential samples

With the advent of radiocarbon dating by Accelerator Mass Spectrometry (AMS), the concept of a radiocarbon sample fundamentally changed. The required sample size is now so small (one carbonised cereal grain or c. 1.0 g of human or animal bone) that it is physically possible to obtain a radiocarbon measurement on almost any organic material that is recovered during fieldwork. The question then was which of the thousands, if not millions, of potential samples retrieved from Alsónyék should be selected for dating.

We started to narrow down the pool of potential samples by only considering materials that meet three essential criteria:

1. The carbon in the sampled organism must be in equilibrium with the carbon in the atmosphere (or some other well-characterised reservoir) at the time when the organism died;
2. The sample must not be irretrievably contaminated by any other carbon-containing material;
3. The datable material must be unequivocally associated with the archaeological activity that is of interest.

Given the ongoing post-excavation analysis at Alsónyék, a fourth criterion intruded in practice: that the material had to be available for sampling. This meant, for example, that no charred plant remains, including charcoal, could be dated. Although soil samples were collected during the excavation from many features (including features, such as ovens, where the charred plant remains could be considered to have a strong functional relationship with the excavated deposit), flotation has so far been undertaken of only some of the soil samples and the resultant flots are still being analysed. It was also not possible to find carbonised food crusts on any of the pottery that could date its use. The ceramics from the settlements had been washed during excavation by conscientious site workers, who appear to have removed almost all charred residues that may have once existed. Only a proportion of the pottery from the graves had been cleaned, by the specialists who reconstructed the vessels, but again charred food crusts were not found (this is not unexpected, as charred residues usually occur on cooking vessels).

Given these practical constraints, our sampling programme for radiocarbon dating concentrated on animal and human bone.

Bones from terrestrial herbivores (such as cattle, deer and sheep) are in equilibrium with atmospheric carbon through the plants they eat, and so constitute ideal samples for radiocarbon dating. Bone collagen from terrestrial omnivores and carnivores (such as pigs, dogs and humans) derives from food that potentially comes from a mixture of sources, not all of which may be in carbon equilibrium with the atmosphere.

Consumption of marine resources adds a component of older carbon to an individual since, although ^{14}C from the atmosphere is absorbed into the surface ocean within a few years of its production (Craig 1957), this is diluted by the upwelling of radiocarbon-depleted water from the deep oceans (Mangerud 1972). Both direct radiocarbon measurements and global modelling of the surface ocean suggest that its apparent age is in the order of 400 radiocarbon years (Broecker et al. 1960; Stuiver / Braziunas 1993), although the variation is such that local corrections are essential (http://calib.qub.ac.uk/marine/). Distance from the sea (over 400 km) presumably precludes the consumption of a significant component of marine fish by the Neolithic community and its commensals at Alsónyék, although some marine organisms such as *Spondylus* shells were present.

Reservoir effects have also been observed in freshwater environments, where molluscs and submerged aquatic plants can take up dissolved carbonate from the water (Deevey et al. 1954). This is known as the 'hard-water effect' and, because the carbonate derives from rocks, such as limestone, which were laid down so long ago that all the radiocarbon in them has decayed away, it always makes a radiocarbon sample from such freshwater environments appear older than a contemporary terrestrial sample. There are two important points to note about this type of reservoir effect. First, it affects not only organisms, such as submerged aquatic plants, which metabolise carbon dissolved in the water, but also organisms further up food chains which feed on these plants, such as freshwater fish and waterfowl. Secondly, it is locally highly variable. Some freshwater aquatic resources can be appreciably depleted in radiocarbon (Lanting / van der Plicht 1998; Cook et al. 2001; 2002; Culleton 2006; Ascough et al. 2007; Shishlina et al. 2007). Others, however, appear to have radiocarbon contents in equilibrium with the atmosphere (Beavan Athfield et al. 2001; Lillie et al. 2009). (There are a number of other local situations in which reservoir effects can be found in archaeological materials. These include the incorporation in samples of old carbon from humic acids produced by ancient peat beds and the incorporation of geological-age carbon from artesian springs or out-gassing volcanoes [Taylor / Bar-Yosef 2014, 150–155]. Estuaries exhibit particularly complex reservoir ages, as the marine reservoir mixes with freshwater bodies each with a locally-specific carbon reservoir.)

The consumption of appreciable quantities of freshwater resources from the Danube and its wetlands at Alsónyék is certainly possible. Moreover, a significant freshwater reservoir has been observed downstream in the Danube at the Iron Gates (Cook et al. 2001; 2002; Bonsall et al. 2015).

For this reason, a pilot set of radiocarbon dates was obtained on three 'perfect pairs' of contemporary human and herbivore bones from Lengyel graves at Alsónyék before sampling began in earnest (a fourth 'perfect pair' was subsequently obtained from one of the Sopot graves; *fig. 6*). These results are listed in *table 1*. In each case the measurements on the human and animal bone are statistically consistent (Ward / Wilson 1978), and so there appears to be no measurable freshwater reservoir offset. (Statistically consistent groups of human and animal bone have also been reported [Raczky / Siklósi 2013, 558–561 tab. 1] from Copper Age graves in Hungary at Hajdúböszörmény-Ficsori-tó-dűlő [VERA-3785, 5370 ± 40 BP and VERA-3788, 5370 ± 45 BP ($T' = 0.0$, $T'[5\%] = 3.8$, $\nu=1$), and VERA-3787, 5425 ± 35 BP and VERA-3789, 5360 ± 35 BP ($T' = 0.0$, $T'[5\%] = 3.8$, $\nu = 1$)] and

Fig. 6. Samples of contemporary animal bone (articulated cattle ribs) and human bone (articulated skeleton) forming a 'perfect pair' of samples for assessing the possibility of a dietary reservoir effect at Alsónyék (5603/2-475).

Pusztataskony-Ledence Site 1 [Poz-33547-50, 5460 ± 40 BP, 5490 ± 40 BP, 5420 ± 40 BP and 5420 ± 40 BP ($T' = 2.2$, $T'[5\%] = 7.8$, $\nu = 3$)].)

Whilst the consistency of the radiocarbon results from the 'perfect pairs' of contemporary human and animal bone that are currently available from the Hungarian Neolithic and Copper Age may suggest that the consumption of freshwater resources has not led to a wide-scale freshwater reservoir effect in human bone samples, this does not mean that particular individuals may not have consumed a larger proportion of such resources and thus exhibit a measurable freshwater reservoir effect. The stable isotopic analyses for each individual, which were used to estimate the percentage of fish in their diet (see below), attempted to identify and account for such individuals.

The second scientific criterion which a sample must meet if it is to be considered suitable for radiocarbon dating is that it must not be contaminated by any other carbon-containing material. This is impossible in practice as, at the very least, the organic component of groundwater will have added contaminants to the sample. Generally, bone is one of the more challenging sample types to date accurately as it requires more complex chemical preparation than most other sample types routinely submitted for dating by archaeologists (Longin 1971; Brown et al. 1988; Bronk Ramsey et al. 2004a; Higham et al. 2006), although the inter-laboratory reproducibility on bone measurements undertaken as part of the most recent international inter-comparison study is similar to that produced for other sample types (Scott et al. 2010a; 2010b). All bones sampled for radiocarbon dating from Alsónyék had been washed in water, marked with black indelible ink and stored in plastic bags. No consolidants had been used on any of the material.

The final criterion which a potential sample must meet before it can be judged suitable for radiocarbon dating is that there must be a clear association between the datable material and the archaeological activity that is of interest (Waterbolk 1971). This relationship, between the *dated event* (such as the death of a cow) and the *target event* (such as the

digging of a refuse pit), is never known but is inferred on the basis of archaeological evidence. The basis of this inference, and its security, must be specifically considered for every potential sample. The golden rule is that every potential sample should be considered residual unless there is a plausible argument showing that it was freshly deposited.

The scale of the finds assemblages recovered from Alsónyék enabled us to confine the dating programme to samples where the archaeological association between sample and context can be inferred with a reasonable degree of confidence. Samples of animal and human bone weighing 2–5 g were taken, usually with a circular dental drill. For animal bone samples, herbivores (cattle, aurochs and red deer) were sampled in preference to omnivorous (pig and wild boar) or carnivorous (dog) species because of the possibility of freshwater reservoir effects arising from diet, as discussed above.

All the human remains sampled were articulated skeletons, probably deposited shortly after death in deliberately cut graves (although a few of the Starčevo burials were placed in disused ovens). In contrast, after death or slaughtering, animal carcasses are usually processed in some way before the bones are finally deposited in the ground. What is important for radiocarbon dating is to determine whether a bone was deposited in the feature from which it was recovered very soon after the animal's death, so that the radiocarbon date on the sampled bone accurately reflects the age of the feature. Where there is a mixture of earlier animal bones, derived from previous activity in that location, the earlier bones must be identified so that they are not sampled and provide erroneous dates for the deposit.

When a bone is exposed on the ground surface, over time weathering and other forms of environmental and biological erosion cause diagenesis of bone collagen which, in many cases, makes it unsuitable for scientific analyses. Many bones that are buried soon after death, however, are in a physical and chemical condition that allows radiocarbon dating but, in order to avoid reworked bones from earlier activity, it is necessary to sample articulated skeletal elements (such as a cattle limb). To appear articulated, anatomically fitting bones need to have been buried together as a coherent part of the carcass with the ligaments and tendons holding the bones together. This apposition shows that the bones cannot have been disturbed since deposition and that they must have been buried soon after the animal's death. In this case their association with the archaeological context is clear.

Alternatively, the refitting parts of an unfused bone can be dated, usually a long bone of an immature individual. A long bone is made up of three main parts: two articular ends (proximal and distal epiphyses) and a shaft (diaphysis) in between. The fusion *(synostosis)* of these elements progresses with the individual's age. The cartilaginous epiphyseal plate of immature animals, located at the growth section between the diaphyseal and epiphyseal line, is absorbed and reconstructed during this process. The surfaces of the epiphyseal cartilage have a characteristic pattern. In the case of immature bones this integral cartilaginous part decomposes after the death of the individual, thus eliminating the epiphyseal and diaphyseal connection. If the long bone was buried when it was complete and it has not been exposed to disturbance later, although some soil may get in the place of the thin layer of decomposing cartilage, the surrounding soil keeps the diaphyseal and epiphyseal parts together. Thus the unfused surfaces at the ossification line keep their sharp characteristic forms. These distinctive epiphyseal and diaphyseal surfaces provide evidence that the elements of an unfused bone were buried together even when, as often happens, the parts are disturbed during excavation.

These kinds of evidence allow us to infer that a bone sample was deposited in the ground soon after the death of the individual, and is clearly associated with the formation of the deposit from which it was recovered. The categories of sample in descending order of reliability can be summarised as follows *(fig. 7)*:

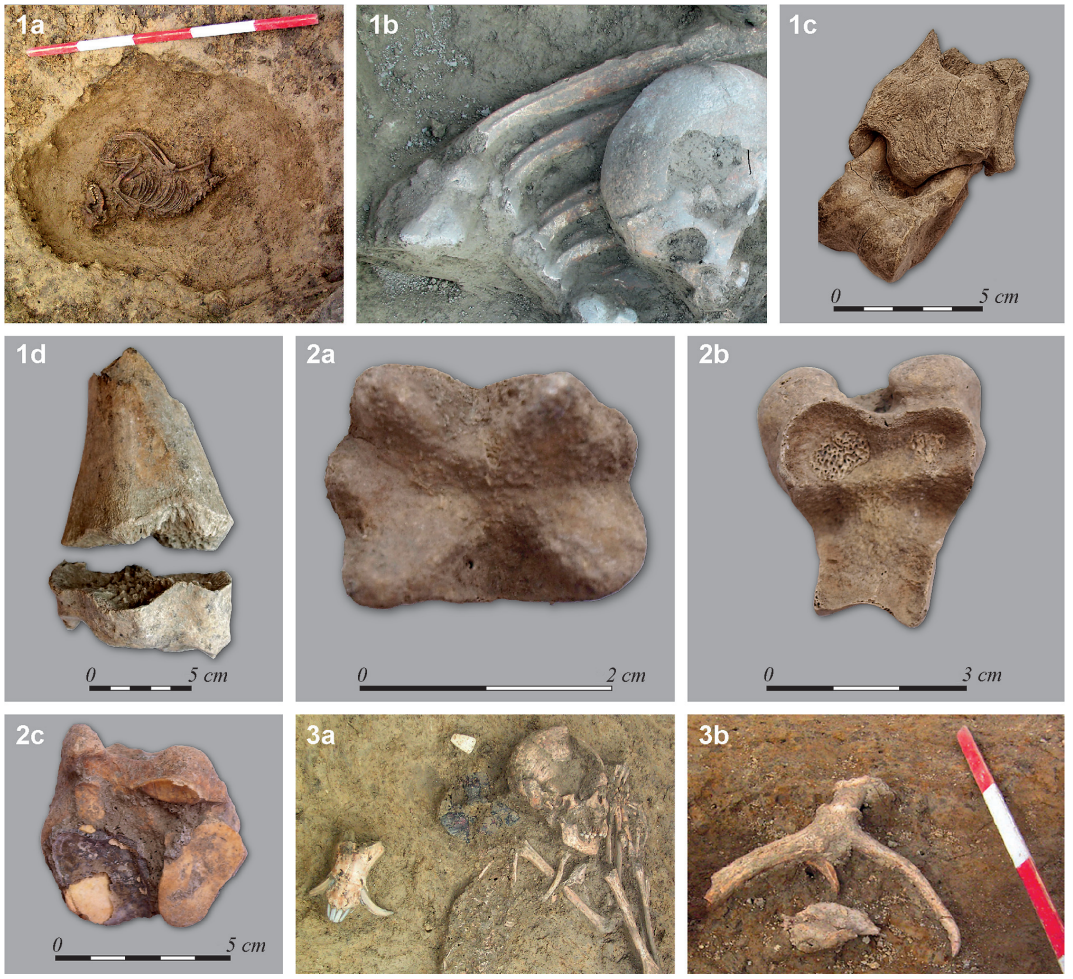

Fig. 7. Photo montage of articulated (1a–b), articulating (1c and 2c), refitting (1d and 2a–b), functionally associated disarticulated (3a), and potentially residual (3b) bones that form a hierarchy of samples potentially suitable for radiocarbon dating. 1a) articulated dog skeleton from pit 10B-723, 1b) articulated adult cattle right ribs from grave 5603/2-475, 1c) articulating cattle left tibia and astragalus, 1d) subadult cattle right radius with refitting unfused distal epiphysis, 2a) juvenile sheep/goat left tibia with refitting unfused distal epiphysis (lost on excavation), 2b) subadult sheep/goat right femur distal epiphysis, with refitting unfused diaphysis (lost on excavation), 2c) cattle right centrotarsal, showing marks of articulating intermediate and lateral tarsals (lost on excavation), 3a) wild boar mandible deliberately placed in grave 10B-3472, and 3b) disarticulated red deer antler from pit 10B-77.

1a) A complete articulated animal or human skeleton documented as such during excavation *(fig. 7,1a)*.

1b) Articulated bones from part of the skeleton of an individual (e. g. a cattle limb), documented as such during excavation *(fig. 7,1b)*.

1c) Articulating bones of an individual, recognised after the excavations during archaeozoological (or more rarely, osteological) investigation *(fig. 7,1c)*.

1d) Unfused bone with refitting unfused epiphysis, recognised after the excavations during archaeozoological (or more rarely, osteological) investigation *(fig. 7,1d)*.

2a–b) Unfused diaphysis or epiphysis where an epiphyseal surface retains its characteristic forms *(fig. 7,2a–b)*, suggesting that the epiphysis/diaphysis was present in the ground but lost during excavation.
2c) Well preserved bone with marks on its surface which suggest that it was articulated with an anatomically adjacent bone in the ground *(fig. 7,2c)*, which was separated on excavation.
3a) Single bones with a functional relationship to the context from which they were recovered (e. g. a wild boar mandible in a grave *(fig. 7,3a)*.
3b) Single bones reliably known to be from a particular feature, providing a *terminus post quem* dating for the filling of the feature *(fig. 7,3b)*.

At Alsónyék, once features had been identified for potential sampling on stratigraphic or other grounds, the faunal assemblage from those features was swiftly scanned to locate material in the categories listed above. This strategy was generally successful, and overall 271 of the dated bones were classes 1a–d (88%), 28 were classes 2a–c (9%), four were class 3a (2%), and three were class 3b (1%).

Simulation

Once the relevant archaeological information has been identified for inclusion in the model and a pool of potential samples that are suitable for radiocarbon dating located, then a sampling strategy needs to be constructed. This needs to combine these components into a chronological model that will achieve the identified objectives of the dating programme in a cost-effective and timely manner. Typically there are hundreds, in the case of Alsónyék thousands, of potentially suitable samples for radiocarbon dating. We need to decide how many should be dated and exactly which ones.

One tool that can aid us in determining how many samples should be dated, given the prior archaeological information that can be included in the model, is statistical simulation (Bronk Ramsey 1998; Buck / Christen 1998).

The following information needs to be defined:
– the prior information relevant to the problem that can be included in the model
– the pool of samples which are potentially suitable for dating, and their relationships to that prior information
– the error terms which are likely to be returned by the selected radiocarbon facilities, given the likely age and material of the samples to be submitted
– a representative range of scenarios for the likely actual calendar dating of the problem under consideration.

An example is shown in *figure 8*, for the Sopot occupation. This simulation model includes the archaeological information that all the dates are related (by being on a site whose occupants used Sopot pottery). It also includes a stratigraphic relationship between a ditch and two burials which are cut into it. The five existing radiocarbon dates (those shown in *fig. 5*) are included in the model, along with a further 11 simulated radiocarbon dates. Simulated dates are produced using a process of 'back calibration' from samples of known calendar date. For example, if we have a sample that actually dates to 4950 BC and produces a measurement with an error term of ±30 BP, then we can transfer the calendar date through the calibration curve to the radiocarbon age scale. Each simulation will produce a slightly different value because of the error term on the radiocarbon age but, for example, 4950 BC might produce a simulated radiocarbon age of 6014 ± 30 BP. This is then cali-

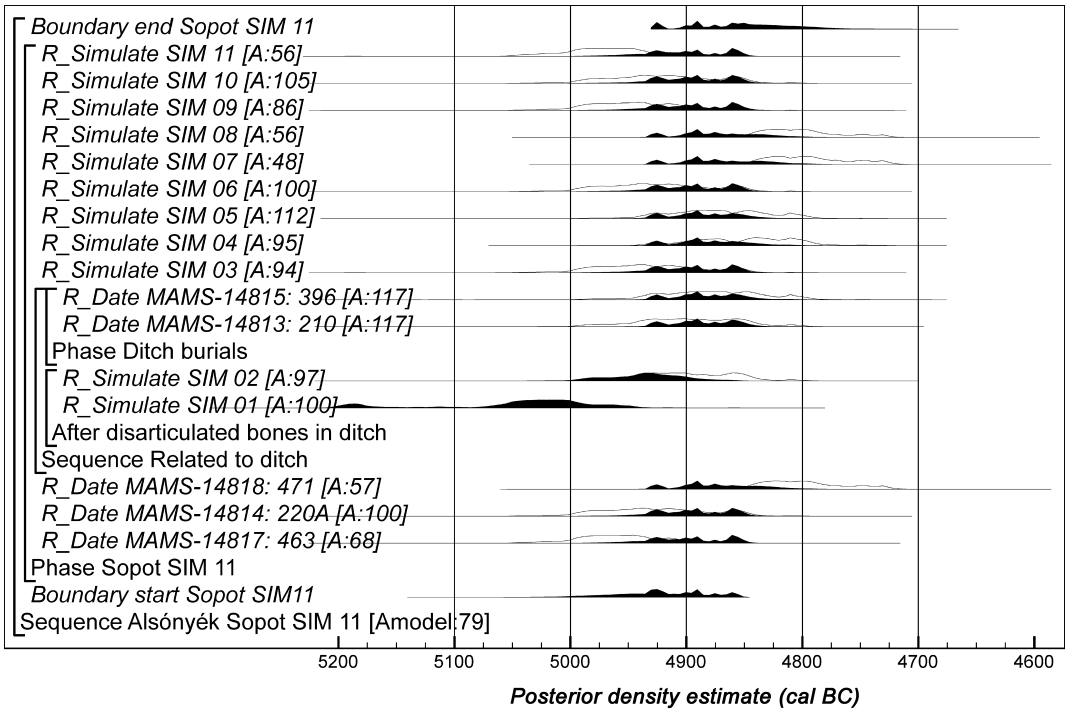

Fig. 8. Probability distributions of dates from Sopot burials at Alsónyék available in 2012, with eleven further simulated dates (spanning 4950–4850 BC). The format is identical to that of *fig. 4*. The large square brackets down the left-hand side along with the OxCal keywords define the overall model exactly.

brated to produce a realistic estimate of the calibrated radiocarbon date that would be produced by a sample of this calendar age, given the constraints of the simulation model.

The simulated dates in *figure 8* have been produced from calendar dates put into the model between 4950 BC and 4850 BC. From the existing radiocarbon dates *(fig. 5)* and present understanding of the currency of Sopot pottery in south-west Hungary, this is plausible. But of course, we do not actually know that this site was used for 100 years between 4950 BC and 4850 BC. It could have been used for 50 years between 4950 BC and 4900 BC, or for 100 years between 4900 BC and 4800 BC, and so on. So, we need to produce a series of simulations for different plausible scenarios to see how the model outputs will vary given the actual chronology of the site (could we, for example, distinguish a burial ground that was in use for 100 years from one that was in use for 50 years with this number of samples?).

This example also illustrates how it is not simply a matter of determining the optimal number of samples, and then submitting a selection of the 'best' samples identified until this total is reached. The relationships between the prior information and the potential samples are vital. In this case, two disarticulated animal bones (class 3b from the bottom of the sample hierarchy used at Alsónyék) are selected for dating to provide additional stratigraphic constraints on the model.

Simulation models were used for all the sites, and at each stage of sample selection, in the applications reported in this volume. These are only a guide to efficient and effective sampling strategies, however, and it is essential that the selected samples also meet relevant archaeological criteria. In the case of Alsónyék, this meant that the samples:

– were closely associated with activity associated with the relevant diagnostic material culture type
– were spread across the spatial extent of the relevant activity
– were spread across the typological variation within the relevant diagnostic material culture type.

Mitigating risk

In an ideal world, all archaeological samples would date the target event intended and all radiocarbon measurements would be accurate to within their quoted uncertainty. The real world is not like this. Few radiocarbon samples, and even fewer sampling strategies, are perfect. There is always some element of risk in dating a chosen set of samples, which our sampling strategies must recognise and attempt to mitigate.

At Alsónyék we judged the risks posed by the archaeological weaknesses of our samples to be relatively low. Punctilious attention to the association between the selected samples and the archaeological material or feature with which they were associated (described in the previous section), meant that almost 90% of samples were judged contemporary with their context with the highest degree of confidence. This archaeological rigour comes at a price in terms of the scientific risks of the programme.

Two major scientific risks were identified for the Alsónyék sampling programme. First was the possibility of reservoir effects on radiocarbon dates from human individuals who had consumed freshwater fish or waterfowl. Second was the complete reliance on a single datable material – bone – and one, moreover, which requires complex chemical pretreatment for accurate dating.

Dietary analysis of human remains

Although the series of 'perfect pairs' of contemporary human and animal samples obtained before the main phase of sampling at Alsónyék began *(tab. 1; fig. 6)* suggested that dietary reservoir effects in human bone from the site were probably not widespread, this does not mean that particular individuals might not have consumed a larger component of freshwater resources.

For this reason, source-proportional dietary modelling was undertaken on the basis of carbon and nitrogen stable isotopic values, so that mixed-source calibration models could be constructed which would account for any potential reservoir effects in particular individuals.

Diet reconstruction for the Alsónyék humans was determined by the Bayesian mixing model FRUITS v2.0β (Food Reconstruction Using Isotopic Transferred Signals; Fernandes et al. 2014). The FRUITS program is the most recent development of mixed-source proportional models, which have been employed over the past decade to reconstruct ancient diets. Early models, such as ISOSOURCE (Phillips / Gregg 2003), did not incorporate sources of uncertainty, such as variations in the isotopic signal within food groups or uncertainty relating to a diet-to-consumer offset (Fernandes et al. 2014). The FRUITS program, however, uses the isotopic averages of possible food sources and allows the user to define isotopic offsets between diet and consumer, the weighting and concentration of food sources, and prior information to constrain the calculations of the stable isotope mixing model. FRUITS produces estimates of the mean percentage and standard deviation of each food source for a given consumer.

For the FRUITS modelling on two diet proxies ($\delta^{13}C$ and $\delta^{15}N$) on Alsónyék adult and sub-adult humans from the Starčevo, LBK, Sopot and Lengyel sites, we employed the following food source data and assumptions in the model.

Three likely food sources were identified for this region. Mean isotope values and analytical error means for each food source *(tab. 3)* were the baseline for a simple FRUITS model where the whole food input is considered. Cereal values came from archaeobotanical samples of wheat (n = 12) and barley (n = 6) from Ogrinc and Budja (2005) and emmer wheat (n = 1) and barley (n = 3) from Bogaard et al. (2013). The values for terrestrial animals were from analyses of faunal materials in the Lengyel, Sopot and Starčevo sites (*tab. 2*, except UBA-22012; n = 62), and a further 27 sets of unpublished results on terrestrial faunal from Alsónyék, which were kindly provided by the Bioarchaeology Workgroup Mainz. The values used for freshwater fish were from archaeological samples from Nehlich et al. (2010; n = 3), Borić et al. (2004; n = 12), samples from Alsónyék measured as part of this project at the University of Otago (*tab. 2*; n = 4), and a further six sets of unpublished results on freshwater fish from Alsónyék, which were also kindly provided by the Bioarchaeology Workgroup Mainz. Mean isotope values and analytical error means for each food source *(tab. 3)* were the baseline for a simple FRUITS model where the whole food input is considered. The isotopic offset between diet and consumers used for $\delta^{13}C$ was 4.8 ± 0.2‰ (Fernandes et al. 2014), and for $\delta^{15}N$ it was 6.0 ± 0.5‰ (O'Connell et al. 2012). This simple FRUITS model also set the weight and concentration of each of the three diet sources at 100%.

The FRUITS program allows the user to constrain the calculations by incorporating *a priori* information from the archaeological record. While the consumption of freshwater resources from the Danube and its wetlands at Alsónyék is certainly possible, and a significant freshwater reservoir is known in the Danube at the Iron Gates (Cook et al. 2001; 2002; Bonsall et al. 2015), we suspected that fish played a very small to negligible role in the diet, given the available archaeological evidence and the radiocarbon results from the 'perfect pairs' of humans and terrestrial herbivores *(tab. 1)*. Therefore, our first choice of prior information was to set terrestrial herbivores in the diet to be greater than the proportion of freshwater fish. We considered the isotopic values from the four human skeletons included in the 'perfect pairs', and four additional human skeletons which between them exhibited the range of enriched/depleted $\delta^{13}C$ and $\delta^{15}N$ values. Whilst the terrestrial herbivore > freshwater fish prior belief has produced reasonable results for three food sources in other Neolithic sites considered in the project, *The Times of Their Lives* (e. g. at Vinča-Belo Brdo; Tasić et al. forthcoming a), at Alsónyék this approach produced low percentages of fish (mean 3.4 ± 2.6%), but unreasonably high percentages of cereals (mean 85.0 ± 5.2%), and very low percentages of terrestrial herbivores (mean 11.6 ± 4.6%) *(tab. 4)*.

The average human adult and subadult $\delta^{15}N$ value of 10.1 ± 0.2‰ is in the range for consumers with animal products as a substantial proportion of the diet (Hedges / Reynard 2007). Given that the proportion of fish in human diets was probably small and consequently that fish probably contributed little to human nitrogen values, we refine our prior belief to weight the terrestrial herbivores as the more likely source of enriched nitrogen values than cereals. The model produced mean diet proportions of cereals (47.4% ± 1.7%), terrestrial herbivores (49.9% ± 1.8%) and freshwater fish (0.8% ± 0.8% to 5.2% ± 4.9%) *(tab. 4)* which are compatible both with the archaeological record and the radiocarbon results from the 'perfect pairs'.

Mixing models are greatly improved by the use of a third isotope, such as sulphur ($\delta^{34}S$) to better define the relative contribution of particular food sources (Nehlich et al. 2010; Richards et al. 2001; Petchey / Green 2005; Beavan Athfield et al. 2008; Petchey et al.

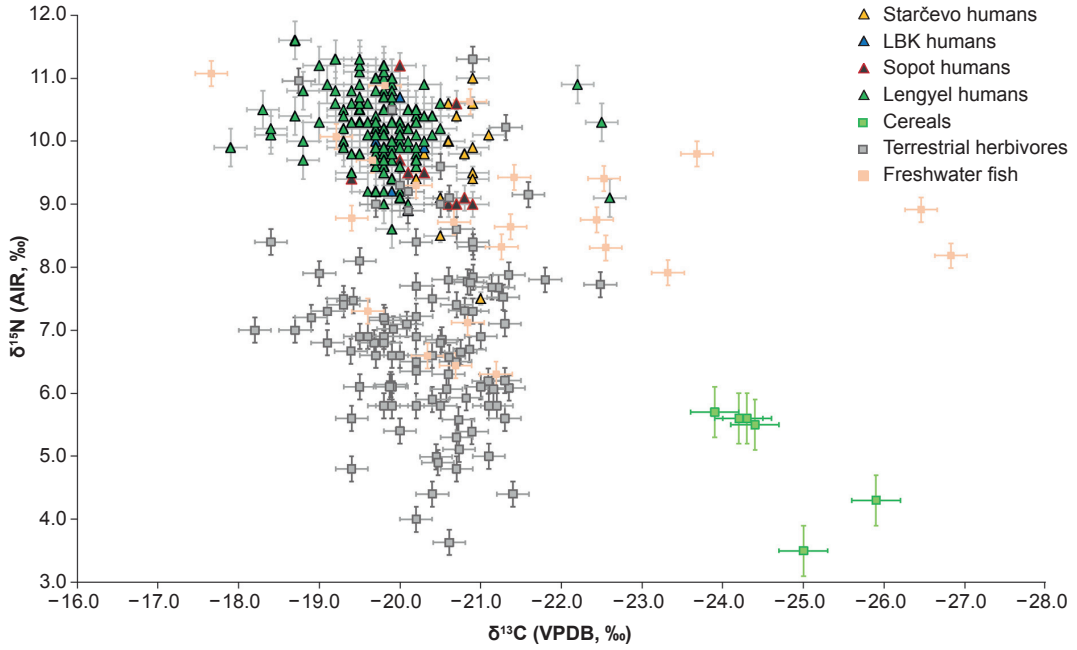

Fig. 9. $\delta^{13}C$ and $\delta^{15}N$ values for adult and sub-adult human skeletons of different periods from Alsónyék, plotted with the values of food sources used in the FRUITS modelling of their diets (error bars at 1σ).

2011). Alsónyék is one of those cases where a three-isotope approach would be particularly beneficial as the carbon and nitrogen isotopic ranges of the possible diet sources are not clearly separated. Unfortunately our application for funds to measure a third isotope was not successful.

The $\delta^{13}C$ and $\delta^{15}N$ values for all human skeletons dated from Alsónyék (except for those from infants below three years of age) are given in *table 5* and illustrated in *figure 9*. The dietary source estimates for each individual provided by the preferred FRUITS model, which incorporates the prior belief that terrestrial herbivores contributed more than cereals, are provided in *table 5*. Weighted means have been taken of replicate measurements before inclusion in the analysis (Ward / Wilson 1978). A few $\delta^{34}S$ values for freshwater fish and human skeletons, obtained as part of the initial sampling to test for a significant dietary offset in human burials from the site, are also reported in *tables 2* and *5*, although these isotopic data have not been used in the dietary modelling.

The potential for enriched $\delta^{15}N$ values in the three infants under three years of age (OxA-30353–4, 5603-1398; OxA-27461, 11-272; OxA-27460, 11-228) to reflect a nursing signal is a consideration for interpreting the estimates of the dietary source proportions produced by the FRUITS model for these children (as the enrichment of $\delta^{15}N$ in the metabolism of breastmilk is not included in the FRUITS models described so far).

We examine the possibility that the enriched $\delta^{15}N$ in this age group may be a breastfeeding signal. There is an enrichment of +2.1‰ in $\delta^{15}N$ values of children up to three years old (the breastfeeding/weaning age cohort) in comparison to women in the 20–30-year-old age group (which we have assumed include females in the reproductive age range) *(tab. 6)*. Unpaired *t*-test results of this nitrogen enrichment are very statistically significant ($P = 0.0001$). There is no statistical significance in the difference in $\delta^{13}C$ values between

these two groups (P = 0.6131). When infants below the age of three are compared to other children, the $\delta^{13}C$ of the infants is enriched by only 0.48‰ in comparison to children in the 4–10 years cohort, and enriched by 0.24‰ in comparison to children aged 11–15 years. However, there are significant differences in the $\delta^{15}N$ between these cohorts; infants below the age of three years have enriched $\delta^{15}N$ values over 4–10-year-olds by 2.06‰ (P = 0.0174) and over 11–15-year-olds by 2.6‰ (P = 0.0045).

But is this enrichment a breastfeeding signal? We employed a variation of the FRUITS model to examine this question, informed by previous studies. Nursing and weaning-age children present different considerations for diet modelling, as enriched $\delta^{15}N$ for these subjects would be associated with breastfeeding (Jay et al. 2008; Fuller et al. 2006) rather than fish or other higher protein foods, and the gradual introduction of solids which were commonly cereal gruels (Fildes 1986).

We then consider the appropriate isotopic offset to use between mother's milk and the isotopic signal in a breastfeeding child. It is difficult to draw conclusions on breastfeeding signals from the enrichment of $\delta^{15}N$ in the infants in the Lengyel population as the studied sample consists of only two individuals. Fortunately, comparisons of breastfeeding children's isotopic signature to mothers' are examined in a number of studies (Fogel et al. 1989; Richards et al. 2002; Tsutaya / Yoneda 2013), and the variation in this breastfeeding signal/enrichment in $\delta^{15}N$ is noted to vary between 0.5‰ and 4.4‰ in archaeological populations (Waters-Rist / Katzenberg 2010). Bone collagen turnover rates of new-born children are rapid, as infant bone collagen reflects $\delta^{15}N$ breastfeeding signals at 31 weeks (Tsutaya / Yoneda 2013). Other studies in archaeological populations indicate that by 18–20 months these breastfeeding signals are waning, which has been interpreted as a weaning signal (Fogel et al. 1989; Richards et al. 2002).

Cereal values in the FRUITS infants model used archaeobotanical stable isotope values as for the adults and subadults (as in *tab. 3*). There are no published values estimating the isotopic values of breastmilk, but breastmilk isotopic values would reflect the diet of the nursing mother, as breastmilk is essentially the lactating mother's tissue (Song 2004, 125). We created an estimated breastmilk isotopic signature for modelling nursing/weaning children from the adult female population of females in the 20–30-year-old cohort in the complete dataset for Alsónyék. The weighted mean isotopic values of 46 females were compared with children under three years, who were likely to be within a breastfeeding or weaning stage. The female group had a weighted mean for $\delta^{13}C$ of –19.9‰ ± 0.2‰ and a weighted mean of 9.9‰ ± 0.3‰ for $\delta^{15}N$. These values were used as a proxy for the isotopic values of breastmilk.

Children below the age of three years had a mean $\delta^{13}C$ value of –19.7‰ ± 0.2‰ and a mean $\delta^{15}N$ value of 12.0‰ ± 0.3‰. Infants were depleted in $\delta^{13}C$ by +0.2‰ compared to females, and enriched in $\delta^{15}N$ by +2.1‰. As we do not have any cases where we have both a mother and child, we set the FRUITS offsets (the consumer's trophic enrichment of the metabolised food) for the infants at 1.0 ± 0.5‰ for $\delta^{13}C$ and 3 ± 0.5‰ for $\delta^{15}N$, following the enrichment factors noted between mothers and nursing infants in other studies (Fuller et al. 2006; Katzenberg et al. 1996; White / Schwarcz 1994). The results of the FRUITS modelling for the three infants below the age of three are given in *table 6*.

We also examine the possibility of dietary offsets in radiocarbon ages on samples of dog bone, using a further FRUITS diet model. The six Lengyel dogs have $\delta^{13}C$ values which vary by 1.3‰ (–19.2‰ to –20.5‰) and $\delta^{15}N$ which vary by 2.4‰ (8.1‰ to 10.5‰). Several assumptions have been made which contrast with the inputs for the models of adult and infant human diets at Alsónyék. These canines were commensals of the human population, and so would have subsisted on human food waste, yet cereals would have probably

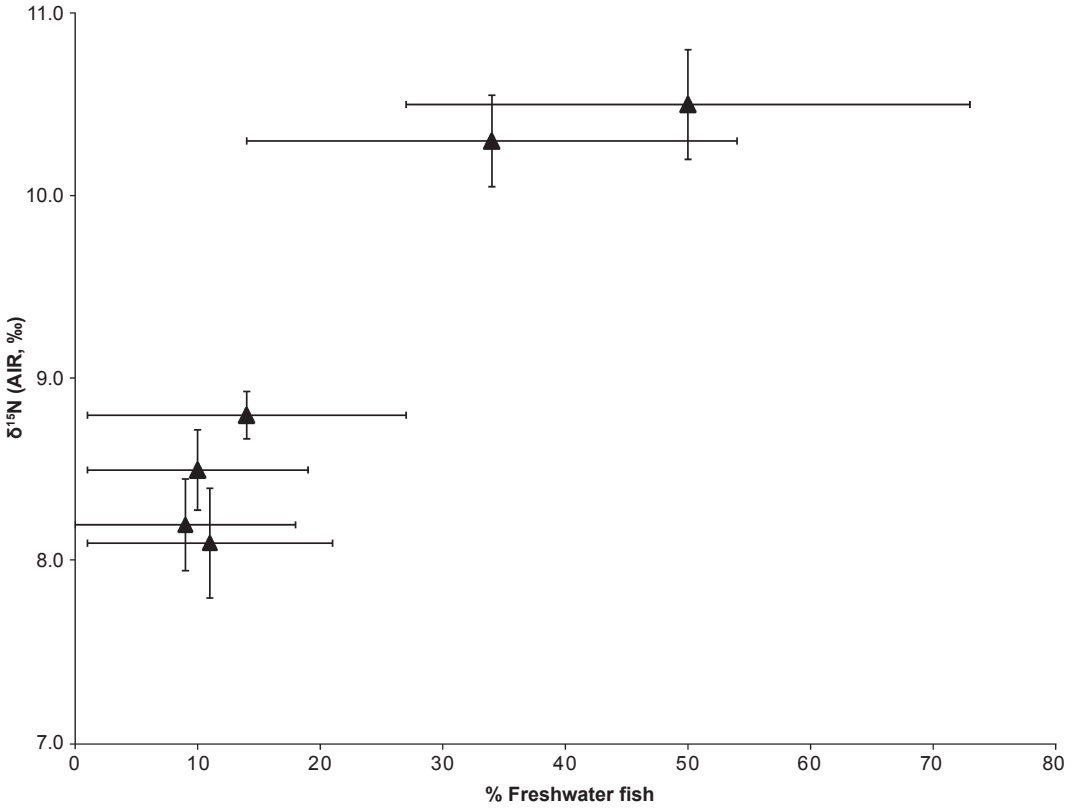

Fig. 10. $\delta^{15}N$ values for Lengyel dog skeletons from Alsónyék, and the estimated percentage of freshwater fish in their diets as derived from the FRUITS model for dogs (error bars at 1σ).

played a negligible part in dog diets. Therefore, we have used only the terrestrial herbivore and fish baseline isotope values from *table 3*. We also assume that the enrichment factors (offsets) for dogs are not similar to humans, based on trophic enrichment estimations of Roth and Hobson (2000) on captive foxes, and the application of these values in the work of Urton and Hobson (2005) on grey wolf diets. These diet-to-consumer enrichment values are 2.6 ± 0.5‰ for $\delta^{13}C$ and 3.4 ± 0.5‰ for $\delta^{15}N$. As FRUITS estimates for human diets indicated that fish were not an important part of human diets, we asked FRUITS to weight the protein contribution in favour of the terrestrial herbivore diet source, with a prior belief that the $\delta^{15}N$ signal derives more from terrestrial than freshwater fish. The weight and concentration of the two diet sources were set at 100%, following Fernandes et al. (2014) for unrouted diet models.

The FRUITS modelling suggests that freshwater foods provided a very low proportion of diet amongst adult and sub-adult humans at Alsónyék, generally well under 5% *(tab. 5)*, and consequently also in infant diets *(tab. 6)*. Freshwater resources may have played a greater part in canine diets *(tab. 7)*. FRUITS estimates for Lengyel dogs *(tab. 7)* show that terrestrial herbivores make up 50 ± 23% to 91 ± 9% % of canine diets, with a freshwater fish contribution from a low of 9 ± 9% to a high of 50 ± 23%. The percentage of fish appears to be driven by the $\delta^{15}N$ values, as illustrated in *figure 10*. Given that negligible fish is estimated in human diets, the high estimates of fish in dogs suggest that fish may have been considered as dog food.

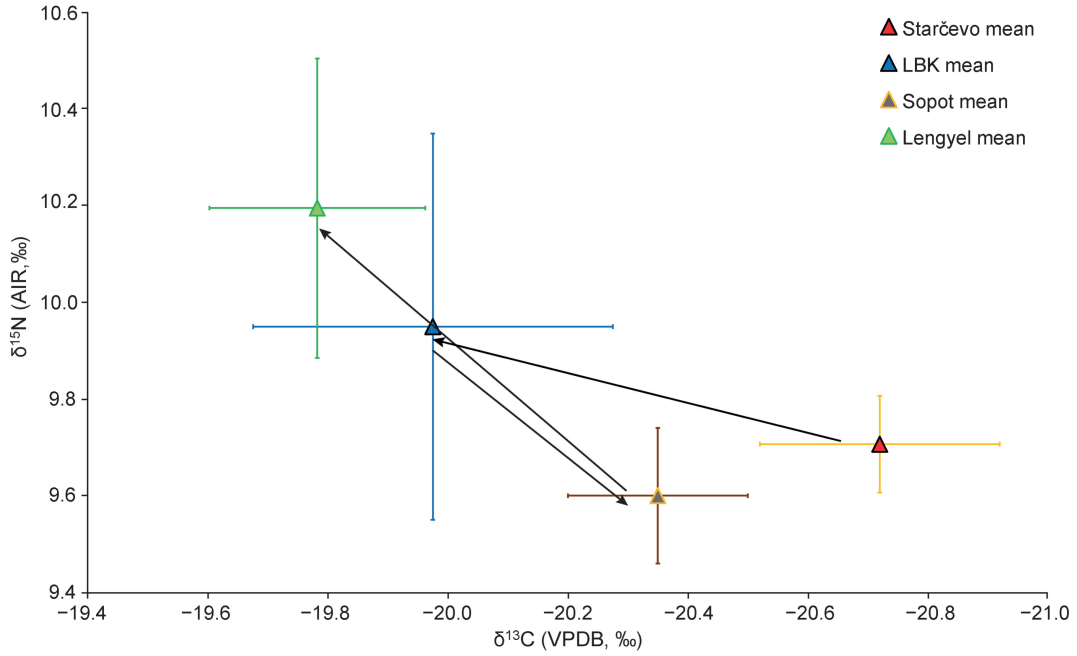

Fig. 11. Changes in mean $\delta^{13}C$ and $\delta^{15}N$ by site and through time. Children under the age of three have been removed from the site datasets for this figure so possible breastfeeding signals do not confound the site mean values (error bars at 1σ).

Nonetheless, even small proportions of freshwater foods could impart a slight reservoir age to the dated individuals, so we have constructed chronological models that allow for this possibility. Bonsall et al. (2015) have calculated a freshwater reservoir effect of 540 ± 70 BP for the Danube at the Iron Gates Gorge. So we can use this reservoir, offset from the atmospheric calibration dataset (Reimer et al. 2013), and the Mix_Curves function of OxCal v4.2 (Bronk Ramsey 2001, amended following Jones / Nicholls 2001). For each dated human individual (and dog), a personal calibration curve can be constructed, which incorporates the freshwater reservoir in the proportion suggested by the dietary estimate for freshwater fish provided by the appropriate FRUITS model in that particular individual *(tabs 5; 7)*. For infants, we have multiplied the proportion of breastmilk in that individual *(tab. 6)* by the proportion of freshwater resources estimated by the adult human FRUITS model for the mean isotopic values for nursing mothers (1.87 ± 1.84%). So, for example, OxA-27471 (11-1937) can be calibrated using a calibration curve including a component of 2.7 ± 2.6% freshwater fish (note that the proportion of any curve is constrained to be 0–100%). The remainder of diet sources will be in equilibrium with the contemporary atmosphere and have been calibrated using IntCal13 (Reimer et al. 2013).

In no case does the mixed-source calibration based on the FRUITS modelling make a substantive difference to the outputs of the chronological models for Alsónyék presented elsewhere in this volume.

Although the main focus of the stable isotope analyses presented here was as part of the construction of an accurate and precise chronology for the Alsónyék sites, these data are of importance for their wider contribution to our understanding of the communities who lived in them. We consider two points briefly here.

The Starčevo, LBK, Sopot and Lengyel sites represent a progression in time from the first farmers in Transdanubia to an established agricultural subsistence base. The distribution of the human isotope values through time shows slight shifts in human isotopic values to reflect a dietary change which resulted in small enrichments of ^{13}C and ^{15}N over time *(fig. 11)*. The enrichment of ^{15}N over time may be associated with an increase in the amount of animal products (including an increase in the consumption of dairy products; Spangenberg et al. 2008; Evershed et al. 2008; Salque et al. 2013) as well as the manuring practices employed by Neolithic farmers which would increase ^{15}N values in cereal crops (Fraser et al. 2013; Bogaard et al. 2007; 2013; Bogaard 2012).

Other isotopic comparisons enhance our understanding of dietary differences within a population and through time. Statistical comparisons use *t*-tests with a Welch correction for comparisons of normally distributed populations with different standard deviations, and Mann-Whitney tests for non-parametric population comparisons (Conover 1980, 225–226). The LBK individuals are represented by just two older adults and two children over five years old and so has too few individuals (n = 4) for meaningful statistical comparisons to be made.

The latest, Lengyel site shows enrichment in $\delta^{13}C$ values over the preceding, Sopot site (+0.65‰, Mann-Whitney two tailed, P = 0.0004) and the earliest, Starčevo site populations (+0.94‰; [P = 0.0001]). Lengyel $\delta^{15}N$ is also significantly enriched over the earlier Sopot site by +0.75‰ (Mann-Whitney two tailed, P = 0.0042), although the $\delta^{15}N$ enrichment is not quite statistically significant (+0.48‰; *t*-test with a Welch correction, P = 0.0534) over the Starčevo site.

The Lengyel site offers the largest dataset (n = 153, plus two children aged under three years), allowing us to examine dietary differences between different age cohorts within the Lengyel population. The overall mean $\delta^{13}C$ value for Lengyel burials is -19.8 ± 0.6‰ and, with the exception of a few individuals whose isotopic signature are outliers to this pattern, no age group notably varies from the mean *(fig. 12[a])*. The overall mean $\delta^{15}N$ value is 10.2 ± 0.6‰. However, differences in individual isotopic profiles reveal how varied a population's dietary preferences may have been. The variation of minimum and maximum values for a specific isotope within each age group *(fig. 12[a].[b])* is the greatest in the 31–45-years cohort (4.2‰ variation in $\delta^{13}C$; 2.6‰ in $\delta^{15}N$) and the 45+ cohort (4.6‰ variation in $\delta^{13}C$; 1.6‰ in $\delta^{15}N$). Differences in the 31–45-years cohort are more likely due to individual dietary preferences, whereas in the 45 year+ population, aging and pathology-influenced isotopic fractionation (Reitsema 2013) are also possible contributing factors.

Cross-checking for laboratory error

The second major risk identified for the sampling strategies designed for the Alsónyék sites was the complete reliance on a single datable material – bone. Moreover, this is a material which requires complex chemical pretreatment for accurate dating.

Once results have been reported, the coherence of a suite of related radiocarbon dates can be assessed for evidence of clear outliers or misfits, and a series of results on samples from an archaeological sequence (such as stratigraphy) can be compared with the relative chronology provided by that archaeological information. How this is done is described below (page 56).

A third method for ensuring against laboratory error is replication. This is where a sample is split into several parts and dated more than once, either by the same laboratory or by different laboratories. All five radiocarbon laboratories that dated samples from Alsónyék

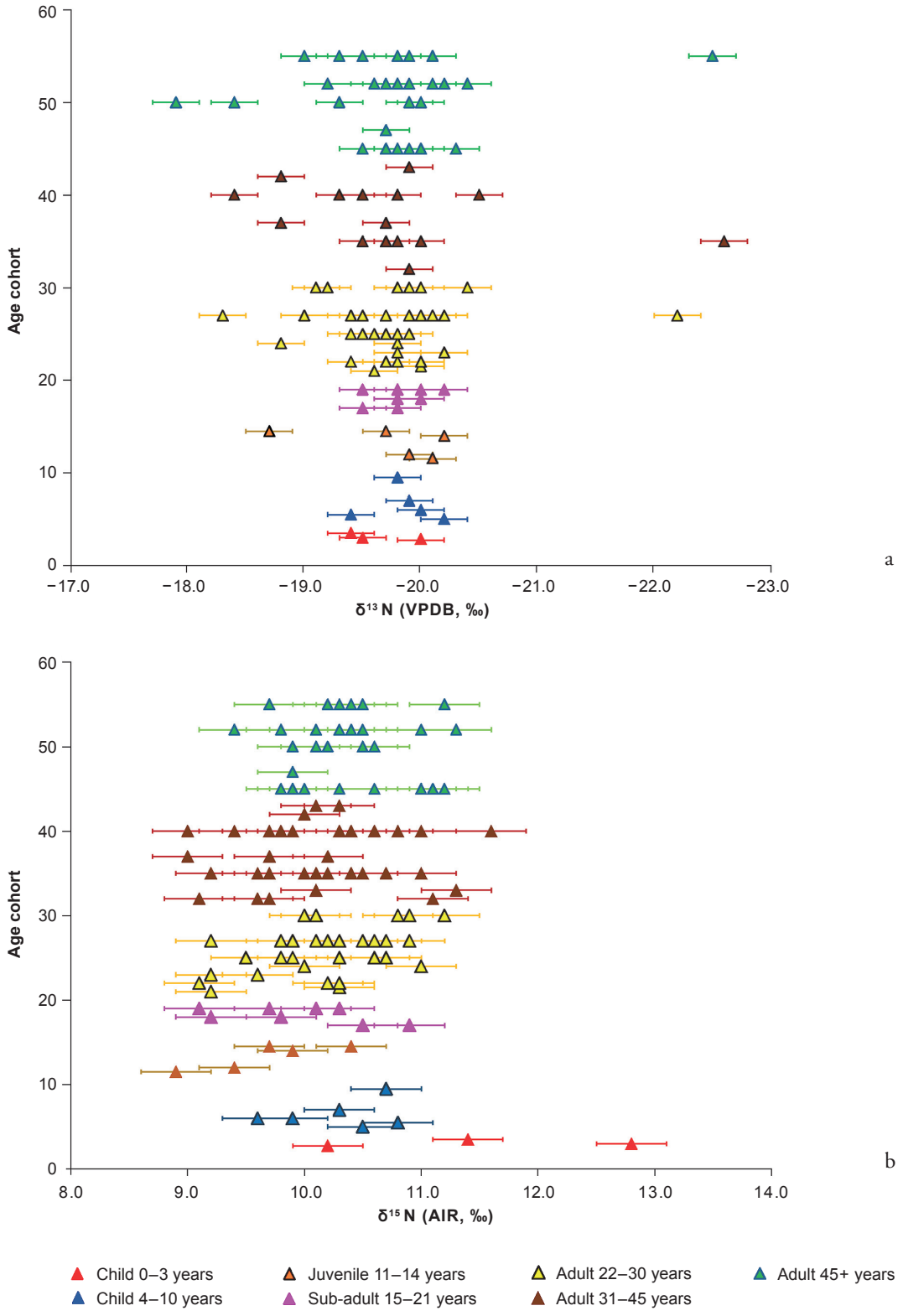

Fig. 12. (a) $\delta^{13}C$ values and (b) $\delta^{15}N$ values for Lengyel skeletons by age cohort (error bars at 1σ).

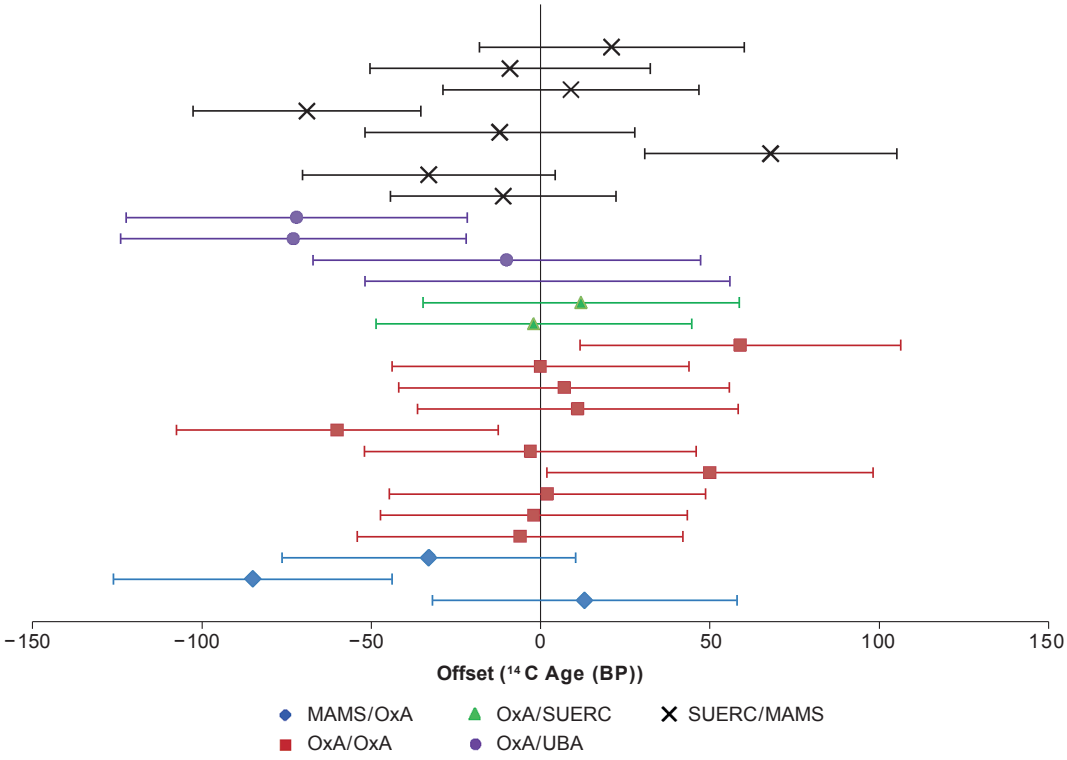

Fig. 13. Offsets between pairs of replicate radiocarbon measurements (error bars at 1σ; see *tab. 8*).

maintain continuous programs of internal quality control, and also take part in international intercomparisons (Scott et al. 2010a; 2010b). One common method of intra-laboratory quality control is to undertake replicate measurements on a random basis. These replicate measurements are not usually reported, although those produced at the Oxford Radiocarbon Accelerator Unit for the sites on this project are included in *tab. 8*. Further replicate measurements are available on samples that have been dated by two different laboratories *(tab. 8)*.

Twenty-five replicate groups are included in *table 8*, including one sample that has been dated four times. Twenty-three of these groups are statistically consistent at 95% confidence, with the other two being statistically inconsistent at 95% confidence, but consistent at 99% confidence (Ward / Wilson 1978). This scatter is in line with statistical expectation. The offsets between the pairs of measurements are shown in *figure 13*. These scatter around zero, suggesting that there is no detectable bias between laboratories.

No fewer than 77 replicate pairs of $\delta^{13}C$ and $\delta^{15}N$ measurements are available *(tabs 2; 5–7)*. Sixty-nine of the pairs of $\delta^{13}C$ values are statistically consistent at 95% confidence, with a further five being statistically inconsistent at 95% confidence, but consistent at 99% confidence (Ward / Wilson 1978). This is again in line with statistical expectation, although there are also two clear misfits. (One of the $\delta^{13}C$ values for 5603/2-464 and one of the $\delta^{13}C$ values for 5603-2360/8759 are probably erroneous, although it is not possible to determine which one as all values lie within the expected range for the dated material.) The offsets between the pairs of $\delta^{13}C$ measurements are shown in *figure 14*. This graph shows that there may be some bias between laboratories in $\delta^{13}C$, although this is probably

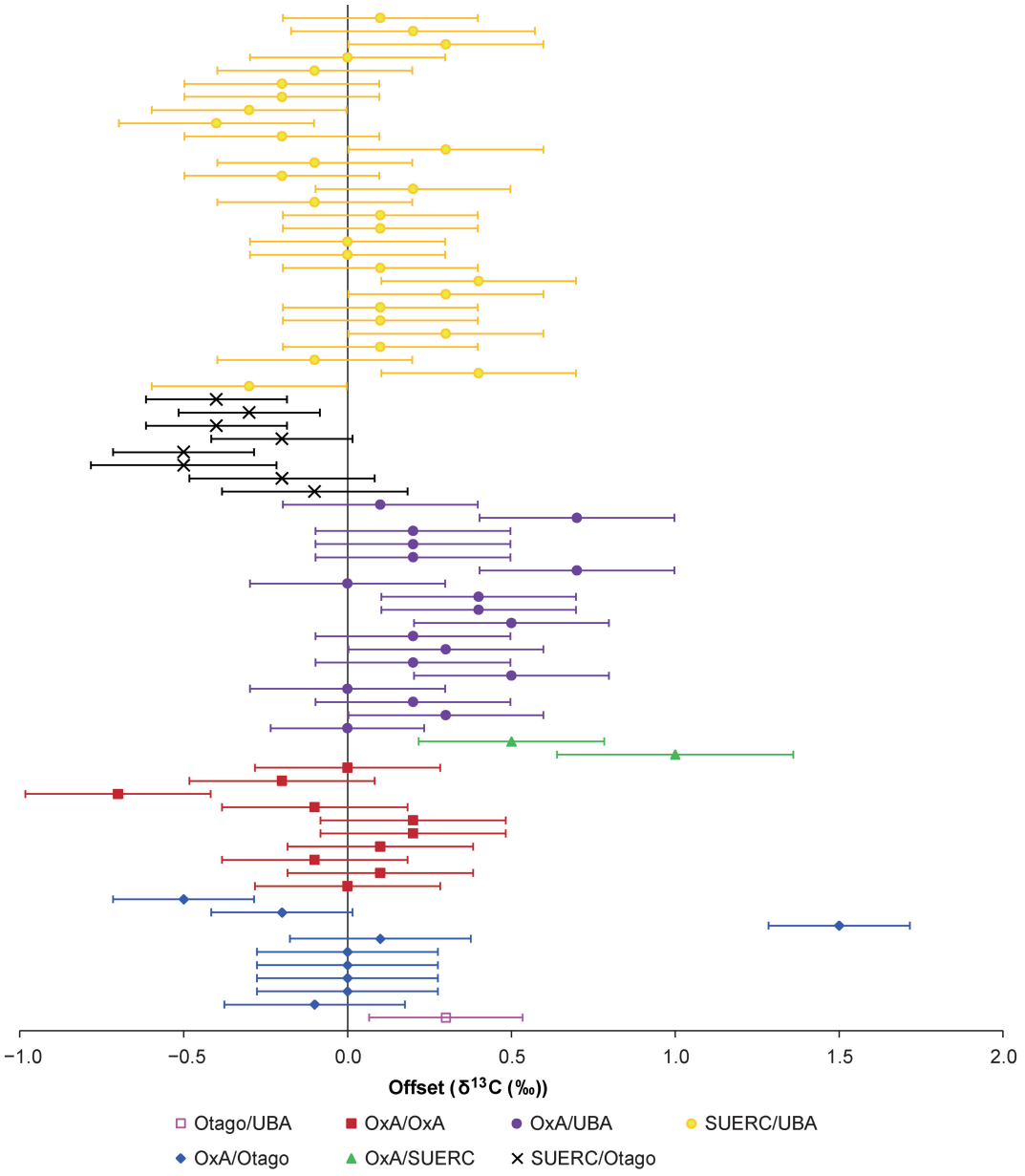

Fig. 14. Offsets between pairs of replicate $\delta^{13}C$ values (error bars at 1σ; see *tabs 2; 5–7*).

of less than the quoted errors at one standard deviation. Seventy-one of the pairs of $\delta^{15}N$ values are statistically consistent at 95% confidence, with a further five being statistically inconsistent at 95% confidence, but consistent at 99% confidence (Ward / Wilson 1978). This is again in line with statistical expectation. There is one pair which differs to a greater extent, although one of these values may simply be an extreme outlier. The offsets between the pairs of $\delta^{15}N$ measurements are shown in *figure 15*. These scatter around zero, suggesting that there is no detectable bias between laboratories in the measurement of $\delta^{15}N$.

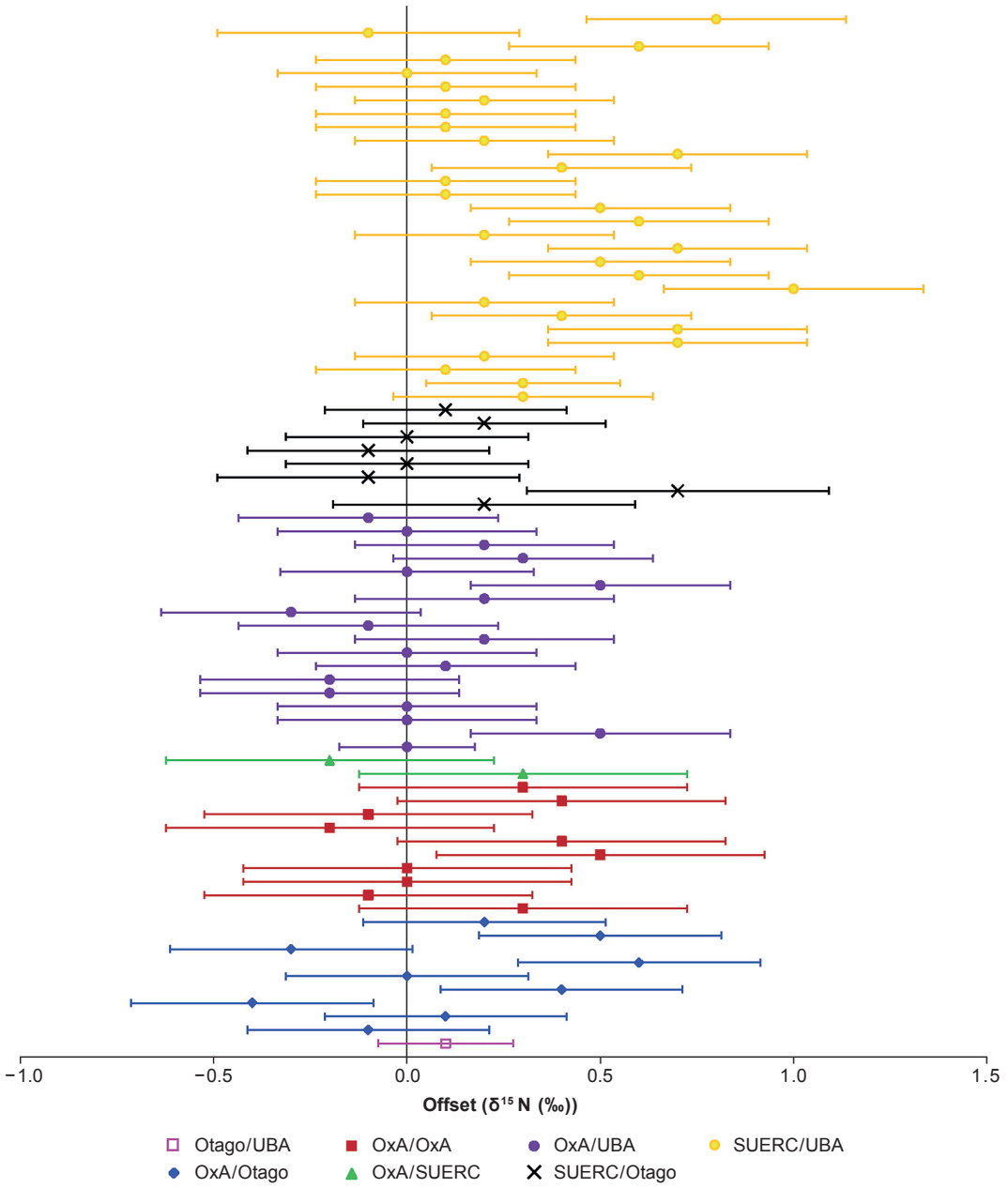

Fig. 15. Offsets between pairs of replicate $\delta^{15}N$ values (error bars at 1σ; see *tabs 2; 5–7*).

This replicate analysis demonstrates the reproducibility of the published radiocarbon and stable isotopic measurements from Alsónyék. As reported below, however, the protocols described in this section identified a technical problem with some of the results in an initial batch of measurements from the Lengyel cemetery reported by the ^{14}CHRONO Centre, Belfast. This enabled us to withdraw the affected measurements and re-date the samples where appropriate. Perhaps more importantly, the laboratory was able to resolve this issue swiftly.

Sampling in practice at Alsónyék

Following the results of the pilot series of radiocarbon dates on 'perfect pairs' of human and animal bone samples from the same grave *(tab. 1)*, it was apparent that human bone from the Lengyel burials was not subject to wide-scale freshwater reservoir effects. Free of this complication, sampling began in earnest with the submission of first sets of samples from the Lengyel and Sopot burials in the autumn of 2012.

Approximately 20 graves from each of the three excavation areas of the Lengyel site were submitted for dating to investigate questions relating to the overall use of the site and the potential for its growth and spatial development over time. Most samples came from skeletons buried with grave assemblages which were likely to fit into the site seriation of Lengyel ceramics that was under construction at this time. In addition to these a selection of graves were sampled where the skeletal remains showed signs of pathology, or the burial rite was outside of the norm. The initial sample selection was informed not only by the overall spread of the graves across the site, which we attempted to keep relatively even, but also by the preliminary analysis that had been made on the grave goods in advance of more detailed seriation work, to ensure that we were incorporating graves covering the suspected chronological range. In the end, 95 samples were submitted as part of the initial sampling rounds, with all but 17 providing results (5603 = 23; 11 = 28; 10B = 27).

Eight samples were also submitted for dating from the Sopot burial ground in the autumn of 2012. These samples were from the ditch that was cut by the graves dated by MAMS-14813 and MAMS-14815 *(figs 5;8)*, the 'perfect pair' from grave 5603/2-475 *(fig. 6)*, and an intercutting sequence of three burials, 5603/2-476, which cut 5603/2-464, which cut 5603/2-475.

No replicate samples were included in this round of sample submission. Partly this was so that replicates could be chosen later in the programme where they could be targeted on deposits where additional precision would be welcome (thus refining the site chronology, in addition to their quality assurance role), but mostly this was because we expected a site seriation of the ceramics to be available by the time the results were reported which would provide a relative sequence for many of the burials that could be used to cross-check the radiocarbon dates.

The results from this round of sample submission were reported in the spring of 2013, and preliminary modelling was undertaken. This modelling raised concerns about the comparability of the results reported by the Belfast and Oxford laboratories, with a proportion of the results on bone from Belfast appearing to be offset towards slightly more recent ages, although no offset was apparent in the laboratory bone standards (VIRI samples; Scott et al. 2010a; 2010b). The initial results from the three intercutting graves from the Sopot burial ground were incompatible with the recorded stratigraphy, with a Belfast result from the stratigraphically earliest burial (5603/2-476) being several hundred years later than the results (from Oxford and Belfast respectively) from the two overlying burials. The result from 5603/2-464 was, however, much earlier than was expected on archaeological grounds.

The second series of samples, submitted for dating in the summer of 2013, included a series of nine replicate samples intended to investigate this suspected issue.

The initial modelling suggested that Lengyel burial in subsite 10B at Alsónyék probably covered only part of the suspected currency of Lengyel pottery in Transdanubia (although there might be sporadic later graves), but that burial in subsite 11 probably covered a greater time span, and that burial in subsite 5603 went on for longest of all. It seemed that particular grave groups might have been used for relatively restricted periods within the use

of each area of the site. Consequently, the second set of samples for the Lengyel site focused more intently on specific grave groups to answer or clarify questions relating to the timing or temporality of each group or a specific artefact type. Potentially later graves, those that contained copper artefacts, especially heavy arm rings and multi-row necklaces, were also targeted. A satistifactory site-based seriation of the ceramics in Lengyel graves had still not been produced, although it had been extended by inclusion of a sample of graves from subsite 11. The longer timespan suggested by the preliminary modelling of subsites 11 and 5603, however, suggested that sufficient variation was likely to exist for this to be possible. A new typology and seriation of stone axe types were also under construction (Zalai-Gaál et al. 2014a), and some additional samples came from graves containing diagnostic stone axe-heads. A total of 37 further samples were submitted in the second round, all to the Oxford Radiocarbon Accelerator Unit.

The first samples were also submitted from the Starčevo and LBK sites in the summer of 2013. On the Starčevo site the samples came from settlement features containing diagnostic assemblages of the identified ceramic style groups, as far as possible from features which were cut by burials that had already been dated as part of the aDNA project. The samples from the LBK settlement derived from the long pits of houses that were laid out in a row-like arrangement, or from long pits from houses adjacent to these, and from burials that cut the sampled long pits. In both cases, the minimum number of samples was submitted that would produce the desired precision (as determined by the simulation models), given the expected date ranges of these sites. Samples were submitted to the Oxford Radiocarbon Accelerator Unit and the Scottish Universities Environmental Research Centre.

The replicate measurements were reported in the autumn of 2013, with the results reported by Belfast being more than 3σ younger than those from Oxford on slightly more than half the samples. Since it was not possible to know which of the Belfast ages were anomalously recent, regretfully, we decided that all the results reported by the laboratory in the spring of 2013 should be withdrawn. Further replicate material was, however, submitted to aid in the resolution of the technical problem.

Unfortunately, by the spring of 2014, it had become clear that this issue persisted. The second stage of interim modelling, undertaken using the results reported by Oxford in the spring and autumn of 2013, made it clear that the majority of burials had occurred in a concentrated span of little more than a century. This explained why there was insufficient variation in the ceramics in the grave-assemblages from subsites 10B and 11 for a viable site-based seriation. The spatial extent of this seriation, and the radiocarbon dating programme associated with it, was consequently extended to cover Transdanubia and areas further north, and will be reported elsewhere (see Zalai-Gaál et al. 2014b). Given the short duration of the burial activity, which meant that further samples would do little to refine our understanding of the chronology of the site, the third set of samples for the Lengyel cemetery was confined to repeat of a sub-set of the sample originally dated at Belfast by another laboratory. A total of 31 samples were submitted to the Scottish Universities Environmental Research Centre.

The sampling of the Lengyel settlement at Alsónyék was also undertaken in the spring of 2014, in an attempt to discern whether there was any chronological difference in the use of the three areas for settlement or burial activity. Articulating and articulated animal bone samples were selected from pits that were spread across the site, had close associations with individual houses and had stratigraphic relationships with other pits or human burials. A total of 77 samples were dated at the Scottish Universities Environmental Research Centre and the Curt-Engelhorn-Zentrum Archäometrie, Mannheim (including eight replicate samples).

By the autumn of 2014, the technical issue at the ^{14}CHRONO Centre in Belfast had been resolved. A slightly revised protocol for bone pretreatment was adopted (for samples UBA-24991 and above; Reimer et al. 2015), and four statistically consistent results on samples that had already been dated at Oxford were reported *(tab. 8; fig. 13)*.

The final round of sampling was undertaken in the winter of 2014. Small numbers of additional samples were submitted from the Starčevo and LBK sites, largely to replace samples that had failed. These samples were sent to the Scottish Universities Environmental Research Centre and the Poznań Radiocarbon Laboratory.

Final modelling was undertaken over the spring and summer of 2015.

This narrative is important because it explains how the iterative approach to sampling, radiocarbon dating and modelling shown in *figure 3* worked in practice. It explains how the radiocarbon dates for each site were assembled.

The sample for the Lengyel cemetery is not ideal, as the selection of samples in the summer of 2013 was based on a preliminary model which gave an exaggerated idea of the duration of the cemetery because it contained a proportion of dates that were subsequently withdrawn. If the short duration of burial, particularly in subsite 10B, had been apparent at this time, the concentrated sampling of particular grave groups in an attempt to untangle their chronological relationships would not have been undertaken. As it is, the sample of radiocarbon dates from these grave groups is out of proportion with the overall span of the cemetery. This has affected the approach taken to modelling the chronology of this cemetery (Osztás et al. this volume [b], 144).

The sample for the LBK settlement is also not ideal, but this is because samples suitable for radiocarbon dating were surprisingly scarce and the preservation of collagen in the bones that were submitted for dating was surprisingly poor.

Radiocarbon dating

All samples were of animal or human bones and were prepared using gelatinisation and ultrafiltration (Brown et al. 1988; Brock et al. 2010). Samples were then combusted, graphitised and dated by Accelerator Mass Spectrometry (AMS). Methods differ slightly according to the preferences and available equipment in different laboratories.

The 128 samples dated at the Oxford Radiocarbon Accelerator Unit (OxA-) were gelatinised and ultra-filtered as described by Brock et al. (2010), combusted and graphitised (Dee / Bronk Ramsey 2000), and dated by AMS (Bronk Ramsey et al. 2004b). The 99 samples dated at the Scottish Universities Environmental Research Centre (SUERC-) were similarly gelatinised and ultra-filtered as described by Brock et al. (2010), combusted to carbon dioxide (Vandeputte et al. 1996), graphitised (Slota et al. 1987), and dated by AMS (Freeman et al. 2010). The 56 samples dated at the Curt-Engelhorn-Zentrum Archäometrie, Mannheim (MAMS-) were prepared by gelatinisation and ultra-filtration (Brown et al. 1988), combusted in an elemental analyser, graphitised and dated by AMS (Kromer et al. 2013). The nine samples dated by the Poznań Radiocarbon Laboratory (POZ-) were gelatinised and ultra-filtered (Brown et al. 1988), combusted and graphitised (Czernik / Goslar 2001), and dated by AMS (Goslar et al. 2004). The four results reported from the ^{14}CHRONO Centre, Belfast (UBA-) underwent the revised bone pretreatment protocol adopted in Belfast (for samples UBA-24991 and above), were graphitised using zinc reduction (Slota et al. 1987) and dated by AMS (Reimer et al. 2015).

The $\delta^{13}C$ and $\delta^{15}N$ measurements reported for these samples were obtained by Isotope Ratio Mass Spectrometry (IRMS) on the gelatin extracted for dating. At Oxford $\delta^{13}C$ and

$\delta^{15}N$ were measured by a mass spectrometer attached directly to the CN analyser used to combust the samples to carbon dioxide. At SUERC $\delta^{13}C$ and $\delta^{15}N$ samples were prepared and analysed as described by Sayle et al. (2014). Sub-samples of the dated gelatin prepared at MAMS- were analysed for $\delta^{13}C$ and $\delta^{15}N$ at the Isotrace facility, University of Otago Chemistry Department, using methods outlined by Beavan Athfield et al. (2008, 3). Sub-samples of the dated gelatin prepared at Poznań were analysed for $\delta^{13}C$ and $\delta^{15}N$ at the Institute of Geological Sciences, Polish Academy of Sciences, Warsaw. Samples were wrapped in tin foil, combusted at 1020 °C, and their stable isotopic composition determined using a Thermo Flash EA 1112HT elemental analyser connected to a Thermo Delta V Advantage Stable Isotope Ratio Mass Spectrometer. Sub-samples of collagen prepared at Belfast were sealed in tin foil capsules and analysed using a Thermo Delta V Advantage Stable Isotope Ratio Mass Spectrometer with Flash EA. Additional stable isotopic measurements reported from the Bioarchaeology Workgroup Mainz were obtained as described by Knipper et al. (2013).

Model construction and calculation

After each set of results is returned, chronological models are constructed to provide an indication of how the data so far gathered achieve the objectives of the dating programme. In theory, this is a simple process – the archaeological prior information identified during the sampling process is combined with the radiocarbon dates reported from the samples that have been selected and dated in relation to that prior information *(figs 2; 3)*. In practice, it is rarely simply a matter of replacing the simulated ages input into the simulation models during the sample selection process with actual radiocarbon ages. Almost always elements of the model will conflict with one another, and thus Wylie's (2002, 162–163) 'dynamic judgements and revisions' are required to resolve the disparate strands of evidence.

In principle, once the model has been defined, the posterior beliefs can be calculated using Bayes' theorem *(fig. 2)*. In practice, however, almost all chronological models have so many independent parameters that the number of possible outcomes to consider at a useful resolution makes such a calculation impractical. For this reason, Markov Chain Monte Carlo (MCMC) methods are used to provide a possible solution set of all of the parameters of the model.

MCMC methods simulate a stochastic process in which future states are independent of past states given the present state. This means that each iteration of the algorithm is random and retains no memory of where it has been. It allows us to infer quantities of interest of a distribution from simulated draws from that distribution, although very large numbers of draws are required to generate a representative solution (see Bronk Ramsey 2009a, 353). The Monte Carlo sampling process allows OxCal to 'sample' the prior probability distributions (i. e. usually calibrated radiocarbon dates), and then attempt to reconcile these distributions with the prior beliefs included in the model, by repeatedly sampling each distribution to build up a set of solutions consistent with the model structure. The probability of a particular solution appearing in the MCMC analysis should be directly proportional to its probability as defined by the posterior probability density. In OxCal v4.2, this is done using the Metropolis-Hastings algorithm (Gilks et al. 1996).

In most cases a representative solution can be generated by this method, although, because a sampler is employed, each solution will be very slightly different. In practice, this means that every run of a model produces slightly different results, and so Highest Poster-

ior Density intervals can vary by five years, when rounded outwards to the nearest five years, simply based on the solution of the model.

The MCMC algorithm should eventually give representative posterior distributions. If there are too few iterations in the analysis, the resulting probability distributions will usually be noisy and will vary from run to run. The degree to which a truly representative solution set has been generated is called 'convergence'. The verification of convergence in models which employ MCMC sampling is not straightforward and a number of diagnostic tools have been proposed (Cowles / Carlin 1996). That employed in OxCal is described by Bronk Ramsey (1995, 429).

The convergence integral used in OxCal has a critical value of 95%, and models which fail to pass this threshold may be unstable and their outputs should be regarded with the utmost caution (Bronk Ramsey 1998, 469). The program attempts to produce stable models by increasing the number of passes the MCMC sampler calculates each time the convergence value falls below 95%. In an attempt to ensure stable outcomes, in this project all models described in this volume have been calculated using a minimum of 20 million passes (and at a resolution of one year).

Model validation

Stability of the model outputs is not the only criterion which models must satisfy to be believable. We also need to consider whether the two components input into the model, the 'prior beliefs' and the 'standardised likelihoods', are compatible.

At present the validation of Bayesian models is an inexact science, although several statistical approaches have been developed which can assist in the identification of incorrect models and incompatible prior beliefs and standardised likelihoods. Statistics alone cannot be relied upon to identify all the incorrect components of a model, and archaeological critique of the character and context of the dated material and scientific understanding of the complexities of radiocarbon dating are key elements in model validation. At Alsónyék, we have employed two alternative statistical approaches for assessing the compatibility of the components of a model, both provided with OxCal v4.2.

The first method utilises diagnostic statistics provided with OxCal v4.2 called agreement indices (Bronk Ramsey 1995, 429; 2009a, 356–357) to aid in the validation of models. These are not derived from a formal statistical approach and have the disadvantage that there is no theoretically defined cut-off applicable in all cases, but they do have the advantage that the model itself is not affected by the calculations. They are also easy to calculate and have proved useful and robust in practice for a wide range of case studies (e. g. Bayliss / Whittle 2007).

The individual index of agreement (A: Bronk Ramsey 1995, 429) provides a measure of how well the posterior distribution (i. e. that incorporating the prior information and shown in black in *fig. 4*) agrees with the prior distribution (i. e. the calibrated date, or standardised likelihood, shown in outline in *fig. 4*); if the posterior distribution is situated in a high-probability region of the prior distribution, the index of agreement is high, and if it falls in a low-probability region, it is low. Most individual indices of agreement in a model should be above 60 (a threshold value obtained by simulation). Usually those that fall below this level are statistical outliers, although a very low index of agreement may suggest that a particular component of the model is wrong and needs further examination.

An overall index of agreement is then calculated for the model from the individual indices of agreement, providing a measure of the consistency between the prior information

and the scientific dates (Amodel: Bronk Ramsey 2009a, 357). Again, the model index of agreement generally has a threshold value of 60, and models which produce values lower than this should be subject to critical re-examination. This statistic is shown in the bottom left-hand corner of the technical graphs (e. g. [Amodel: 95]; *fig. 4*). It should be noted that indices of agreement provide an indication of whether the components of a model are compatible; they do not provide a quantitative measure of their plausibility. So, for example, a model with an overall index of agreement of Amodel: 120 is no more plausible than one with Amodel: 80 (although both are more plausible than one with Amodel: 50).

Having identified problems with particular dates, or with particular components of a model, these need to be resolved. Sometimes this may involve a reassessment of elements of the prior archaeological information included in the model. For example, the radiocarbon dates from Graves 5603/2-475 and 5603/2-464 in the Sopot site were incompatible with the recorded stratigraphy, which led to a reassessment of the archive and subsequently a revision to the relative sequence of these burials (Oross et al. this volume [c], 166).

In other cases, single dates need to be reinterpreted individually and handled appropriately. The best way of dealing with such dates depends on our assessment of why they are problematic. The most common categories are:

– Misfits – dates which do not fit in the expected stratigraphic position, or which are inaccurate for some technical reason. Generally, samples which prove to be residual can be used as *termini post quos* for their contexts, but intrusive samples or inaccurate dates need to be excluded from the analysis. Into this category fall the five radiocarbon dates on post-Neolithic samples from Alsónyék *(tab. 9)*.
– Outliers – the 1 in 20 dates whose true calendar date lies outside the 95% range. These must be retained in the model as their exclusion would statistically bias the results. An example is *MAMS-11929: Burial 748* (Oross et al. this volume [a], fig. 6), which has an individual index of agreement of (A: 55) but is retained in the model.
– Offsets – measurements that are systematically offset from the calibration data by a knowable amount. Reservoir effects can be accounted for in the calibration process (as has been discussed above in relation to a potential freshwater reservoir effect for samples from human and dog skeletons).

The major advantage of the individual agreement indices provided by OxCal (Bronk Ramsey 1995, 429) is that they identify potential mismatches between components of a model without affecting the outputs of the model. This allows us to deal with each case individually, using our archaeological judgement about the character of particular samples and deposits to decide how to include each date in the model depending on its specific characteristics. The major disadvantage of this approach is that the indices of agreement provided by OxCal are not derived from a formal statistical approach. This is the approach used for outlier detection by Oross et al. (this volume [a], [b] and [c]).

The second statistical approach that we have employed for assessing the compatibility of the components of a model is formal statistical outlier analysis (Christen 1994; Bronk Ramsey 2009b). This assumes that we can never really be sure whether any particular measurement is an outlier, and so weights each sample according to how likely it is be correct using a model averaging approach. In this method each measurement is given a prior probability of being an outlier (typically a low probability like 5%) and the date is further down-weighted in the model if it is incompatible with the rest of the available information. The output from the model is affected by this down-weighting, and in addition to the normal model outputs, a posterior probability for the sample being an outlier is also generated. These probabilities are shown on the figures so, for example, *OxA-27472: 11-679* has

a prior outlier probability of 5% but a posterior outlier probability of 28% (Ostzás et al. this volume [b], fig. 15). Either this probability can be used to identify outliers and remove them, or the model which incorporates outlier weighting can be accepted (Bronk Ramsey et al. 2010).

The advantage of this method is that it is an explicit statistical process; the disadvantage is that it may not take account of the archaeological information we may have about the relative strengths and weaknesses of particular samples or deposits. It is particularly useful, however, in situations where we do not have archaeological information about which samples are problematic in a model. This is the case, for example, for the Lengyel cemetery and settlement in subsite 10B where the issue appears to be that there is infrequent activity earlier and later than the main, intense phase of occupation in this area, but there is no way (other than by radiocarbon dating) to tell which features and burials may belong outside this phase of concentrated occupation. Since in this case we aim to identify samples that are outliers on the calendar scale, we use the general outlier model proposed by Bronk Ramsey (2009b, 1028) for the preferred Lengyel models presented by Ostzás et al. (this volume [b], figs 12–13; 15–16; 18–19).

Model comparison

Having constructed a plausible chronological model, the next step in Bayesian modelling is to assess its sensitivity to different aspects of the model being incorrect. This construction of alternative models is called sensitivity analysis. One component of a model is changed and it is rerun. The posterior density estimates from the original model and its variant are then compared. When these outputs are very similar, then the model can be regarded as insensitive to the component of the model that has been varied. When the outputs differ markedly, the model is sensitive to that component. Sensitivity analyses are useful not only in determining how far the outputs of a model are stable, but also help us to identify which components of a model are most critical.

For example, the sensitivity analyses incorporating mixed-source calibration for those sites whose models include a significant number of radiocarbon measurements on human bone vary little from the models calculated using a fully terrestrial calibration, demonstrating that these models are insensitive to the technical risk of a freshwater reservoir effect in these samples (Oross et al. this volume [c], 167; Osztás et al. this volume [b], 231).

Prehistoric histories

With much more robust estimates of both date and duration, we can begin to write different kinds of (pre)histories of the Neolithic. This means we need to configure narrative from succession (Ricoeur 1984, 52), using more refined timings and tempo to investigate relationships and causation. At Alsónyék we can see diverse communities inhabiting the landscape in the centuries around 5000 cal BC. People probably lived contemporaneously in the LBK and Sopot settlements, which were less than 1.5 km apart, for perhaps 3–5 generations and yet maintained their distinctive ceramic and cultural identities. We also have the big data of extensive excavation to complement our precise timings. This enables us to provide quantitative estimates for the intensity of occupation at Alsónyék by spreading the estimated number of features in each site or subsite across the period during which it was occupied (Bánffy et al. this volume, fig. 7).

The Lengyel settlement clearly saw a sustained aggregation of the community at an unprecedented scale. Our timings allow us to assess the pace of this coming together and the subsequent diaspora. And we can estimate the size of this assembly not just on a scale relative to earlier Neolithic settlements in this landscape, but on an absolute scale of people. Combining the chronologies for different areas of the Lengyel burial ground with formal population estimates based on the osteological analysis of the skeletal assemblage, we can not only estimate the population of the Lengyel settlement, but track how this changed at a generational scale (Bánffy et al. this volume, fig. 9). Combining the chronologies for different areas of the Lengyel settlement with the estimated number of timber houses which each area of the site contained, we can estimate how many houses were occupied at any one time, again tracking change at a generational scale (Bánffy et al. this volume, fig. 10). Putting these two estimates together, we can even provide formal estimates for the average size of a Neolithic household at Alsónyék (Bánffy et al. this volume, 304).

This illustrates the need to go beyond chronology. A mere recitative of dates treats past events as isolated happenings laid out in succession like beads on a string (Ingold 1993, 157). We need to use our new, precise chronologies to reveal the web of connections and successions that made up past lives. We need to add plot and context to the chronicle. This is peopling the past.

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Summary · Zusammenfassung · Résumé

SUMMARY Imprecise chronology has entailed a fuzzy kind of prehistory. Prehistorians should no longer be content with timeframes that employ successive units of 200 years or more duration, or with slow change over the long term as their dominant chronological and interpretative perspective. The means to get away from very generalised accounts of the past is formal chronological modelling in a Bayesian framework. The Bayesian approach in general is outlined, with emphasis on its interpretive and iterative nature. The approach combines calibrated radiocarbon dates with knowledge of the archaeological contexts from which they are derived to produce a series of formal, probabilistic date estimates. Stringent demands are made of both the radiocarbon dates and our archaeological understanding of stratigraphy, associations, sample taphonomy and context in general. The Bayesian process at Alsónyék involved assessment of existing dates, careful definition of aims and objectives, the construction of a rigorous sampling strategy, with an explicit hierarchy of suitable samples, precise understanding of the contexts from which samples are derived, and simulation to achieve cost-effective use of resources. The principal material dated at Alsónyék was human and animal bone. Potential age offsets from non-vegetarian diets are carefully considered; 'perfect pairs' of human and animal bone samples from the same contexts indicate that human bone samples are not subject to wide-scale freshwater reservoir effects. Dietary inputs are estimated formally using a series of Bayesian mixing models. The sequence of iterative sampling submissions between 2012 and 2015 is described, and the procedures of the five laboratories involved are detailed. Procedures for model construction, validation and comparison are discussed. Finally, we consider how we can use precise timings to reveal the web of connections and successions that made up past lives, adding plot and context to a more precise chronicle to create narratives for peopling the past.

ZUSAMMENFASSUNG Ungenaue Chronologien bewirken ein sehr unscharfes Bild der Ur- und Frühgeschichte. Prähistoriker sollten sich nicht länger mit zeitlichen Rahmen zufrieden geben, die mit aufeinander folgenden Einheiten von 200 Jahren oder noch längerer Dauer oder mit nur langsamen Veränderungen über lange Zeitspannen als Grundlage für ihre Chronologien und Interpretationen arbeiten. Ein Mittel, diesen sehr verallgemeinernden Aufstellungen zu begegnen, ist die Modellierung einer Chronologie, die auf dem Bayes'schen Ansatz beruht. Dieses Vorgehen wird hier vorgestellt, mit einem Fokus auf seine interpretative und iterative Natur. Der Bayes'sche Ansatz kombiniert kalibrierte Radiocarbondaten mit Erkenntnissen zu archäologischen Kontexten, aus denen sie stammen, um eine Serie von Wahrscheinlichkeitsvorhersagen zu gewinnen. Sowohl die Radiocarbondaten als auch das archäologische Verständnis von Stratigraphie, Vergesellschaftungen, Taphonomie der Proben und Kontext im Allgemeinen unterliegen strengen Anforderungen. Der Bayes'sche Prozess in Alsónyék umfasst die Bewertung bereits existierender Daten, eine umsichtige Definition von Zielen und die Erstellung einer zielführenden Strategie für die Beprobung. Letztere beinhaltet mit Ziel einer kosteneffizienten Ressourcennutzung eine klare Hierarchie geeigneter Proben, ein genaues Verständnis ihrer Kontexte und Simulationen. Die Proben wurden hauptsächlich menschlichem und tierischem Knochenmaterial entnommen. Mögliche Altersunterschiede aus nicht-pflanzlicher Ernährung wurden genauestens geprüft; „perfekte Paare" menschlicher und tierischer Knochenproben aus dem gleichen Kontext belegen, dass Proben von Menschenknochen nicht von größeren Frischwasser-Reservoir-Effekten betroffen sind. Ernährungsdaten werden durch den Einsatz einer Serie von Bayes'schen Mischmodellen berechnet. Der Ablauf der iterativen Probeneingaben zwischen 2012 und 2015 und die Arbeitsprozesse innerhalb der fünf beteiligten Labore werden

ausführlich beschrieben. Die Prozesse der Erarbeitung, der Gültigkeitsprüfungen und der Gegenüberstellung der Modelle werden diskutiert. Zum Schluss wird abgewogen, wie genaue Zeitberechnungen am besten verwendet werden können, um das Netzwerk von Verbindungen und Abfolgen der vergangenen Kulturen aufzudecken. Handlungen und Kontexte werden dann in eine präzise Chronik eingebunden, um ein Bild des prähistorischen Lebens zu zeichnen. (M. E.)

RÉSUMÉ Des chronologies imprécises ont mené à une image plutôt vague de notre préhistoire. Les préhistoriens ne devraient plus se contenter de cadres chronologiques construits sur des unités de 200 ans ou plus, ni même de lentes évolutions à long terme en guise de principale perspective chronologique et interprétative. Le moyen d'échapper à une description très grossière du passé est de recourir à une modélisation chronologique se basant sur l'approche bayésienne. Cette dernière est présentée ici, avec une attention centrée sur sa nature interprétative et itérative.

L'approche bayésienne permet de combiner à la fois des dates radiocarbone calibrées et des informations issues de leurs contextes archéologiques, pour établir une série d'estimations probabilistes. Tant les datations au radiocarbone que notre compréhension archéologique de la stratigraphie, des associations, de la taphonomie des échantillons et du contexte en général, sont soumises à des exigences rigoureuses. La procédure bayésienne adoptée impliqua l'évaluation de datations existantes, une définition précise des buts et objectifs, l'élaboration d'une stratégie d'échantillonnage rigoureuse avec une hiérarchie explicite d'échantillons appropriés, une idée précise des contextes de provenance des échantillons, et une simulation en vue d'utiliser les ressources de la manière la plus rentable possible. Le matériel daté du site d'Alsónyék fut constitué essentiellement d'os humains et de faune. De potentielles différences d'âge issues d'une alimentation carnée sont examinées avec attention ; des « paires parfaites » d'échantillons d'os humains et d'animaux révèlèrent que les échantillons d'os humains n'ont pas subi les effets d'eau dure à grande échelle. Les apports alimentaires sont estimés selon les normes d'une série mixte de modèles bayésiens. La séquence des remises itératives d'échantillons entre 2012 et 2015 ainsi que les procédures des cinq laboratoires sont présentées en détail. Les procédures de création, de validation et de comparaison des modèles sont également discutées. La manière d'employer des chronologies plus précises afin d'identifier le tissu de liens et de successions qui ont constitué les existences passées est enfin examinée. Trames et contextes sont ensuite incorporés dans une description dense afin de créer des récits capables de faire vivre le passé. (Y. G. / E. P.)

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Laboratory code	Context description [sample identifier]	Radiocarbon age (BP)	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N$ (‰)	C:N ratio	Statistical consistency (Ward / Wilson 1978)
OxA-26698	Deer antler fragment about 20cm long, found as a grave good in burial 1821 [5603-1821 (animal)]	5742 ± 32	–19.9 ± 0.2	6.1 ± 0.3	3.2	T′ = 2.0; T′ (5%) = 3.8; ν = 1
OxA-26699	Human right femur from crouched articulated adult male skeleton in grave 1821 [5603-1821 (human)]	5805 ± 31	–19.5 ± 0.2	9.8 ± 0.3	3.2	
OxA-26696	Complete aurochs bucranium found as grave good in burial 3060 [10B-3060 (animal)]	5860 ± 32	–19.7 ± 0.2	6.8 ± 0.3	3.2	T′ = 0.0; T′ (5%) = 3.8; ν = 1
OxA-26697	Human right femur from crouched articulated adult male skeleton in grave 3060 [10B-3060 (human)]	5855 ± 32	–19.5 ± 0.2	11.5 ± 0.3	3.2	
OxA-26694	Wild boar skull found as grave good in burial 3472 [10B-3472 (animal)]	5814 ± 31	–20.5 ± 0.2	4.9 ± 0.3	3.2	T′ = 0.0; T′ (5%) = 3.8; ν = 1
OxA-26695	Human right femur from crouched articulated adult male skeleton in grave 3472 [10B-3472 (human)]	5820 ± 32	–19.8 ± 0.2	11.1 ± 0.3	3.2	
OxA-27307	Cattle rib from five articulated right cattle ribs found under the head of the human skeleton in grave 475 [5603/2-475a]	5979 ± 37	–20.0 ± 0.2	6.6 ± 0.3	3.1	T′ = 0.0; T′ (5%) = 3.8; ν = 1
MAMS-20486	Human bone from supine skeleton of an older child/early adolescent (14–15 years old) buried with their head lying on a rack of cattle ribs in grave 475 [5603/2-475]	5981 ± 26	–20.3 ± 0.08	9.5 ± 0.09	3.3	

Tab. 1. Radiocarbon results and associated measurements from ‘perfect pairs’ of contemporary human and animal bone from Alsónyék.

Cultural association	Laboratory number	Sample No.	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
Starčevo		5603/1 F1373	*Abramis brama*, precaudal vertebra	−26.8 ± 0.19	8.2 ± 0.09	5.2 ± 0.15
Starčevo		5603/1 F610	*Abramis brama*, precaudal vertebra	−19.8 ± 0.19	10.9 ± 0.09	9.5 ± 0.15
Starčevo	SUERC-51451	5603-708/871	Aurochs, left tibia	−21.3 ± 0.2	5.6 ± 0.3	
Lengyel		10B-3060	Aurochs, skull	−19.8 ± 0.2	7.2 ± 0.09	6.6 ± 0.15
Lengyel	OxA-26696	10B-3060	Aurochs, skull	−19.7 ± 0.2	6.8 ± 0.3	
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.8 ± 0.14‰; $\delta^{15}N$: T′ = 1.6, T′(5%) = 3.8, ν = 1, 7.2 ± 0.09‰						
Lengyel	SUERC-52825	11-1373	Aurochs, left horn core	−19.8 ± 0.2	6.8 ± 0.3	
Lengyel	SUERC-52832	11-1703	Aurochs, left os tarsale	−19.5 ± 0.2	8.1 ± 0.3	
Lengyel	SUERC-52827	11-1502-2	Aurochs, metacarpal	−19.3 ± 0.2	7.5 ± 0.3	
Lengyel	MAMS-20676	11-1025	Aurochs, right tarsal	−18.9 ± 0.08	7.9 ± 0.09	
Lengyel	SUERC-52824	11-1025	Aurochs, right tarsal	−19.1 ± 0.2	7.8 ± 0.3	
$\delta^{13}C$: T′ = 0.8, T′(5%) = 3.8, ν = 1, −18.9 ± 0.1‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 7.9 ± 0.1‰						
Starčevo	SUERC-51450	5603-687/1248	Cattle, cervical vertebra	−20.7 ± 0.2	7.4 ± 0.3	
Starčevo	SUERC-57541	5603-704/358	Cattle, left humerus	−20.9 ± 0.2	7.3 ± 0.3	
Starčevo	OxA-X-2586-27	5603-720/848	Cattle, left radius	−21.2 ± 0.2	6.1 ± 0.3	
Starčevo	Poz-67492	5603-708/872	Cattle, right tibia	−20.9 ± 0.33	5.0 ± 0.43	
Starčevo	SUERC-51453	5603-1383/1930	Cattle, left ulna	−21.4 ± 0.2	4.4 ± 0.3	
LBK	SUERC-57548	5603-2368/8748	Cattle, right calcaneum	−20.2 ± 0.2	8.4 ± 0.3	
LBK	OxA-30432	11-2035/3964	Cattle, left femur	−20.6 ± 0.2	6.6 ± 0.3	
LBK	Poz-68349	11-2567/4532	Cattle, right femur	−21.3 ± 0.33	5.7 ± 0.43	

Cultural association	Laboratory number	Sample No.	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
LBK	SUERC-51461	5603-2396/8908	Cattle, left femur	–20.5 ± 0.2	5.8 ± 0.3	
LBK	OxA-30356	11-2527/4391	Cattle, metacarpal	–20.8 ± 0.2	5.9 ± 0.3	
LBK	SUERC-51462	11-2526/4525	Cattle, right metacarpal	–19.6 ± 0.2	6.9 ± 0.3	
LBK	OxA-30357	11-2674/4559	Cattle, right metacarpal	–19.4 ± 0.2	6.7 ± 0.3	
LBK	SUERC-58485	11-2674/4559	Cattle, right metacarpal	–19.9 ± 0.2	6.9 ± 0.3	
$\delta^{13}C$: T′ = 3.1, T′(5%) = 3.8, ν = 1, –19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.2, T′(5%) = 3.8, ν = 1, 6.8 ± 0.22‰						
LBK	SUERC-57543	11-2222/3969	Cattle, right radius	–19.4 ± 0.2	4.8 ± 0.3	
LBK	SUERC-57544	11-2787/4570	Cattle, left radius	–20.9 ± 0.2	8.4 ± 0.3	
LBK	OxA-X-2587-14	11-2564/4891	Cattle, right radius	–20.7 ± 0.2	5.1 ± 0.3	
LBK	SUERC-51464	11-3010/4880	Cattle, thoracic vertebra	–21.3 ± 0.2	6.2 ± 0.3	
LBK	SUERC-51460	5603-2351/9072	Cattle, right ulna	–18.7 ± 0.2	7.0 ± 0.3	
LBK	Poz-68720	11-2519/4385-2	Cattle, left ulna	–21.1 ± 0.33	5.8 ± 0.43	
Sopot	OxA-27872	5603/2-211.1	Cattle metatarsal unfused distal epiphysis	–20.4 ± 0.2	6.5 ± 0.3	
Sopot	UBA-22012	5603/2-211.1	Cattle metatarsal unfused distal epiphysis	–20.7 ± 0.22	6.0 ± 0.15	
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, –20.5 ± 0.15‰; $\delta^{15}N$: T′ = 2.2, T′(5%) = 3.8, ν = 1, 6.1 ± 0.13‰						
Sopot	OxA-27308	5603/2-211.2	Cattle, juvenile right metatarsal	–21.3 ± 0.2	7.1 ± 0.3	
Sopot	OxA-27307	5603/2-475a	Cattle, right rib	–20.0 ± 0.2	6.6 ± 0.3	

Tab. 2. Stable isotopic values obtained on terrestrial herbivores, pigs and wild boar, and freshwater fish samples from Alsónyék. All values were measured by Isotope Ratio Mass Spectrometry. Replicate measurements have been compared and combined using the method of Ward / Wilson (1978). Measurements that are statistically significantly different at 95% confidence are in bold.

Cultural association	Laboratory number	Sample No.	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
Lengyel	SUERC-52843	5603-1889	Cattle, left humerus	−19.1 ± 0.2	6.8 ± 0.3	
Lengyel	MAMS-20672	11-1687	Cattle, left metatarsal	−18.0 ± 0.08	7.0 ± 0.09	
Lengyel	SUERC-52828	11-1687	Cattle, left metatarsal	−18.4 ± 0.2	7.0 ± 0.3	
$\delta^{13}C$: T′ = 3.4, T′(5%) = 3.8, ν = 1, −18.1 ± 0.1‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 7.0 ± 0.1‰						
Lengyel	MAMS-20678	11-208	Cattle, left tibia	−20.0 ± 0.08	5.4 ± 0.09	
Lengyel	SUERC-52845	5603-1974	Cattle, left tibia	−20.2 ± 0.2	6.9 ± 0.3	
Lengyel	SUERC-52853	5603-2827-1	Cattle, left ulna	−19.3 ± 0.2	7.4 ± 0.3	
Lengyel	MAMS-20663	5603-2256	Cattle, metapodial	−19.2 ± 0.08	5.5 ± 0.09	
Lengyel	SUERC-52847	5603-2256	Cattle, metapodial	−19.5 ± 0.2	5.7 ± 0.3	
$\delta^{13}C$: T′ = 1.9, T′(5%) = 3.8, ν = 1, −19.2 ± 0.1‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 5.5 ± 0.1‰						
Lengyel	MAMS-20649	10B-77-3	Cattle, right metatarsal	−20.2 ± 0.2	6.3 ± 0.25	
Lengyel	SUERC-52805	10B-349-1	Cattle, 1st phalanx	−20.4 ± 0.2	6.6 ± 0.3	
Lengyel	MAMS-20670	11-779	Cattle, right radius	−19.8 ± 0.08	5.8 ± 0.09	
Lengyel	SUERC-52826	11-1388	Cattle, right metacarpal	−20.9 ± 0.2	11.3 ± 0.3	
Lengyel	SUERC-52836	5603-1583-1	Cattle, right metatarsal	−19.9 ± 0.2	6.6 ± 0.3	
Lengyel	MAMS-20677	11-538	Cattle, right ulna	−19.2 ± 0.08	6.1 ± 0.09	
Lengyel	SUERC-52822	11-538	Cattle, right ulna	−19.7 ± 0.2	6.1 ± 0.3	
$\delta^{13}C$: T′ = **5.4**, T′(5%) = 3.8, ν = 1, −19.3 ± 0.1‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 6.1 ± 0.1‰						
Lengyel	SUERC-52795	10B-3144-1	Cattle, right ulna	−19.1 ± 0.2	7.3 ± 0.3	
Lengyel	SUERC-52838	5603-1716	Cattle/Red deer, left os carpale	−21.0 ± 0.2	6.1 ± 0.3	

Cultural association	Laboratory number	Sample No.	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
Starčevo		5603/1 F691	*Cyprinus carpio*, caudal vertebra	–26.5 ± 0.19	8.9 ± 0.09	5.5 ± 0.15
Starčevo		5603/1 F1100	*Esox lucius*, precaudal vertebra			5.2 ± 0.15
Lengyel	MAMS-20652	10B-382-1	Pig, right humerus	–20.4 ± 0.2	8.8 ± 0.25	
Lengyel	SUERC-52802	10B-382-1	Pig, right humerus	–20.5 ± 0.2	9.0 ± 0.3	
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, –20.5 ± 0.15‰; $\delta^{15}N$: T′ = 0.3, T′(5%) = 3.8, ν = 1, 8.9 ± 0.2‰						
Lengyel	SUERC-52846	5603-2255	Pig, left tibia	–20.0 ± 0.2	9.3 ± 0.3	
Lengyel	SUERC-52815	11-2	Pig, right tibia	–20.1 ± 0.2	8.9 ± 0.3	
Lengyel	MAMS-20659	5603-1583-2	Pig, right tibia	–20.7 ± 0.08	8.6 ± 0.09	
Lengyel	MAMS-20653	10B-395-2	Pig, left tibia	–19.7 ± 0.2	9.0 ± 0.25	
Lengyel	SUERC-52823	11-772	Pig, tibia	–19.9 ± 0.2	10.5 ± 0.3	
Lengyel	MAMS-20673	11-1625	Pig/wild boar, cranium	–20.1 ± 0.08	9.2 ± 0.09	
Lengyel	SUERC-52817	11-375	Pig/wild boar, left cranium	–20.4 ± 0.2	7.5 ± 0.3	
Lengyel	OxA-26698	5603-1821	Red deer, antler	–19.9 ± 0.2	6.1 ± 0.3	
Lengyel		5603-1821	Red deer, antler	–19.9 ± 0.2	6.1 ± 0.09	
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, –19.9 ± 0.14‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 6.1 ± 0.09‰						
Lengyel	SUERC-52812	10B-77-2	Red deer, antler	–19.9 ± 0.2	5.8 ± 0.3	
Lengyel	MAMS-20651	10B-349-3	Red deer, 1st phalanx	–20.7 ± 0.2	4.8 ± 0.25	
Lengyel	MAMS-20669	11-490	Red deer, radius	–19.7 ± 0.08	6.6 ± 0.09	
Lengyel	MAMS-20667	5603-2772	Red deer, right carpal	–20.5 ± 0.08	4.7 ± 0.09	

Tab. 2. (continued)

Cultural association	Laboratory number	Sample No.	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
Lengyel	SUERC-53036	5603-2772	Red deer, right carpal	−20.9 ± 0.2	4.8 ± 0.3	
$\delta^{13}C$: T′ = 3.4, T′(5%) = 3.8, ν = 1, −20.6 ± 0.1‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 4.7 ± 0.1‰						
Lengyel	MAMS-20666	5603-2592	Red deer, right metatarsal	−20.2 ± 0.08	4.0 ± 0.09	
Lengyel	MAMS-20656	10B-2525-2	Red deer, left tibia	−18.4 ± 0.2	8.4 ± 0.25	
Lengyel	SUERC-52804	10B-476-1	Red deer, right ulna	−20.5 ± 0.2	6.8 ± 0.3	
LBK	SUERC-51468	11-3259/4905	Sheep, left radius	−21.1 ± 0.2	5.8 ± 0.3	
Lengyel	SUERC-52814	10B-69-4	Sheep, radius	−20.2 ± 0.2	7.7 ± 0.3	
Starčevo	OxA-30230	5603-605/179	Sheep/goat right femur	−20.7 ± 0.2	5.6 ± 0.3	
Starčevo	SUERC-51458	5603-1526/2717	Sheep/goat, left femur	−20.7 ± 0.2	5.3 ± 0.3	
Starčevo	SUERC-51454	5603-1501/2248	Sheep/goat, metapodial	−19.8 ± 0.2	6.9 ± 0.3	
Starčevo	OxA-30231	5603-676/410	Sheep/goat, right radius	−21.1 ± 0.2	6.2 ± 0.3	
Starčevo	Poz-67494	5603-1072/1296	Sheep/goat, left radius	−20.4 ± 0.33	4.8 ± 0.43	
Starčevo	OxA-30481	5603-675/346	Sheep/goat, left centrotarsal	−20.9 ± 0.2	7.8 ± 0.3	
Starčevo	SUERC-51452	5603-1078/5112	Sheep/goat, left tibia	−21.8 ± 0.2	7.8 ± 0.3	
LBK	SUERC-51463	11-2568/4536	Sheep/goat, left tibia	−21.0 ± 0.2	6.9 ± 0.3	
Lengyel	MAMS-20664	5603-2257-1	Sheep, right ulna	−20.2 ± 0.08	8.4 ± 0.09	
Starčevo		5603/1 F708	*Silurus glanis*, precaudal vertebra			6.4 ± 0.15
Starčevo		5603/1 F705	*Stizostedion luciperca*, caudal vertebra	−22.5 ± 0.19	9.4 ± 0.09	7.1 ± 0.15
Lengyel	SUERC-53379	11-1800	Ungulate, vertebra	−21.2 ± 0.2	5.8 ± 0.3	
Starčevo	OxA-X-2583-19	5603-1428/4865	Wild boar, right femur	−21.3 ± 0.2	7.9 ± 0.3	

Cultural association	Laboratory number	Sample No.	Species	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)
Starčevo	SUERC-51449	5603-617/222	Wild boar, left radius	−19.5 ± 0.2	6.9 ± 0.3	
Starčevo	SUERC-57540	5603-720/453	Wild boar, right ulna	−20.6 ± 0.2	7.8 ± 0.3	
LBK	OxA-30355	5603-2360/8759	Wild boar?, lumbar vertebra	−18.7 ± 0.2	11.0 ± 0.3	
LBK	SUERC-58484	5603-2360/8759	Wild boar?, lumbar vertebra	−19.7 ± 0.2	10.7 ± 0.3	
$\delta^{13}C$: T′ = **12.5**, T′(5%) = 3.8, ν = 1, −19.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.5, T′(5%) = 3.8, ν = 1, 10.9 ± 0.22‰						
Lengyel	SUERC-52808	10B-126-2	Wild boar, left femur	21.1 ± 0.2	5.0 ± 0.3	
Lengyel	MAMS-20662	5603-1931-2	Wild boar, left ulna	20.4 ± 0.08	5.9 ± 0.09	
Lengyel	MAMS-20650	10B-140-3	Wild boar, left metatarsal	20.1 ± 0.2	6.1 ± 0.25	
Lengyel	SUERC-52806	10B-140-3	Wild boar, left metatarsal	20.3 ± 0.2	6.8 ± 0.3	
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 3.2, T′(5%) = 3.8, ν = 1, 6.3 ± 0.2‰						
Lengyel	SUERC-52807	10B-140-2	Wild boar, right radius	−20.2 ± 0.2	5.8 ± 0.3	
Lengyel	SUERC-52837	5603-1667	Wild boar, right femur	−20.5 ± 0.2	9.6 ± 0.3	
Lengyel	MAMS-20671	11-2077	Wild boar, right ulna	−20.4 ± 0.08	4.4 ± 0.09	
Lengyel	OxA-26694	10B-3472	Wild boar, skull	−20.5 ± 0.2	4.9 ± 0.3	
Lengyel		10B-3472	Wild boar, skull	−20.4 ± 0.2	5.0 ± 0.09	−0.48 ± 0.15
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.4 ± 0.14‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 5.0 ± 0.09‰						
Lengyel	MAMS-20668	5603-2827-2	Wild boar, vertebra	−18.9 ± 0.08	7.2 ± 0.09	

Tab. 2. (continued)

Food Source	$\delta^{13}C$ (‰)	Uncertainty	$\delta^{15}N$ (‰)	Uncertainty
Cereals	–24.6	0.3	+5.0	0.4
Terrestrial animal protein	–20.3	0.2	+6.9	0.2
Freshwater fish	–21.4	0.2	+8.7	0.2

Tab. 3. Mean isotopic values for the food sources used in the FRUITS source proportional diet modelling for Alsónyék.

Laboratory number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Terrestrial herbivores > freshwater fish			Terrestrial herbivores > cereals (preferred model)		
			Cereals	Terrestrial herbivores	Freshwater fish	Cereals	Terrestrial herbivores	Freshwater fish
OxA-26695	–19.8 ± 0.2	11.1 ± 0.3	88.0 ± 5.7%	8.6 ± 4.5%	3.1 ± 2.5%	47.8 ± 1.5%	49.7 ± 1.6%	2.5 ± 2.4%
OxA-26697	–19.5 ± 0.2	11.5 ± 0.3	84.3 ± 6.7%	11.5 ± 5.3%	4.2 ± 3.1%	47.3 ± 1.9%	49.6 ± 1.9%	3.2 ± 3.1%
OxA-26699	–19.6 ± 0.2	9.2 ± 0.3	90.2 ± 5.2%	7.5 ± 4.3%	2.3 ± 2.0%	48.0 ± 1.4%	50.0 ± 1.4%	2.0 ± 2.0%
MAMS-20486	–20.3 ± 0.08	9.5 ± 0.09	94.9 ± 3.0%	3.9 ± 2.4%	1.3 ± 1.1%	48.5 ± 1.1%	50.0 ± 1.1%	1.5 ± 1.5%
OxA-29060	–20.1 ± 0.2	9.4 ± 0.3	93.4 ± 3.9%	5.0 ± 3.2%	1.6 ± 1.5%	48.3 ± 1.2%	50.0 ± 1.2%	1.7 ± 1.8%
OxA-27577	–18.7 ± 0.2	11.6 ± 0.3	70.2 ± 7.8%	22.1 ± 7.0%	7.7 ± 5.0%	45.5 ± 2.9%	49.2 ± 3.1%	5.2 ± 4.9%
OxA-28943	–17.9 ± 0.2	9.9 ± 0.3	61.0 ± 8.3%	32.8 ± 8.6%	6.3 ± 5.1%	45.0 ± 3.1%	50.7 ± 3.3%	4.3 ± 4.0%
OxA-28946	–22.5 ± 0.2	10.3 ± 0.3	97.9 ± 1.4%	1.6 ± 1.1%	0.5 ± 0.5%	49.2 ± 0.6%	50.0 ± 0.6%	0.8 ± 0.8%

Tab. 4. Stable isotopic values obtained on selected human skeletons from Alsónyék, with estimated proportions of dietary sources provided by alternative FRUITS models.

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
LBK	SUERC-51459	11-1972	40–45	M	−19.9 ± 0.2	9.2 ± 0.3		48.0 ± 1.0	50.0 ± 1.0	2.0 ± 2.0
LBK	Poz-68719	11-2559	40–45	F	−20.3 ± 0.33	9.9 ± 0.43		47.0 ± 2.0	50.0 ± 2.0	3.0 ± 3.0
LBK	Poz-67495	11-2888	12–13	Child	−20.0 ± 0.33	10.7 ± 0.43		46.9 ± 2.1	49.7 ± 2.2	3.4 ± 3.2
LBK	Poz-68350	11-2910	5–6	Child	−19.7 ± 0.33	10.0 ± 0.43		46.9 ± 2.1	49.9 ± 2.2	3.2 ± 3.1
Lengyel	OxA-27471	11-1937	35–45	M	−19.8 ± 0.2	11.5 ± 0.3		47.7 ± 1.6	49.6 ± 1.6	2.7 ± 2.6
Lengyel	MAMS-20679	11-43		Child	−19.9 ± 0.08	10.9 ± 0.09		48.6 ± 0.9	49.9 ± 1.0	1.5 ± 1.4
Lengyel	OxA-27531	11-1967	40–59	F	−19.6 ± 0.2	10.1 ± 0.3		47.9 ± 1.4	49.9 ± 1.5	2.2 ± 2.1
Lengyel	OxA-27530	11-2028	20–30	F	−19.6 ± 0.2	9.8 ± 0.3		48.3 ± 1.2	50.0 ± 1.2	1.7 ± 1.7
Lengyel	OxA-27580	11-2028	20–30	F	−19.7 ± 0.2	9.8 ± 0.3				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 9.8 ± 0.22‰										
Lengyel	OxA-29049	11-2330	25–35	M	−19.9 ± 0.2	10.7 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.7
Lengyel	UBA-22013	11-2330	25–35	M	−20.0 ± 0.22	10.8 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.9 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.8 ± 0.22‰										
Lengyel	OxA-27481	10B-1008	3–4	Child	−19.4 ± 0.2	11.4 ± 0.3		47.2 ± 1.9	49.6 ± 1.9	3.2 ± 3.0
Lengyel	SUERC-53323	10B-1473	40–59	F	−19.7 ± 0.2	11.0 ± 0.3		47.7 ± 1.5	49.7 ± 1.6	2.6 ± 2.5
Lengyel	OxA-28248	10B-1799	30–39	?F	−19.5 ± 0.2	9.0 ± 0.3		48.5 ± 1.1	50.0 ± 1.1	1.5 ± 1.5
Lengyel	UBA-22457	10B-1799	30–39	?F	−20.0 ± 0.22	9.2 ± 0.15				

Tab. 5. Stable isotopic values obtained on samples of adult and sub-adult (> 3 years) human skeletons from Alsónyék, with estimated proportions of dietary sources provided by the FRUITS modelling. Replicate measurements have been compared and combined using the method of Ward / Wilson (1978). Measurements that are statistically consistently significantly different at 95% confidence are in bold.

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
$\delta^{13}C$: T′ = 0.8, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 9.2 ± 0.13‰										
Lengyel	OxA-29191	10B-1814	25–29	F	−22.2 ± 0.2	10.9 ± 0.3		49.0 ± 0.7	50.0 ± 0.7	1.0 ± 1.0
Lengyel	SUERC-52796	10B-2549	35–39	?F	−19.9 ± 0.2	9.7 ± 0.3		48.1 ± 1.2	49.9 ± 1.3	2.0 ± 1.9
Lengyel	OxA-28926	10B-256	6–7	Child	−20.2 ± 0.2	10.5 ± 0.3		48.2 ± 1.3	49.8 ± 1.3	2.0 ± 2.0
Lengyel	SUERC-53324	10B-2959	35–44	M	−19.9 ± 0.2	11.0 ± 0.3		47.9 ± 1.4	49.7 ± 1.5	2.4 ± 2.3
Lengyel	OxA-29025	10B-3020	30–39	?F	−19.7 ± 0.2	9.7 ± 0.3		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	OxA-26697	10B-3060	40–49	M	−19.5 ± 0.2	11.5 ± 0.3		48.0 ± 1.4	49.8 ± 1.4	2.2 ± 2.1
Lengyel		10B-3060	40-49	M	−19.5 ± 0.19	11.1 ± 0.9	5.4 ± 0.15			
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −19.5 ± 0.14‰; $\delta^{15}N$: T′ = 1.6, T′(5%) = 3.8, ν = 1, 11.1 ± 0.09‰										
Lengyel	OxA-X-2508-50	10B-3089	40–59	F	−19.2 ± 0.2	11.3 ± 0.3		46.9 ± 2.1	49.6 ± 2.2	3.5 ± 3.4
Lengyel	MAMS-20657	10B-3241	14–15	Juvenile	−18.7 ± 0.2	10.4 ± 0.25		46.7 ± 2.2	49.9 ± 2.3	3.4 ± 3.2
Lengyel	OxA-26695	10B-3472	23–25	M	−19.8 ± 0.2	11.1 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.7
Lengyel		10B-3472			−19.8 ± 0.19	11.0 ± 0.9	5.4 ± 0.15			
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −19.8 ± 0.14‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 11.0 ± 0.09‰										
Lengyel	OxA-27566	10B-362	35–44	M	−19.6 ± 0.2	10.0 ± 0.3		48.3 ± 1.2	50.0 ± 1.2	1.7 ± 1.7
Lengyel	OxA-27581	10B-362	35–44	M	−19.8 ± 0.2	9.5 ± 0.3				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 1.4, T′(5%) = 3.8, ν = 1, 9.8 ± 0.22‰										
Lengyel	OxA-29023	10B-3715	20–23	?M	−20.0 ± 0.2	10.3 ± 0.3		48.1 ± 1.3	49.9 ± 1.3	2.0 ± 2.0
Lengyel	OxA-28250	10B-3735	40–44	?M	−19.2 ± 0.2	10.1 ± 0.3		48.0 ± 1.0	50.0 ± 1.0	2.0 ± 2.0
Lengyel	UBA-22459	10B-3735	40–44	?M	−19.5 ± 0.22	10.0 ± 0.15				

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −19.3 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.0 ± 0.13‰										
Lengyel	UBA-22460	10B-3741	17–20	M	−19.8 ± 0.22	9.8 ± 0.15		48.0 ± 1.4	50.0 ± 1.4	2.0 ± 1.9
Lengyel	OxA-29063	10B-3742	40–59	?F	−19.6 ± 0.2	10.3 ± 0.3		47.8 ± 1.5	49.8 ± 1.6	2.4 ± 2.3
Lengyel	OxA-28249	10B-3758	11–13	Child	−19.8 ± 0.2	9.2 ± 0.3		48.5 ± 1.0	50.0 ± 1.0	1.5 ± 1.4
Lengyel	UBA-22458	10B-3758	11–13	Child	−20.0 ± 0.22	9.4 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.9 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 9.4 ± 0.13‰										
Lengyel	OxA-29067	10B-3760	40–59	F	−19.9 ± 0.2	9.4 ± 0.3		48.3 ± 1.2	50.0 ± 1.3	1.8 ± 1.8
Lengyel	OxA-27483	10B-3770	35–44	F	−19.2 ± 0.2	10.6 ± 0.3		47.7 ± 1.6	49.9 ± 1.6	2.4 ± 2.4
Lengyel	OxA-27484	10B-3770	35–44	F	−19.1 ± 0.2	10.6 ± 0.3				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −19.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 10.6 ± 0.22‰										
Lengyel	UBA-22018	10B-3771	25–34	M	−20.0 ± 0.22	10.0 ± 0.15		48.1 ± 1.2	50.0 ± 1.3	1.9 ± 1.8
Lengyel	OxA-27476	10B-3831	30–40	M	−19.7 ± 0.2	10.1 ± 0.3		47.9 ± 1.4	49.9 ± 1.5	2.2 ± 2.1
Lengyel	OxA-28947	10B-3918	30–34	M	−22.6 ± 0.2	9.1 ± 0.3		49.2 ± 0.5	50.0 ± 0.5	0.8 ± 0.7
Lengyel	OxA-28946	10B-3956	50–59	M	−22.5 ± 0.2	10.3 ± 0.3		49.2 ± 0.6	50.0 ± 0.6	0.8 ± 0.8
Lengyel	OxA-27486	10B-398	30–39	M	−18.4 ± 0.2	10.1 ± 0.3		46.1 ± 2.5	50.1 ± 2.7	3.8 ± 3.6
Lengyel	OxA-28945	10B-4005	25–29	F	−19.0 ± 0.2	10.3 ± 0.3		47.2 ± 1.9	49.9 ± 2.0	3.0 ± 2.9
Lengyel	OxA-27572	10B-4011	25–28	M	−19.4 ± 0.2	10.6 ± 0.3		47.5 ± 1.7	49.8 ± 1.7	2.7 ± 2.5
Lengyel	UBA-21393	10B-4012	25–30	F	−19.9 ± 0.22	9.8 ± 0.15		48.1 ± 1.3	50.0 ± 1.3	1.9 ± 1.9

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	SUERC-53382	10B-4027	30–35	M	−19.7 ± 0.2	11.0 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	2.0 ± 1.9
Lengyel	UBA-21394	10B-4027	30–35	M	−19.9 ± 0.22	11.1 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 11.1 ± 0.13‰										
Lengyel	UBA-21395	10B-4028	20–24	M	−19.7 ± 0.22	10.2 ± 0.15		47.9 ± 1.5	49.9 ± 1.5	2.3 ± 2.1
Lengyel	OxA-28927	10B-422	11–12	Child	−20.1 ± 0.2	9.1 ± 0.3		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2
Lengyel	UBA-22512	10B-422	11–12	Child	−20.1 ± 0.22	8.9 ± 0.15				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −20.1 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 8.9 ± 0.13‰										
Lengyel	SUERC-52798	10B-4279	25–34	F	−20.4 ± 0.2	10.1 ± 0.3		48.4 ± 1.1	49.9 ± 1.2	1.7 ± 1.7
Lengyel	SUERC-53314	10B-4307	25–30	M	−19.6 ± 0.2	10.3 ± 0.3		48.4 ± 1.1	49.9 ± 1.1	1.7 ± 1.6
Lengyel	UBA-21412	10B-4307	25–30	M	−20.0 ± 0.22	10.0 ± 0.15				
$\delta^{13}C$: T′ = 0.8, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 0.8, T′(5%) = 3.8, ν = 1, 10.1 ± 0.13‰										
Lengyel	OxA-27465	10B-497	40–59	F	−19.8 ± 0.2	9.8 ± 0.3		48.1 ± 1.3	49.9 ± 1.3	2.0 ± 1.9
Lengyel	OxA-27467	10B-5196	40–49	?F	−20.0 ± 0.2	10.3 ± 0.3		48.1 ± 1.3	49.9 ± 1.3	2.0 ± 2.0
Lengyel	OxA-27466	10B-552	45–54	M	−19.9 ± 0.2	10.5 ± 0.3		48.0 ± 1.3	49.8 ± 1.4	2.1 ± 2.0
Lengyel	OxA-29060	10B-6337	17–20	?M	−20.1 ± 0.2	9.4 ± 0.3		48.6 ± 0.9	50.0 ± 0.9	1.4 ± 1.3
Lengyel	OxA-29061	10B-6337	17–20	?M	−19.9 ± 0.2	9.0 ± 0.3				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.0 ± 0.15‰; $\delta^{15}N$: T′ = 0.9, T′(5%) = 3.8, ν = 1, 9.2 ± 0.22‰										
Lengyel	OxA-27574	10B-6438	25–29	M	−18.3 ± 0.2	10.5 ± 0.3		45.5 ± 2.8	49.9 ± 3.1	4.6 ± 4.2
Lengyel	SUERC-53321	10B-679	21–24	M	−19.9 ± 0.2	10.2 ± 0.3		48.6 ± 1.0	50.0 ± 1.0	1.5 ± 1.4
Lengyel	UBA-21411	10B-679	21–24	M	−20.2 ± 0.22	9.5 ± 0.15				

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −20.0 ± 0.15‰; $\delta^{15}N$: T′ = 4.4, T′(5%) = 3.8, ν = 1, 9.6 ± 0.13‰										
Lengyel	MAMS-20654	10B-691	40–49	M	−19.8 ± 0.2	11.1 ± 0.25		47.8 ± 1.5	49.7 ± 1.6	2.5 ± 2.4
Lengyel	MAMS-20655	10B-736	19–23	?F	−19.5 ± 0.2	10.3 ± 0.25		48.3 ± 1.1	50.0 ± 1.2	1.7 ± 1.7
Lengyel	SUERC-52813	10B-736	19–23	?F	−20.0 ± 0.2	10.2 ± 0.3				
$\delta^{13}C$: T′ = 3.4, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.2 ± 0.2‰										
Lengyel	OxA-27477	10B-7562	35–44	M	−19.7 ± 0.2	10.3 ± 0.3		47.9 ± 1.4	49.9 ± 1.5	2.3 ± 2.2
Lengyel	OxA-27575	10B-7655	45–54	?M	−18.4 ± 0.2	10.2 ± 0.3		46.1 ± 2.5	50.1 ± 2.7	3.8 ± 3.7
Lengyel	OxA-28941	10B-7753	30–34	F	−19.1 ± 0.2	9.6 ± 0.3		47.5 ± 1.7	50.0 ± 1.7	2.5 ± 2.4
Lengyel	OxA-28942	10B-7753	30–34	F	−18.4 ± 0.2	9.7 ± 0.3				
$\delta^{13}C$: **T′ = 6.1**, T′(5%) = 3.8, ν = 1, −18.8 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 9.7 ± 0.22‰										
Lengyel	OxA-29062	10B-7756	50–59	M	−19.9 ± 0.2	10.3 ± 0.3		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.1
Lengyel	OxA-29048	10B-783	40–59	M	−19.9 ± 0.2	10.3 ± 0.3		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.1
Lengyel	OxA-27571	10B-791	40–49	M	−19.5 ± 0.2	10.6 ± 0.3		47.6 ± 1.6	49.8 ± 1.7	2.6 ± 2.5
Lengyel	SUERC-53383	10B-792	50–59	M	−19.5 ± 0.2	11.1 ± 0.3		48.1 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	UBA-21387	10B-792	50–59	M	−19.6 ± 0.22	10.3 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.5 ± 0.15‰; $\delta^{15}N$: T′ = **5.7**, T′(5%) = 3.8, ν = 1, 10.5 ± 0.13‰										
Lengyel	OxA-27487	10B-796	23–26	F	−18.8 ± 0.2	10.0 ± 0.3		47.0 ± 2.0	49.9 ± 2.1	3.1 ± 2.9
Lengyel	OxA-27573	10B-798	50–59	M	−19.0 ± 0.2	11.2 ± 0.3		46.7 ± 2.2	49.6 ± 2.3	3.7 ± 3.5
Lengyel	UBA-21390	10B-804	7–8	Child	−19.8 ± 0.22	9.9 ± 0.15		48.0 ± 1.4	50.0 ± 1.4	2.0 ± 1.9

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	OxA-27640	10B-811	23–26	?	−19.6 ± 0.2	10.6 ± 0.3		47.7 ± 1.6	49.8 ± 1.6	2.5 ± 2.5
Lengyel	OxA-27488	10B-813	25–34	M	−19.1 ± 0.2	10.9 ± 0.3		47.0 ± 2.1	49.7 ± 2.2	3.4 ± 3.3
Lengyel	OxA-27641	10B-818	40–49	F	−19.7 ± 0.2	11.0 ± 0.3		47.7 ± 1.5	49.7 ± 1.6	2.6 ± 2.5
Lengyel	UBA-21391	10B-819	23–29	M	−19.9 ± 0.22	9.9 ± 0.15		48.1 ± 1.3	50.0 ± 1.3	2.0 ± 1.9
Lengyel	OxA-27480	10B-822	18–21	Juvenile	−19.2 ± 0.2	10.3 ± 0.3		48.1 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	UBA-22526	10B-822	18–21	Juvenile	−19.9 ± 0.22	10.3 ± 0.15				
$\delta^{13}C$: T′ = **5.5**, T′(5%) = 3.8, ν = 1, −19.5 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 10.3 ± 0.13‰										
Lengyel	OxA-27482	10B-827	35–44	M	−19.8 ± 0.2	9.0 ± 0.3		48.3 ± 1.2	50.0 ± 1.2	1.8 ± 1.7
Lengyel	OxA-27485	10B-828	30–39	?F	−19.7 ± 0.2	10.1 ± 0.3		47.9 ± 1.4	49.9 ± 1.5	2.2 ± 2.1
Lengyel	OxA-29024	10B-847	20–24	F	−19.1 ± 0.2	10.7 ± 0.3		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	UBA-21385	10B-847	20–24	F	−19.8 ± 0.22	10.2 ± 0.15				
$\delta^{13}C$: **T′ = 5.5**, T′(5%) = 3.8, ν = 1, −19.4 ± 0.15‰; $\delta^{15}N$: T′ = 2.2, T′(5%) = 3.8, ν = 1, 10.3 ± 0.13‰										
Lengyel	SUERC-53322	10B-853	40–49	F	−19.6 ± 0.2	10.5 ± 0.3		48.4 ± 1.1	49.9 ± 1.1	1.7 ± 1.6
Lengyel	UBA-21392	10B-853	40–49	F	−19.7 ± 0.22	9.8 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: **T′ = 4.4**, T′(5%) = 3.8, ν = 1, 9.9 ± 0.13‰										
Lengyel	UBA-21389	10B-799	35–44	F	−19.5 ± 0.22	10.6 ± 0.15		47.6 ± 1.6	49.9 ± 1.6	2.5 ± 2.3
Lengyel	UBA-22010	10B-910	40–59	M	−20.1 ± 0.22	10.5 ± 0.15		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	UBA-21386	10B-953	16–18	Juvenile	−19.8 ± 0.22	10.5 ± 0.15		47.9 ± 1.5	49.9 ± 1.5	2.3 ± 2.2
Lengyel	UBA-21407	11-1006	about 7	Child	−19.9 ± 0.22	10.3 ± 0.15		48.0 ± 1.4	49.9 ± 1.5	2.1 ± 2.1
Lengyel	OxA-27474	11-1184	30–40	M	−19.3 ± 0.2	10.2 ± 0.3		47.6 ± 1.7	49.9 ± 1.7	2.5 ± 2.5

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	OxA-29032	11-1189	18–20	F	−20.2 ± 0.2	9.7 ± 0.3		48.4 ± 1.1	50.0 ± 1.2	1.7 ± 1.7
Lengyel	SUERC-53331	11-1190	40–59	F	−20.3 ± 0.2	10.9 ± 0.3		48.6 ± 0.9	49.9 ± 1.0	1.4 ± 1.4
Lengyel	UBA-21404	11-1190	40–59	F	−20.4 ± 0.22	10.3 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.4 ± 0.15‰; $\delta^{15}N$: T′ = 3.2, T′(5%) = 3.8, ν = 1, 10.4 ± 0.13‰										
Lengyel	OxA-27475	11-1191	30–40	F	−19.8 ± 0.2	9.6 ± 0.3		48.1 ± 1.3	50.0 ± 1.3	1.9 ± 1.8
Lengyel	SUERC-53332	11-1192	25–45	?F	−19.9 ± 0.2	10.4 ± 0.3		48.4 ± 1.0	50.0 ± 1.1	1.6 ± 1.5
Lengyel	UBA-21405	11-1192	25–45	?F	−19.9 ± 0.22	9.9 ± 0.15				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −19.9 ± 0.15‰; $\delta^{15}N$: T′ = 2.2, T′(5%) = 3.8, ν = 1, 10.0 ± 0.13‰										
Lengyel	OxA-27529	11-1235	40–50	M	−19.5 ± 0.2	11.2 ± 0.3		47.5 ± 1.7	49.7 ± 1.8	2.8 ± 2.7
Lengyel	SUERC-53336	11-1320	35–45	F	−19.8 ± 0.2	10.2 ± 0.3		48.5 ± 1.1	50.0 ± 1.1	1.5 ± 1.5
Lengyel	UBA-21408	11-1320	35–45	F	−19.9 ± 0.22	9.6 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 3.2, T′(5%) = 3.8, ν = 1, 9.7 ± 0.13‰										
Lengyel	OxA-27470	11-1391	40–55	F	−19.8 ± 0.2	10.8 ± 0.3		48.4 ± 1.1	49.9 ± 1.1	1.7 ± 1.6
Lengyel	UBA-22529	11-1391	40–55	F	−20.0 ± 0.22	10.6 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.9 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 10.6 ± 0.13‰										
Lengyel	OxA-28940	11-145	5–6	Child	−19.4 ± 0.2	10.8 ± 0.3		47.4 ± 1.7	49.8 ± 1.8	2.9 ± 2.7
Lengyel	SUERC-53340	11-1669	25–30	M	−20.1 ± 0.2	10.9 ± 0.3		48.5 ± 1.0	50.0 ± 1.1	1.6 ± 1.5
Lengyel	UBA-21409	11-1669	25–30	M	−20.0 ± 0.22	10.4 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.1 ± 0.15‰; $\delta^{15}N$: T′ = 2.2, T′(5%) = 3.8, ν = 1, 10.5 ± 0.13‰										

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	MAMS-20675	11-1705	Adult		−19.7 ± 0.08	9.6 ± 0.09		48.7 ± 0.9	50.0 ± 0.9	1.3 ± 1.3
Lengyel	SUERC-52833	11-1755	Adult	?	−20.2 ± 0.2	10.4 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	2.0 ± 1.9
Lengyel	OxA-28251	11-1793	?	M	−19.5 ± 0.2	10.4 ± 0.3		48.1 ± 1.3	49.9 ± 1.3	1.9 ± 1.9
Lengyel	UBA-22452	11-1793	?	M	−19.7 ± 0.22	10.4 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.6 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 10.4 ± 0.13‰										
Lengyel	OxA-28252	11-1802	?	F	−19.5 ± 0.2	10.3 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.7
Lengyel	UBA-22454	11-1802	?	F	−20.0 ± 0.22	10.1 ± 0.15				
$\delta^{13}C$: T′ = 2.8, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 10.1 ± 0.13‰										
Lengyel	OxA-28253	11-1808	?	M	−19.4 ± 0.2	9.7 ± 0.3		48.4 ± 1.1	50.0 ± 1.1	1.7 ± 1.6
Lengyel	OxA-28254	11-1808	?	M	−19.3 ± 0.2	9.9 ± 0.3				
Lengyel	UBA-22455	11-1808	?	M	−19.9 ± 0.22	9.8 ± 0.15				
$\delta^{13}C$: T′ = 4.5, T′(5%) = 6.0, ν = 2, −19.5 ± 0.12‰; $\delta^{15}N$: T′ = 0.2, T′(5%) = 6.0, ν = 2, 9.8 ± 0.12‰										
Lengyel	OxA-29028	11-1822	?	F	−19.9 ± 0.2	8.6 ± 0.3		48.4 ± 1.1	50.1 ± 1.2	1.6 ± 1.6
Lengyel	SUERC-53333	11-1848	?	F	−19.6 ± 0.2	10.3 ± 0.3		47.8 ± 1.5	49.8 ± 1.6	2.4 ± 2.3
Lengyel	SUERC-53380	11-1850	Adult	?	−20.5 ± 0.2	10.6 ± 0.3		48.5 ± 1.1	49.9 ± 1.1	1.7 ± 1.7
Lengyel	OxA-29031	11-1860	30–35	?F	−19.8 ± 0.2	9.6 ± 0.3		48.1 ± 1.3	50.0 ± 1.3	1.8 ± 1.8
Lengyel	SUERC-53334	11-190	40–49	F	−20.3 ± 0.2	10.6 ± 0.3		48.7 ± 0.9	50.0 ± 0.9	1.4 ± 1.4
Lengyel	UBA-21406	11-190	40–49	F	−20.3 ± 0.22	9.9 ± 0.15				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −20.3 ± 0.15‰; $\delta^{15}N$: **T′ = 4.4**, T′(5%) = 3.8, ν = 1, 10.0 ± 0.13‰										
Lengyel	OxA-27576	11-263	30–50	?	−18.8 ± 0.2	10.8 ± 0.3		46.5 ± 2.3	49.7 ± 2.4	3.8 ± 3.6

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	OxA-27463	11-264	25–35	?F	−19.8 ± 0.2	11.2 ± 0.3		47.8 ± 1.5	49.7 ± 1.6	2.5 ± 2.4
Lengyel	SUERC-52816	11-275	?	Child	−20.3 ± 0.2	10.9 ± 0.3		48.2 ± 1.2	49.8 ± 1.3	2.0 ± 2.0
Lengyel	UBA-21398	11-278	30–40	?F	−20.0 ± 0.22	10.2 ± 0.15		48.1 ± 1.3	49.9 ± 1.3	1.9 ± 1.9
Lengyel	SUERC-53325	11-293	35–45	M	−19.9 ± 0.2	11.3 ± 0.3		48.3 ± 1.1	49.9 ± 1.2	1.8 ± 1.8
Lengyel	UBA-22011	11-293	35–45	M	−20.0 ± 0.22	10.9 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.9 ± 0.15‰; $\delta^{15}N$: T′ = 1.4, T′(5%) = 3.8, ν = 1, 11.0 ± 0.13‰										
Lengyel	OxA-27464	11-295	30–40	F	−19.9 ± 0.2	10.0 ± 0.3		48.1 ± 1.3	49.9 ± 1.3	2.0 ± 1.9
Lengyel	UBA-21399	11-304	35–45	?	−20.1 ± 0.22	9.9 ± 0.15		48.2 ± 1.2	49.9 ± 1.3	1.9 ± 1.8
Lengyel	UBA-21400	11-318	20–25	F	−19.8 ± 0.22	9.2 ± 0.15		48.1 ± 1.3	50.1 ± 1.3	1.8 ± 1.8
Lengyel	OxA-27577	11-319	35–45	F	−18.7 ± 0.2	11.6 ± 0.3		45.5 ± 2.9	49.2 ± 3.1	5.2 ± 4.9
Lengyel	OxA-27462	11-324	25–35?	?F	−19.4 ± 0.2	9.8 ± 0.3		47.7 ± 1.6	49.9 ± 1.7	2.4 ± 2.4
Lengyel	OxA-27468	11-333	20–30	F	−19.6 ± 0.2	10.2 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.8
Lengyel	OxA-27469	11-333	20–30	F	−19.7 ± 0.2	10.3 ± 0.3				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.3 ± 0.22‰										
Lengyel	OxA-27528	11-337	25–35	M	−19.2 ± 0.2	10.8 ± 0.3		47.1 ± 2.0	49.7 ± 2.0	3.2 ± 3.1
Lengyel	SUERC-52818	11-379	Adult	?	−20.2 ± 0.2	10.3 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	1.9 ± 1.9
Lengyel	UBA-22017	11-665	45–55	M	−20.0 ± 0.22	10.1 ± 0.15		48.1 ± 1.3	49.9 ± 1.3	2.0 ± 1.9
Lengyel	OxA-27473	11-673	30–50	F	−19.9 ± 0.2	9.4 ± 0.3		48.3 ± 1.2	50.0 ± 1.3	1.8 ± 1.8
Lengyel	OxA-27472	11-679	c. 6	Child	−20.0 ± 0.2	9.6 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	1.8 ± 1.9

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	SUERC-53326	11-699	35–45	M	−19.7 ± 0.2	11.0 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	2.0 ± 1.9
Lengyel	UBA-22019	11-699	35–45	M	−20.0 ± 0.22	10.8 ± 0.15				
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 10.8 ± 0.13‰										
Lengyel	SUERC-53330	11-724	20–25	M	−19.8 ± 0.2	9.9 ± 0.3		48.7 ± 0.9	50.0 ± 0.9	1.3 ± 1.3
Lengyel	UBA-21403	11-724	20–25	M	−20.2 ± 0.22	8.9 ± 0.15				
$\delta^{13}C$: T′ = 1.8, T′(5%) = 3.8, ν = 1, −20.0 ± 0.15‰; $\delta^{15}N$: **T′ = 8.9**, T′(5%) = 3.8, ν = 1, 9.1 ± 0.13‰										
Lengyel	SUERC-53335	11-743	35–45	M	−19.6 ± 0.2	11.0 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	1.9 ± 1.9
Lengyel	UBA-22014	11-743	35–45	M	−19.7 ± 0.22	10.8 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 10.8 ± 0.13‰										
Lengyel	OxA-29030	11-808	?	F	−19.8 ± 0.2	10.2 ± 0.3		48.0 ± 1.4	49.9 ± 1.5	2.2 ± 2.1
Lengyel	OxA-29029	11-809	c. 9–10	Child	−19.8 ± 0.2	10.7 ± 0.3		48.0 ± 1.4	49.8 ± 1.4	2.2 ± 2.2
Lengyel	OxA-28255	11-815	?	M	−19.5 ± 0.2	10.1 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.8
Lengyel	UBA-22453	11-815	?	M	−19.9 ± 0.22	10.4 ± 0.15				
$\delta^{13}C$: T′ = 1.8, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.8, T′(5%) = 3.8, ν = 1, 10.3 ± 0.13‰										
Lengyel	SUERC-53315	5603-122	25–30	M	−20.3 ± 0.2	10.2 ± 0.3		48.7 ± 0.9	50.0 ± 1.0	1.4 ± 1.4
Lengyel	UBA-21414	5603-122	25–30	M	−20.2 ± 0.22	10.1 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.3 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.1 ± 0.13‰										
Lengyel	MAMS-11941	5603-1535	30–45	F	−20.5 ± 0.2	10.2 ± 0.1		48.6 ± 1.0	50.0 ± 1.0	1.5 ± 1.5
Lengyel	SUERC-52834	5603-1579	Adult	?	−19.3 ± 0.2	9.9 ± 0.3		47.7 ± 1.6	49.9 ± 1.7	2.4 ± 2.4
Lengyel	SUERC-52835	5603-1580	30–40	F	−19.8 ± 0.2	10.7 ± 0.3		48.0 ± 1.4	49.8 ± 1.4	2.2 ± 2.2

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	SUERC-52842	5603-1783	?Adult	?	−20.1 ± 0.2	10.0 ± 0.3		48.3 ± 1.2	49.9 ± 1.3	1.8 ± 1.8
Lengyel	MAMS-20661	5603-1798	?Adult	?	−19.4 ± 0.08	9.5 ± 0.09		48.5 ± 1.0	50.0 ± 1.1	1.5 ± 1.5
Lengyel		5603-1821	20–22	M	−19.6 ± 0.19	9.2 ± 0.1	5.2 ± 0.15	48.5 ± 1.1	50.0 ± 1.1	1.5 ± 1.5
Lengyel	OxA-26699	5603-1821	20–22	M	−19.5 ± 0.2	9.8 ± 0.3				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.6 ± 0.14‰; $\delta^{15}N$: T′ = 3.7, T′(5%) = 3.8, ν = 1, 9.2 ± 0.09‰										
Lengyel	OxA-27448	5603-1867	14–15	Child	−19.7 ± 0.2	9.8 ± 0.3		48.3 ± 1.2	50.0 ± 1.2	1.7 ± 1.7
Lengyel	OxA-27449	5603-1867	14–15	Child	−19.7 ± 0.2	9.5 ± 0.3				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.5, T′(5%) = 3.8, ν = 1, 9.7 ± 0.22‰										
Lengyel	SUERC-53341	5603-1868	30–40	F	−20.2 ± 0.2	10.5 ± 0.3		48.6 ± 1.0	49.9 ± 1.0	1.5 ± 1.5
Lengyel	UBA-21437	5603-1868	30–40	F	−20.4 ± 0.22	10.4 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.3 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.4 ± 0.13‰										
Lengyel	OxA-27453	5603-1875	24–27	?	−19.5 ± 0.2	10.6 ± 0.3		47.6 ± 1.6	49.8 ± 1.7	2.6 ± 2.5
Lengyel	OxA-27457	5603-1877	50–59	?F	−19.8 ± 0.2	9.7 ± 0.3		48.1 ± 1.3	49.9 ± 1.3	2.0 ± 1.9
Lengyel	SUERC-53342	5603-1881	35–45	F	−20.3 ± 0.2	10.5 ± 0.3		48.6 ± 1.0	50.0 ± 1.0	1.5 ± 1.4
Lengyel	UBA-21438	5603-1881	35–45	F	−20.1 ± 0.22	10.4 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.4 ± 0.13‰										
Lengyel	OxA-27450	5603-1920	30–35	F	−19.8 ± 0.2	10.1 ± 0.3		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	OxA-28939	5603-1921	27–30	F	−19.9 ± 0.2	10.7 ± 0.3		48.0 ± 1.4	49.8 ± 1.4	2.2 ± 2.1
Lengyel	OxA-28944	5603-1934	45–55	M	−19.3 ± 0.2	10.5 ± 0.3		47.5 ± 1.7	49.8 ± 1.8	2.7 ± 2.5

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	SUERC-53343	5603-1966	35–40	?F	−20.1 ± 0.2	9.3 ± 0.3		48.7 ± 0.9	50.0 ± 0.9	1.3 ± 1.3
Lengyel	UBA-21439	5603-1966	35–40	?F	−20.0 ± 0.22	8.9 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.1 ± 0.15‰; $\delta^{15}N$: T′ = 1.4, T′(5%) = 3.8, ν = 1, 9.0 ± 0.13‰										
Lengyel	SUERC-52844	5603-1968	25–30	F	−20.2 ± 0.2	9.8 ± 0.3		48.3 ± 1.1	49.9 ± 1.2	1.7 ± 1.7
Lengyel	OxA-27454	5603-1969	30–40	F	−19.8 ± 0.2	10.5 ± 0.3		47.9 ± 1.4	49.9 ± 1.5	2.2 ± 2.1
Lengyel	SUERC-53344	5603-1984	25–30	M	−19.9 ± 0.2	10.6 ± 0.3		48.5 ± 1.0	50.0 ± 1.1	1.5 ± 1.5
Lengyel	UBA-21440	5603-1984	25–30	M	−20.2 ± 0.22	9.9 ± 0.15				
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −20.0 ± 0.15‰; $\delta^{15}N$: **T′ = 4.4**, T′(5%) = 3.8, ν = 1, 10.0 ± 0.13‰										
Lengyel	SUERC-53345	5603-1988	40–45	M	−20.3 ± 0.2	10.5 ± 0.3		48.6 ± 1.0	50.0 ± 1.0	1.5 ± 1.4
Lengyel	UBA-22008	5603-1988	40–45	M	−20.1 ± 0.22	10.3 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 10.3 ± 0.13‰										
Lengyel	OxA-27458	5603-1989	18–20	Juvenile	−19.7 ± 0.2	10.4 ± 0.3		48.4 ± 1.1	49.9 ± 1.1	1.7 ± 1.6
Lengyel	UBA-22534	5603-1989	18–20	Juvenile	−19.9 ± 0.22	10.0 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 10.1 ± 0.13‰										
Lengyel	OxA-27451	5603-1996	40–45	M	−19.7 ± 0.2	10.1 ± 0.3		47.9 ± 1.4	49.9 ± 1.5	2.2 ± 2.1
Lengyel	SUERC-53346	5603-2000	40–50	M	−20.1 ± 0.2	9.9 ± 0.3		48.5 ± 1.1	50.0 ± 1.0	1.5 ± 1.5
Lengyel	UBA-21441	5603-2000	40–50	M	−19.7 ± 0.22	9.8 ± 0.15				
$\delta^{13}C$: T′ = 1.8, T′(5%) = 3.8, ν = 1, −19.9 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 9.8 ± 0.13‰										
Lengyel	OxA-28247	5603-2150	30–40	M	−19.6 ± 0.2	10.1 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.7
Lengyel	UBA-22456	5603-2150	30–40	M	−19.7 ± 0.56	10.1 ± 0.16				

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 10.1 ± 0.13‰										
Lengyel	OxA-27455	5603-2162	?	Child	−19.6 ± 0.2	9.9 ± 0.3		48.4 ± 1.1	49.9 ± 1.1	1.7 ± 1.6
Lengyel	UBA-22531	5603-2162	?	Child	−19.8 ± 0.22	9.9 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.7 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 9.9 ± 0.13‰										
Lengyel	OxA-28943	5603-2165	45–55	M	−17.9 ± 0.2	9.9 ± 0.3		45.0 ± 3.1	50.7 ± 3.3	4.3 ± 4.0
Lengyel	OxA-28938	5603-2222	25–30	?	−19.7 ± 0.2	9.2 ± 0.3		48.1 ± 1.3	50.0 ± 1.3	1.9 ± 1.9
Lengyel	SUERC-53350	5603-2226	50–59	?	−20.2 ± 0.2	10.3 ± 0.3		48.6 ± 1.0	50.0 ± 1.0	1.5 ± 1.4
Lengyel	UBA-21442	5603-2226	50–59	?	−19.9 ± 0.22	10.2 ± 0.15				
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −20.1 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.2 ± 0.13‰										
Lengyel	MAMS-20665	5603-2262	Adult	F	−19.2 ± 0.08	11.3 ± 0.09		47.9 ± 1.5	49.8 ± 1.5	2.4 ± 2.3
Lengyel	SUERC-52854	5603-2276	18–20	?F	−20.0 ± 0.2	9.1 ± 0.3		48.3 ± 1.2	50.0 ± 1.3	1.7 ± 1.8
Lengyel	OxA-27478	5603-253	30–40	M	−19.9 ± 0.2	11.0 ± 0.3		47.9 ± 1.4	49.7 ± 1.5	2.4 ± 2.3
Lengyel	OxA-27459	5603-2579	45–59	F	−19.7 ± 0.2	9.9 ± 0.3		48.0 ± 1.3	49.9 ± 1.4	2.1 ± 2.0
Lengyel	SUERC-53351	5603-2580	Adult	?	−20.3 ± 0.2	9.4 ± 0.3		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2
Lengyel	UBA-21443	5603-2580	Adult	?	−20.1 ± 0.22	9.2 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 9.2 ± 0.13‰										
Lengyel	SUERC-53352	5603-2585	Adult	?	−20.3 ± 0.2	9.8 ± 0.3		48.7 ± 0.9	50.0 ± 0.9	1.4 ± 1.4
Lengyel	UBA-21444	5603-2585	Adult	?	−20.1 ± 0.22	9.7 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 9.7 ± 0.13‰										

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Lengyel	OxA-27452	5603-2597	16–18	Juvenile	−19.5 ± 0.2	10.9 ± 0.3		47.5 ± 1.7	49.8 ± 1.7	2.7 ± 2.6
Lengyel	SUERC-53353	5603-2599	c. 14	Child	−20.2 ± 0.2	9.9 ± 0.3		48.7 ± 1.0	50.0 ± 1.0	1.4 ± 1.4
Lengyel	UBA-21445	5603-2599	c. 14	Child	−20.1 ± 0.22	9.9 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 9.9 ± 0.13‰										
Lengyel	SUERC-53381	5603-2770	4–5	Child	−20.3 ± 0.2	10.4 ± 0.3		48.3 ± 1.2	49.9 ± 1.2	1.8 ± 1.8
Lengyel	OxA-27456	5603-2843	35–45	F	−19.8 ± 0.2	9.9 ± 0.3		48.1 ± 1.3	49.9 ± 1.4	2.0 ± 2.0
Lengyel	SUERC-53354	5603-2844	45–59	M	−20.2 ± 0.2	10.6 ± 0.3		48.6 ± 1.0	49.9 ± 1.0	1.5 ± 1.5
Lengyel	UBA-22009	5603-2844	45–59	M	−20.2 ± 0.22	10.5 ± 0.15				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −20.2 ± 0.15‰; $\delta^{15}N$: T′ = 0.1, T′(5%) = 3.8, ν = 1, 10.5 ± 0.13‰										
Lengyel	SUERC-53355	5603-2906	23–29	M	−19.7 ± 0.2	10.0 ± 0.3		48.5 ± 1.1	50.0 ± 1.1	1.5 ± 1.5
Lengyel	UBA-21446	5603-2906	23–29	M	−20.0 ± 0.22	9.4 ± 0.15				
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −19.8 ± 0.15‰; $\delta^{15}N$: T′ = 3.2, T′(5%) = 3.8, ν = 1, 9.5 ± 0.13‰										
Lengyel	OxA-27637	5603-62	25–30	M	−19.5 ± 0.2	10.7 ± 0.3		47.6 ± 1.6	49.8 ± 1.7	2.6 ± 2.5
Lengyel	SUERC-53316	5603-639	25–30	?M	−20.1 ± 0.2	10.2 ± 0.3		48.2 ± 1.2	49.9 ± 1.3	1.9 ± 1.9
Lengyel	SUERC-53320	5603-677	30–35	M	−19.5 ± 0.2	11.5 ± 0.3		47.9 ± 1.4	49.8 ± 1.5	2.4 ± 2.3
Lengyel	UBA-21415	5603-677	30–35	M	−19.6 ± 0.22	11.3 ± 0.15				
$\delta^{13}C$: T′ = 0.1, T′(5%) = 3.8, ν = 1, −19.5 ± 0.15‰; $\delta^{15}N$: T′ = 0.4, T′(5%) = 3.8, ν = 1, 11.3 ± 0.13‰										
Lengyel	OxA-27479	5603-927	50–59	M	−19.3 ± 0.2	10.4 ± 0.3		47.5 ± 1.7	49.8 ± 1.8	2.7 ± 2.5
Sopot	MAMS-14813	5603/2-210	35–45	M	−20.4 ± 0.2	9.6 ± 0.1		48.6 ± 1.0	50.0 ± 1.0	1.4 ± 1.4
Sopot	MAMS-14814	5603/2-220A	35–45	M	−20.6 ± 0.2	9.0 ± 0.1		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Sopot	MAMS-20487	5603/2-372	18–20	F	−20.0 ± 0.08	9.7 ± 0.09		48.8 ± 0.8	50.0 ± 0.8	1.2 ± 1.2
Sopot	UBA-21433	5603/2-372	18–20	F	−20.3 ± 0.22	9.6 ± 0.15				
$\delta^{13}C$: T′ = 1.6, T′(5%) = 3.8, ν = 1, −20.0 ± 0.08‰; $\delta^{15}N$: T′ = 0.3, T′(5%) = 3.8, ν = 1, 9.7 ± 0.08‰										
Sopot	OxA-27579	5603/2-373	25–35	F	−19.4 ± 0.2	9.4 ± 0.3		47.8 ± 1.5	50.0 ± 1.6	2.3 ± 2.2
Sopot	MAMS-14815	5603/2-396	7	Child	−20.8 ± 0.2	9.1 ± 0.1		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2
Sopot	MAMS-14817	5603/2-463	6	Child	−20.9 ± 0.2	9.0 ± 0.1		48.9 ± 0.8	50.0 ± 0.8	1.1 ± 1.1
Sopot	MAMS-20485	5603/2-464	40–45	M	−20.9 ± 0.08	10.6 ± 0.09		49.1 ± 0.6	50.0 ± 0.6	0.9 ± 0.9
Sopot	OxA-27578	5603/2-464	40–45	M	−19.4 ± 0.2	10.9 ± 0.3				
Sopot	OxA-29068	5603/2-464	40–45	M	−20.7 ± 0.2	10.1 ± 0.3				
Sopot	OxA-30283	5603/2-464	40–45	M	−20.4 ± 0.2	10.4 ± 0.3				
$\delta^{13}C$: **T′ = 50.4**, T′(5%) = 7.8, ν = 3, −20.7 ± 0.07‰; $\delta^{15}N$: T′ = 4.1, T′(5%) = 7.8, ν = 3, 10.6 ± 0.08‰										
Sopot	MAMS-20488	5603/2-470	35–45	M	−20.0 ± 0.08	11.2 ± 0.3		48.6 ± 0.9	49.9 ± 1.0	1.5 ± 1.4
Sopot	MAMS-14818	5603/2-471	13	Child	−20.7 ± 0.2	9.0 ± 0.1		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2
Sopot	MAMS-20486	5603/2-475	14–15	Juvenile	−20.3 ± 0.08	9.5 ± 0.09		49.0 ± 0.7	50.0 ± 0.7	1.0 ± 1.0
Sopot	UBA-21436	5603/2-475	14–15	Juvenile	−20.3 ± 0.22	9.5 ± 0.15				
$\delta^{13}C$: T′ = 0.0, T′(5%) = 3.8, ν = 1, −20.3 ± 0.08‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 9.5 ± 0.08‰										
Sopot	OxA-28246	5603/2-476	18–20	Adult	−20.0 ± 0.2	9.5 ± 0.3		48.7 ± 0.9	50.0 ± 1.0	1.4 ± 1.4
Sopot	UBA-22461	5603/2-476	18–20	Adult	−20.2 ± 0.22	9.5 ± 0.15				
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −20.1 ± 0.15‰; $\delta^{15}N$: T′ = 0.0, T′(5%) = 3.8, ν = 1, 9.5 ± 0.13‰										

Tab. 5. (continued)

Cultural association	Laboratory number	Sample number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	$\delta^{34}S$ (‰)	Cereals (%)	Terrestrial animal (%)	Freshwater fish (%)
Starčevo	SUERC-57542	5603-1061	40–50	M	−20.5 ± 0.2	9.5 ± 0.3		48.6 ± 1.0	50.0 ± 1.0	1.5 ± 1.5
Starčevo	MAMS-11932	5603-1372	35–45	M	−20.9 ± 0.2	11.0 ± 0.1		48.6 ± 1.0	49.9 ± 1.0	1.5 ± 1.5
Starčevo	MAMS-11933	5603-1435	8–9	Child	−21.0 ± 0.2	7.5 ± 0.1		49.1 ± 0.7	50.1 ± 0.7	0.9 ± 0.9
Starčevo	MAMS-11934	5603-1436	25–35	F	−20.9 ± 0.2	9.5 ± 0.1		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2
Starčevo	MAMS-11935	5603-1483	7–8	Child	−20.9 ± 0.2	9.4 ± 0.1		48.8 ± 0.9	50.0 ± 0.9	1.2 ± 1.2
Starčevo	MAMS-11936	5603-1525	25–30	M	−20.2 ± 0.2	9.4 ± 0.1		48.5 ± 1.1	50.0 ± 1.1	1.5 ± 1.6
Starčevo	MAMS-11937	5603-1527	40–50	F	−20.7 ± 0.2	10.4 ± 0.1		48.6 ± 1.0	49.9 ± 1.0	1.5 ± 1.5
Starčevo	MAMS-11938	5603-1528	45–55	F	−20.9 ± 0.2	10.6 ± 0.1		48.7 ± 0.9	49.9 ± 1.0	1.4 ± 1.4
Starčevo	MAMS-11939	5603-1532	20–30	Adult	−20.6 ± 0.2	10.0 ± 0.1		48.6 ± 0.9	50.0 ± 1.0	1.4 ± 1.3
Starčevo	MAMS-11940	5603-1533	35–45	M	−20.3 ± 0.2	9.8 ± 0.1		48.5 ± 1.0	50.0 ± 1.0	1.5 ± 1.5
Starčevo	MAMS-11926	5603-688	23–27	F	−20.5 ± 0.2	9.1 ± 0.1		48.7 ± 0.9	50.0 ± 0.9	1.3 ± 1.3
Starčevo	MAMS-11927	5603-721	30–40	F	−20.9 ± 0.2	9.9 ± 0.1		48.7 ± 0.9	50.0 ± 0.9	1.3 ± 1.3
Starčevo	MAMS-11928	5603-745	35–45	Adult	−20.6 ± 0.2	10.6 ± 0.1		48.5 ± 1.0	49.9 ± 1.1	1.6 ± 1.6
Starčevo	MAMS-11929	5603-746	9–11	Child	−20.5 ± 0.2	8.5 ± 0.1		48.8 ± 0.8	50.1 ± 0.9	1.1 ± 1.1
Starčevo	MAMS-11930	5603-775	8–10	Child	−21.1 ± 0.2	10.1 ± 0.1		48.8 ± 0.9	50.0 ± 0.9	1.3 ± 1.3
Starčevo	MAMS-11931	5603-797	35–45	F	−20.8 ± 0.2	9.8 ± 0.1		48.7 ± 0.9	50.0 ± 0.9	1.3 ± 1.3

Tab. 5. (continued)

Cultural Association	Laboratory Number	Sample Number	Age	Sex	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Cereals	Breastmilk
Lengyel	OxA-27461	11-272	c. 3	Child	–19.5 ± 0.2	12.8 ± 0.3	61.6 ± 6.7	38.4 ± 6.7
Lengyel	OxA-27460	11-228	2.5–3	Child	–20.0 ± 0.2	10.2 ± 0.3	36.7 ± 6.7	63.3 ± 6.7
Starčevo	OxA-30353	5603-1398	c. 1	Child	–19.7 ± 0.2	13.1 ± 0.3	36.5 ± 6.3	63.6 ± 6.3
Starčevo	OxA-30354	5603-1398	c. 1	Child	–19.7 ± 0.2	12.8 ± 0.3		
$\delta^{13}C$: $T' = 0.0$, $T'(5\%) = 3.8$, $\nu = 1$, –19.7 ± 0.15‰; $\delta^{15}N$: $T' = 0.5$, $T'(5\%) = 3.8$, $\nu = 1$, 13.0 ± 0.22‰								

Tab. 6. FRUITS diet proportion of cereal and breastmilk isotopic proxy for children of three years or younger. Replicate measurements have been compared and combined using the method of Ward / Wilson (1978).

Cultural association	Laboratory number	Sample number	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Terrestrial animals (%)	Freshwater fish (%)
Lengyel	MAMS-20648	10B-69-5	−19.2 ± 0.2	10.3 ± 0.25	66 ± 20	34 ± 20
Lengyel	MAMS-20658	10B-4282	−19.6 ± 0.2	8.2 ± 0.25	91 ± 9	9 ± 9
Lengyel	OxA-27567	10B-441	−19.3 ± 0.2	8.7 ± 0.3	90 ± 9	10 ± 9
Lengyel	OxA-27582	10B-441	−19.5 ± 0.2	8.3 ± 0.3		
$\delta^{13}C$: T′ = 0.5, T′(5%) = 3.8, ν = 1, −19.4 ± 0.15‰; $\delta^{15}N$: T′ = 0.9, T′(5%) = 3.8, ν = 1, 8.5 ± 0.22‰						
Lengyel	SUERC-52797	10B-619	−20.2 ± 0.2	8.1 ± 0.3	89 ± 10	11 ± 10
Lengyel	SUERC-52848	5603-2576-1	−19.7 ± 0.2	10.5 ± 0.3	50 ± 23	50 ± 23
Lengyel	UBA-22007	10B-441_723	−20.2 ± 0.22	8.7 ± 0.15	86 ± 13	14 ± 13
Lengyel	SUERC-52803	10B-441_723	−20.5 ± 0.2	9.0 ± 0.3		
$\delta^{13}C$: T′ = 1.0, T′(5%) = 3.8, ν = 1, −20.4 ± 0.15‰; $\delta^{15}N$: T′ = 0.8, T′(5%) = 3.8, ν = 1, 8.8 ± 0.13‰						

Tab. 7. Stable isotopic values obtained on samples of dog bone from Alsónyék, with estimated proportions of dietary sources provided by the FRUITS modelling. Replicate measurements have been compared and combined using the method of Ward / Wilson (1978).

Sample reference	Laboratory number	Radiocarbon age (BP)	Weighted mean & T′ test
5603/2-464	MAMS-20485	6124 ± 27	6151 ± 16 BP; T′ = 5.8; T′(5%) = 7.8; ν = 3
	OxA-27578	6111 ± 36	
	OxA-29068	6209 ± 31	
	OxA-30283	6157 ± 34	
5603-1867	OxA-27448	5866 ± 33	5869 ± 25 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	OxA-27449	5872 ± 35	
11-333	OxA-27468	5804 ± 32	5805 ± 23 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	OxA-27469	5806 ± 32	
10B-3770	OxA-27483	5786 ± 33	5785 ± 24 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	OxA-27484	5784 ± 33	
11-2028	OxA-27530	5801 ± 36	5811 ± 26 BP; T′ = 0.2; T′(5%) = 3.8; ν = 1
	OxA-27580	5821 ± 37	
10B-362	OxA-27566	5852 ± 38	5854 ± 25 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	OxA-27581	5855 ± 31	
10B-411	OxA-27567	5847 ± 36	5882 ± 24 BP; T′ = 1.6; T′(5%) = 3.8; ν = 1
	OxA-27582	5907 ± 31	
11-1808	OxA-28253	5883 ± 33	5878 ± 24 BP; T′ = 0.1; T′(5%) = 3.8; ν = 1
	OxA-28254	5872 ± 34	
10B-7753	OxA-28941	5755 ± 35	5751 ± 25BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	OxA-28942	5748 ± 34	
10B-6337	OxA-29060	5733 ± 33	5727 ± 23 BP; T′ = 0.1; T′(5%) = 3.8; ν = 1
	OxA-29061	5722 ± 31	
Starčevo G1398	OxA-30353	6738 ± 33	6710 ± 24 BP; T′ = 1.6; T′(5%) = 3.8; ν = 1
	OxA-30354	6679 ± 34	
3759/2360	OxA-30355	6305 ± 33	6306 ± 24 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	SUERC-58484	6307 ± 33	
4559/2674	OxA-30357	6317 ± 32	6311 ± 24 BP; T′ = 0.1; T′(5%) = 3.8; ν = 1
	SUERC-58485	6305 ± 34	

Tab. 8. Replicate radiocarbon measurements from Alsónyék, compared and combined using the method of Ward / Wilson (1978). Measurements that are statistically consistently different at 95% confidence are in bold.

Sample reference	Laboratory number	Radiocarbon age (BP)	Weighted mean & T′ test
10B-822	OxA-27480	5808 ± 35	5807 ± 27 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	UBA-22526	5806 ± 41	
11-1391	OxA-27470	5883 ± 34	5887 ± 28 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	UBA-22529	5893 ± 46	
5603-2162	OxA-27455	5674 ± 33	5705 ± 26 BP; T′ = 2.0; T′(5%) = 3.8; ν = 1
	UBA-22531	5747 ± 39	
5603-1989	OxA-27458	5834 ± 33	5865 ± 25 BP; T′ = 2.0; T′(5%) = 3.8; ν = 1
	UBA-22534	5906 ± 38	
10B-140-3	SUERC-52806	5790 ± 28	5798 ± 16 BP; T′ = 0.1; T′(5%) = 3.8; ν = 1
	MAMS-20650	5801 ± 18	
10B-382-1	SUERC-52802	5757 ± 32	5781 ± 17 BP; T′ = 0.8; T′(5%) = 3.8; ν = 1
	MAMS-20652	5790 ± 19	
10B-736	SUERC-52813	5879 ± 32	5829 ± 17 BP; T′ = 3.4; T′(5%) = 3.8; ν = 1
	MAMS-20655	5811 ± 19	
5603-2256	SUERC-52847	5686 ± 31	5693 ± 20 BP; T′ = 0.1; T′(5%) = 3.8; ν = 1
	MAMS-20663	5698 ± 25	
5603-2772	SUERC-53036	5695 ± 27	5740 ± 17 BP; T′ = **4.2**; T′(5%) = 3.8; ν = 1
	MAMS-20667	5764 ± 20	
11-1687	SUERC-52828	5775 ± 30	5769 ± 19 BP; T′ = 0.1; T′(5%) = 3.8; ν = 1
	MAMS-20672	5766 ± 23	
11-1025	SUERC-52824	5778 ± 33	5784 ± 20 BP; T′ = 0.0; T′(5%) = 3.8; ν = 1
	MAMS-20676	5787 ± 25	
11-538	SUERC-52822	5765 ± 30	5753 ± 20 BP; T′ = 0.3; T′(5%) = 3.8; ν = 1
	MAMS-20677	5744 ± 25	

Tab. 8. (continued)

Laboratory number	Context	$\delta^{13}C_{IRMS}$ (‰)	$\delta^{15}N$ (‰)	C:N	Radicarbon age (BP)	Calibrated date (2σ)
Poz-68348	Left sub-adult cattle metatarsal with marks of articulating tarsal from western long pit of house H46				5355 ± 35	4330–4050 cal BC
OxA-29026	Right femur from articulated human burial in grave 10B-3461	−20.5 ± 0.2	9.6 ± 0.3	3.3	3708 ± 31	2200–1980 cal BC
OxA-29027	Right femur from articulated human burial in grave 10B-3463	−20.0 ± 0.2	10.4 ± 0.3	3.2	3676 ± 32	2200–1950 cal BC
OxA-27489	Cranium from articulated dog bones in pit 10B-820	−15.8 ± 0.2	9.8 ± 0.3	3.2	2307 ± 25	410–360 cal BC
OxA-28165	Right tibia from articulated human burial in grave 5603/2-470	−17.0 ± 0.2	10.5 ± 0.3	3.2	1306 ± 22	cal AD 660–770

Tab. 9. Radiocarbon results and associated measurements on post-Neolithic samples from Alsónyék.

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