^{14}C calendar chronologies and cultural sequences in 5th millennium BC in Slovenia and neighbouring regions

Marko Sraka
Department of Archaeology, Faculty of Arts, University of Ljubljana, SI
marko.sraka@ff.uni-lj.si

ABSTRACT – *In the paper, Bayesian analysis of ^{14}C dates implemented in the OxCal program is used to develop calendric time-scale chronologies of individual sites and archaeological cultures of the 5th millennium calBC in Slovenia and Croatia. Case studies are presented in which ^{14}C dates are analysed and reinterpreted with the aid of contextual archaeological data. At the site level, stratigraphic sequences are used in models to constrain and then precisely date activities within them. At the regional level, the results of the chronological modelling of archaeological cultures are used to present them on a calendric time-scale and within a broader spatial framework of Central and Southeastern Europe. Special emphasis is placed upon critical comparison of modelled calendar and cultural sequences. On the basis of this comparison, some inconsistencies and contradictions in the relative chronological schemes of periods and archaeological cultures are presented.*

IZVLEČEK – *V članku uporabljamo bayesove analize ^{14}C datumov v kalibracijskem programu OxCal za oblikovanje koledarskih kronologij posameznih najdišč in arheoloških kultur 5. tisočletja pr. n. št. v Sloveniji in na Hrvaškem. Predstavljamo študijske primere, v katerih s pomočjo kontekstualnih arheoloških podatkov analiziramo in reinterpretiramo ^{14}C datume. Na ravni najdišč stratigrafska zaporedja služijo natančnejšemu datiranju najdišč in v njih prepoznanih aktivnosti. Na regionalni ravni rezultate kronološkega modeliranja arheoloških kultur uporabimo za njihovo umeščanje v koledarski časovni okvir in širši prostorski okvir Srednje in Jugovzhodne Evrope. Poseben poudarek namenjamo primerjavam med modeliranimi koledarskimi in kulturnimi zaporedji. Na osnovi teh primerjav predstavljamo nekatere nedoslednosti in protislovja relativnih kronoloških shem obdobij in arheoloških kultur.*

KEY WORDS – *^{14}C dating; time concepts; chronology; Neolithic; Eneolithic*

Introduction

Contemporary discussions of the concepts of time in archaeology are still concerned with problems of chronology. In contrast to the earlier and often polarizing discussions, it is now becoming increasingly apparent that both relative chronology and calendar (radiometric) chronology in many cases actually have the same basic flaws. In his book 'The Archaeology of Time', Gavin Lucas (*2005.10*) suggests that "*chronology – whether relative or absolute – is theoretically problematic and for one chief reason: it presents time as a uniform, linear phenomenon which has tended to define the model for historical explanation in a similar uniform, linear way … Both the periodisation and the calendar flow in one direction and each is divided into discrete, non-overlapping units,* i.e. *periods or years. The main difference is that periodisation uses much larger units than the calendrical system but, in principle, they share the same structure. In short, they presume a specific conception of time as a uni-linear sequence or series.*"

Alternative approaches have been proposed which share the basic idea that different historical proces-

DOI: 10.4312/dp.39.26

ses operate on different temporal scales. These approaches borrow from the French historical theory developed by the Annales School and non-linear dynamics. Of the more influential theoretical discussions on the concepts of time in archaeology, Geoff Bailey's (*2007*) concept of time perspectivism and Michael Shanks and Christopher Tilley's (*1987*) concept of abstract and substantial time are worth mentioning. Bailey draws attention to the existence of different conceptual timescales and especially to "*... the relatively coarse temporal resolution and palimpsest nature of much of the archaeological record; the possibility that the increased time depth and varied time resolution of observation afforded by archaeological data might allow us to perceive phenomena and processes not visible at smaller scales of observation.*" (*Bailey 2007.199*). He goes on to argue that "*...the analysis of small-scale phenomena such as individual agency, inter-personal interactions and perception, which have become such a dominant tendency in recent archaeological interpretation, is better focused on observation of, say, present-day practices or recent historical periods rather than the deeper prehistoric past.*" (*Bailey 2007.201*). Shanks and Tilley (*1987.128*) criticise one specific detail of Bailey's position, namely that archaeology should deal with the long-term, and they consequently differentiate between two different kinds of time – abstract and substantial time. They equate the abstract with measured time, which is a notion that only recently emerged within the framework of the modern economic worldview. This is the (technical) time concept underlying the construction of relative and calendar archaeological chronologies. Substantial time, on the other hand, is the time of social practice, time as perceived by social actors in the short-term.

Shanks and Tilley and other post-processualists are concerned with the experience and flow of time, issues of the social construction of time, of memory and forgetting, and of the nature of the past in the past. With this focus, in the search for history and temporality, there is a natural tendency to downplay sequence as mere chronology both relative and absolute. (*Whittle* et al. *2011b.3*). In consequence, the discussion again becomes polarizing. At the same time, new methodologies have been developed within the framework of archaeological sciences that place much emphasis on the major (although earlier only qualitative) impact that metric, radiocarbon chronology has had on prehistoric archaeology (*Renfrew 1973*). Today, many tools are available, the common aim of which is the construction of chronologies that simultaneously take into account radiocarbon (^{14}C age) data as well as archaeological information in order to achieve more precise chronologies (*Bronk Ramsey 2008*). Interestingly, the existence of two entirely different concepts of time, as noted above, is even today not widely acknowledged, even to the point that the corresponding schools-of-thought remain largely ignorant of each other. As Robert Paynter (*2002. 97*) puts it, "*the theoretical side of archaeology lost track of time just as the methodological side of archaeology was acquiring the ability to create absolute chronologies*".

Recently the new 'Bayesian' approach to interpreting archaeological chronologies has been applied to the British Neolithic with present focus on long barrows and enclosures (*Bayliss* et al. *2007; Whittle* et al. *2011a*). The research incentive is not only to provide a more precise chronology, but also to bridge the gap between post-processual theoretical discussions and new calendar chronologies. The authors of these projects postulate there is a "*... need to determine the tempo of cultural change, the duration of activities seen in the archaeological record and the nature of temporality or the lived experience and marking of time. But it is hard to see how we can begin to attempt these goals without a framework of calendar dating. The calendrical time scale allows an assessment of elapsed time – how long is significant as well as when*" (*Bayliss* et al. *2007.2*).

Unfortunately, such ongoing theoretical discussions in the English-speaking community rarely meet a response in other European countries, including Slovenia. Here, questions relating to the measurements and conceptualization of time in the archaeological record are still widely treated within traditional chronological schemes, in which time is related to the assumed existence of cultural entities (such as the Neolithic and Eneolithic) and, on shorter timescales, to the assumed existence of archaeological cultures (such as Lengyel and Lasinja). Independent of any dating resolution, within this framework, ^{14}C dates can only be used to replicate such schemes in calendar years.

Problems of chronology

Chronology is fundamental to archaeology, since it allows the time-dependency of variations in the archaeological record to be distinguished from those determined by other factors. As widely recognized, it is inherently difficult to use the material record to distinguish between real historical processes and processes that are only artificially reconstructed as a result of research methodology. Before calendar chronology was possible, only relative chronology could be established, based on the classification of artefacts into typological sequences. The 'cultural' (or 'comparative-stratigraphic') dating method is based on evaluating the superposition of archaeological deposits, to begin on a local or regional scale, and the results are then used in a transfer procedure to date other deposits, on a wider geographical scale. Since the origin of such generalizing periodisation schemes in the 19th century, their meanings constantly shifted, but individual cultural units (*e.g.*, periods) have always been represented as an entity which can be analysed as a coherent whole (*Thomas 1993.390*). Following the introduction of the concept of archaeological cultures in early 20th century, and the increasingly predominant critique of such concepts in the late 20th century, today – despite a general waning of chronological discussion – the application of such schemes became widespread. Importantly, archaeological culture is still today represented as an entity, which is internally stable, time-constant and altogether quite inflexible. Johannes Müller rightly criticizes this view when he writes that "*Most of the archaeologists reconstructed 'cultures' as spatially and temporally limited units that followed one after the other*" (*Müller 2009.722*). If at all, some minor cultural flexibility is allowed to cover the possibility of some minor temporal overlap.

The general notion underlying all classification-based research programs is that culture is simply a materialized sequence of events. In relative chronology, this leads to a vicious cycle, since the material classification is not only used for dating purposes, but also simultaneously for the definition of what is being dated. This is already apparent for cultural dating with low resolution on the temporal level of major chronological periods (*e.g.* Neolithic, Eneolithic), but all the more when the dating is refined to cover the level of cultural units (*e.g.* Lengyel, Lasinja). On both levels, the typologically classified material culture is inevitably presented as temporally exclusive (despite possible contemporaneity). Simultaneously, any observed variability within the material record is used to define the supposedly fixed (and then accepted) limits of the classificatory units under study. In this manner, since these units can only be defined as homogenous, the allowed cultural variability regulates the precision of the cultural dating. The underlying world-view is that prehistory contains a long and steady sequence of artificially homogenous and internally stable periods or cultures that are separated from each other by relatively rapid changes in their material (typological) foundation.

The research program based on relating cultural change to the material variability found within any given sequence of time-exclusive periods and cultures has further (and again inherent) implications, the most important of which is related to the normative culture-historical interpretations, namely that differently classifiable material culture must be the product of different peoples (*Shanks, Tilley 1987.79–95*). This is perhaps best exemplified by Gordon Childe (*1929.v–iv*): "*We find certain types of remains – pots, implements, ornaments, burial rites, and house forms – constantly recurring together. Such a complex of associated traits we shall term a 'cultural group' or just a 'culture'. We assume that such a complex is the material expression of what today would be called a 'people'*". When integrated within a research program, such concepts of how to understand variability within the archaeological record not only provides a chronological background, but also an interpretive framework within which it is possible to define certain norms in culture. The very concept of relating culture to chronology in this manner ultimately makes both constitutive of each other. It is therefore not only (technically) the case that "*the resolution of dating methods ... influences the form in which societies are reconstructed by archaeologists*" (*Müller 2009.721*), but also (ideally) that "*the conceptualization of time through chronology appears to operate through a historical process of accretion and adaptation rather than refutation*" (*Chazan 1995.464*). Ultimately, relative chronological schemes as well as cultural-historical interpretations of prehistoric society are maintained in such approaches, and this is independent of whether a natural-scientific or cultural approach is taken.

With the continuous refinement of radiometric dating (*e.g.*, ^{14}C–AMS) methods, new calendar chronologies can now be established that allow the dating of individual archaeological events irrespective of their relative-chronological and cultural attribution. In the past, this possibility has often been overlooked. ^{14}C dates are still today sometimes used only as occasional hooks onto which archaeological cultures and periods are hung (*Whittle 2011b.1*) and, if the results of the pre-established relative order are not confirmed, they can even be rejected with no further avail. In this way, relative chronological schemes often established long ago and based on less abundant material compared to the variability known today are often simply replicated. Of course we should discontinue using ^{14}C dates in this manner, but to date activities and events that happened in the past. This new approach is supported by using statistical procedures implemented in a simple to use computer software. Earlier researchers initially applied quite simply implemented ^{14}C-age calibration software, wherein the data-input and the computer-output were perceived as representing independent scientific dates, as claimed by Renfrew (*1973.109*). Over the years, archaeologists have become increasingly aware of the necessity, prior to the statistical analysis, to provide a contextual and interpretive framework based on empirical archaeological information as well as on theoretical modelling. This framework merges the archaeological record with the excavation praxis (the source of the record), with archaeological theory (the interpretation of the record), and – in particular – with the basic principles of the applied dating method.

Bayesian modelling of archaeological chronologies

When handling ^{14}C data, it is important to understand that we are dating events in the past, but that these are seldom contemporary with the archaeological event we wish to date, which can be anywhere from the initial deposition of an artefact assemblage, to the construction of a house, its later burning, the beginning and end of any particular settlement or human occupation in a region as a whole.

From the biological perspective, ^{14}C date provides an estimate of the time that has passed since an organism stopped exchanging ^{14}C with the environment. It is therefore important to consider the time-width or the period during which the exchange of carbon was active. For 'short-lived' samples such as a cereal grain, this period is short (1 growing season), but for 'long-lived' samples, such as charcoal, it can be quite long (up to 100 years and more). Trees grow by the addition of rings and once these are laid down, the photosynthetic carbon exchange between the rings and the atmosphere ceases. Unfortunately, for the majority of charcoal samples that derive from any typical archaeological excavation, it is impossible to reconstruct whether the charcoal originates from the (older) heartwood or the (younger) sapwood. Strictly speaking, the time-difference between the calendric age of the charcoal sample and the felling of a tree, not to mention the use of its wood for building or fuel, remains unknown. To avoid the error-prone reconstruction of the 'average' calendric age of a 'typical' charcoal sample (and this is very clearly emphasized by Patrick Ashmore (*1999*), when he recommends only dating single and not multiple events), it is advisable to sample only 'short-lived' samples. As is well-known, the re-analysis of earlier ^{14}C-data is therefore seldom really fruitful, since in the past the large majority of dates were produced on charcoal. But today, the ^{14}C-AMS technique readily allows the dating of very small samples, such as cereals, small bones and organic residue on pottery. AMS-^{14}C-ages that have been obtained on such 'short-lived' samples obviously provide dates that are more closely related to events of archaeological interest, than dates on potentially long-lived charcoal samples.

Since radiocarbon results are supplied as statistical estimates, ^{14}C age values show a sometimes wide scatter around the true ^{14}C age, depending on the quoted error. When ^{14}C-measurements are age-calibrated, this initial scattering effect is further amplified, depending on the shape of the tree-ring based calibration curve in the relevant period. The true calendar ages of ^{14}C measurements can be represented in formally quite simple looking graphs, both for single as well as for grouped dates, but the resulting graph requires some actually quite complex interpretation, and the typically multi-modal distribution of calendric-scale dating probability shown in such graphs can hardly be intuitively understood. In consequence, due to the inevitable statistical scatter of ages in combination with the folding effects of the calibration curve, it is virtually impossible – by a mere visual inspection of calibrated age graphs – to obtain a realistic estimate for the actual age of the archaeological events of interest under study. In particular, due to the unrealistically wide spread of readings induced by the shape of the calibration curve, it is difficult to derive a statistically reliable estimate for the actual durations of the activities under study.

As an helpful alternative, it is possible to analyse extended sets of ^{14}C dates with the use of computer-based methods that are derived from probabilistic Bayesian theory. Such methods, that are becoming increasingly popular in the archaeological community, are capable of providing formally correct age estimates with quantified uncertainties for a wide range of applications. To this purpose, in the present study, we make use of the calibration software OxCal (*Bronk Ramsey 2009*), which implements Bayesian statistics and Markov Chain Monte Carlo sampling.

The underlying idea is to provide statistical constraints for the typically large multiplicity of calendric scale readings, with the aid of additional archaeological information. To be successful, this approach requires a refined look not only at the statistical properties of the ^{14}C-data under study, but also at the archaeological properties of the study samples.

The Bayesian approach to modelling archaeological chronologies has been under development for some 20 years now and has over the years been applied to wide variety of chronological problems. There exist many theoretical, methodological and practical studies that provide introductions to Bayesian calibration procedures. Most recently, the Bayesian methodology is described in detail by Christopher Bronk Ramsey (*1995; 1998; 2008; 2009),* Alex Bayliss *et al.* (*2007*) and Alasdair Whittle *et al.* (*2008; 2011a*). In a nut-shell, the Bayesian approach (as implemented in the OxCal-program) is simultaneously probabilistic as well as contextual, and enables input of the necessary archaeological information for a wide variety of archaeological study situations. In OxCal the analysis procedure is not simply a matter of entering data, and obtaining results (as sometimes assumed), but instead a question of experimenting with the data in the light of available archaeological information. The OxCal program supports this approach by providing a platform for convenient recalculation of the calibrated probability distributions of ^{14}C dates under different conditions. A particularly useful option is to estimate ages of events that have not been directly dated, as well as to estimate the duration of activities.

The OxCal program allows different chronological models to be produced. In these models, archaeological information is used to define the relationships between ^{14}C dates and archaeological events of interest, as is usually available as a stratigraphic or other kind of relative sequence. The two basic tools in OxCal with which basically any chronological problem can be addressed are 'Phases' and 'Sequences'. The former can be used to group ^{14}C dates, the relative chronological order of which is not known, but the data are assumed to be connected. The latter can be used when information is available for the relative chronological order of the dated samples. Phases and sequences can be nested one in another, so that we can, for example, have a sequence of phases within which ^{14}C dates are grouped. We make use of such a simple sequence of phases in the present paper when chronologically modelling the different Neolithic settlement phases at Moverna vas, whereas a more complex nesting of phases and sequences is used in the chronological modelling of the Vinkovci-Sopot site. In Bayesian terminology, archaeological information entered during the modelling process serves as an 'Informative' prior belief which strongly affects the chronological results and therefore has to be used knowledgeably and with an understanding of the chronological questions we wish to ask.

OxCal also uses what is called 'Uninformative' prior belief, the application of which is useful when ^{14}C dates are known to be related, for example when we date a period of past activity (which may be a period of settlement occupation or period of production of a certain pottery type). By implementing a uniform event distribution on the sample set, we assume that the activity began, then continued at a relatively constant rate, and then ended. The assumption, in this case, is that the available set of ^{14}C dates can be visualized as representing a random sample of dates within this period. According to Bayliss *et al.* (*2011.21*) this assumption allows the OxCal program to "*...asses how far the variation in the calibrated radiocarbon dates arises from variation in the actual dates of the samples, and how far from the probabilistic scatter inherent in radiocarbon dating and calibration process*". In short, this enables the program to set an upper limit on the statistical scatter of ^{14}C dates. In OxCal, the assumption of a uniform distribution is introduced by enclosing the phase within boundaries. We use this approach in all of our chronological models, but whereas the underlying assumptions are unproblematic for site-based case studies (Moverna vas and Vinkovci-Sopot), it is harder to substantiate in the case studies in which pottery distinctions are used to further subdivide cultural periods (Sava group of the Lengyel culture and Lasinja culture). The critical question, not only when applying the corresponding OxCal options, is whether pottery styles really do have a beginning and an end, or whether there is a gradual transformation from one style to the next. According to Bronk Ramsey (*1998. 462*), in general terms the validity of the specific assumptions underlying the choice of a uniform sample distribution of ^{14}C samples has only minor influence on the results of chronological models. For security, OxCal nevertheless provides a so-called 'Agreement index', in which the consistency between the archaeological prior information and the data is estimated. For threshold values at 60% or higher the agreement between the model (input) and the chronological results (output) is considered consistent.

Bayesian chronological modelling not only provides a methodology either to constrain chronological data with the aid of archaeological information, or to limit the scatter of probability distributions, but also enables ages for events of archaeological interest, that are not directly dated, to be estimated (*Bronk Ramsey 2009*). In combination with the Phases and Boundaries options, OxCal also provides estimates for the individual calendar age values of the 'Start', 'End' and 'Boundary' of the individual modelled phases as well as other positions in a sequence. We use this OxCal option to estimate the age for the typological change between Sopot II–B and III typological phases. These are constrained in a sequence of superposed houses on the tell-site in Vinkovci-Sopot that will be presented in one of our case studies.

To conclude, the Bayesian approach to chronological modelling is a heuristic tool with which different chronological models combining ^{14}C data and contextual archaeological information can be tested and compared. The results are never absolute or final, and change when additional data becomes available. This 'hermeneutic spiral' (*Bayliss* et al. *2007.Fig. 2)* answers specific chronological questions, introduces new ones and is never complete.

Outline of the study

In the following, Bayesian chronological modelling is applied to five case studies: three from Slovenia and two from the Slavonian region of Croatia. For Bayesian chronological modelling, we used the OxCal program, version 4.1 (*Bronk Ramsey 2009*) with implemented IntCal09 calibration curve (*Reimer* et al. *2009*). All age estimates of dates and duration estimates are presented as 1 sigma or 68.2% probability ranges. It must be pointed out that a majority of the ^{14}C dates used in our models are on charcoal, so an 'old wood effect' must be taken into account. All the ^{14}C dates and the relevant contextual data we used in our models are presented in the appendix.

Two case studies deal with the calendar chronologies of individual sites, where archaeological data allows more precise dating of activities within them. Nesting of phases and sequences is used to model the relationships between ^{14}C dates as represented by the available archaeological information. These are the cases in which Bayesian chronological modelling is most useful, because it is a tool for the precise calendar dating of activities on sites irrespective of the more traditional relative dating by pottery. In the case of the Moverna vas site from Slovenia, the stratigraphic sequence will be used to constrain the dates from individual Neolithic settlement phases. This will provide a more precise calendar dating for pottery assemblages associated with individual settlement phases, as well as a preliminary assessment of the continuity of Neolithic occupation of this site. From the Slavonian region of Croatia, we present a more complex chronological model of a Neolithic site, at Sopot-Vinkovci. The superpositional relations of houses excavated on this site will allow the dates for individual houses to be constrained and precisely dated.

Three case-studies deal with calendar chronologies of periods in which certain types of pottery were produced. In this, we follow the approach to spatiotemporal modelling suggested by Blackwell and Buck (*2003*; see also *Bayliss* et al. *2011.58*). Bayesian chronological modelling is used in these cases to limit the scatter of probability distributions. This is done with the aid of the bounded phases with an assumption of uniform event distribution on the sample set. This kind of Bayesian chronological modelling is already biased, as it uses the relative chronological schemes to group ^{14}C dates from sites into discrete groups on the basis of the typological and cultural attribution of their pottery assemblages. It is used in our paper first to provide the dating of the periods in which certain types of pottery were produced (*e.g.* Sava group of the Lengyel culture, Lasinja culture) that is more precise than one obtained by simple group calibration, and summing the probability distributions. These periods, namely archaeological cultures, can then be better compared on the calendric time scale. Secondly, and perhaps more importantly, this kind of modelling is used to compare calendar and cultural sequences and to show some inconsistencies and contradictions in the latter. Chronological modelling of the Sava group of the Lengyel culture in Slovenia will limit the scatter of dates from sites associated with this cultural group. It will allow the period of pottery production, on the basis of which this group was defined, to be presented within a calendar time frame and compared with some other cultural sequences from Central and Southeastern Europe. In the last case-study from Slovenia, precisely dated burial activity in Neolithic Ajdovska jama cave site together with the constrained calendar dating of the 6th settlement phase in Moverna vas will be compared to ^{14}C dates from Lasinja culture sites in North-eastern Slovenia. It will be shown that sites attributed to different, temporally exclusive periods and cultures can be contemporary. Information on the typological classification of some sequenced houses from Vinkovci-Sopot site will be used to estimate the date of the transition between typological phases II–B and III of the Sopot culture. This date will be compared to dates of the Lasinja culture sites in the same region. On this basis, it will be shown that a relative chronological sequence of cultures in this region is problematic.

In the discussion, the results of our case-studies are considered within a broader temporal and spatial framework by introducing a diagram in which we correlate calendar and some cultural sequences from Central and Southeastern Europe.

Moverna vas settlement phases

In Slovenia, Bayesian chronological modelling is applied to the Neolithic and Eneolithic site at Moverna vas in Bela Krajina. This is the only Slovenian Neolithic and Eneolithic site from which we have a long stratigraphic sequence together with a sequence of ^{14}C dates spanning the 5th millennium calBC. The stratigraphic sequence shows repetitions of natural processes identified as erosion and the deposition of layered deposits, with artefact assemblages deposited more or less accidentally, and anthropogenic activity identified as post-holes, refuse pits, hearths and burnt loam with post impressions. On the basis of their stratigraphic position within layered deposits, different anthropological traces were ascribed to individual settlement phases (*Budja 1993 (1994).18*) (Fig. 1).

Because all the available ^{14}C dates originate from natural layered deposits and not from immediate traces of anthropogenic activity, only the relative order of settlement phases can be modelled and not activities related to pit digging and house construction within these phases. Nevertheless, Bayesian modelling of the settlement phases enables a more precise dating of the pottery assemblages discovered in these deposits, as well as an assessment of the continuity of occupation of the site. ^{14}C dates are available only for Neolithic settlement phases, while Eneolithic phases are not dated. This is unfortunate, since if dates for Eneolithic phases were available, we could use the stratigraphic sequence to constrain and estimate the date when significant typological change that defines the boundary between Neolithic and Eneolithic (Lasinja culture) happened at the site in the late 5th millennium calBC.

In total, twenty-four ^{14}C dates are available from Moverna vas. Three dates obtained in the 1980s from the laboratory in Zagreb were excluded from analysis because their ages have been published inconsistently in different sources. Of the remaining dates, 6 on charcoal were produced in the Oxford Radiocarbon Accelerator Unit (*Budja 1993 (1994). Fig. 5*) and 15 dates on carbonised residue on pottery were produced in Poznań Radiocarbon Laboratory. Among the dates from Poznań, 10 were produced previously (*Žibrat Gašparič 2008.Fig. 5.1*), 5 new ^{14}C dates were obtained just recently and will be published here for the first time. A great majority of the ^{14}C dates were produced on carbonised residues adhering to the interior or partly exterior surfaces of pottery sherds. This material is probably the remains of charred food and, since the sherds of individual vessels refit within the same stratigraphic context, the pottery has a good chance of being in the place where it was originally discarded. Dates on charcoal, however, could be older than the context due to the 'old wood effect'. On the basis of their stratigraphic context and ascription to individual settlement phases, ^{14}C dates are grouped with-

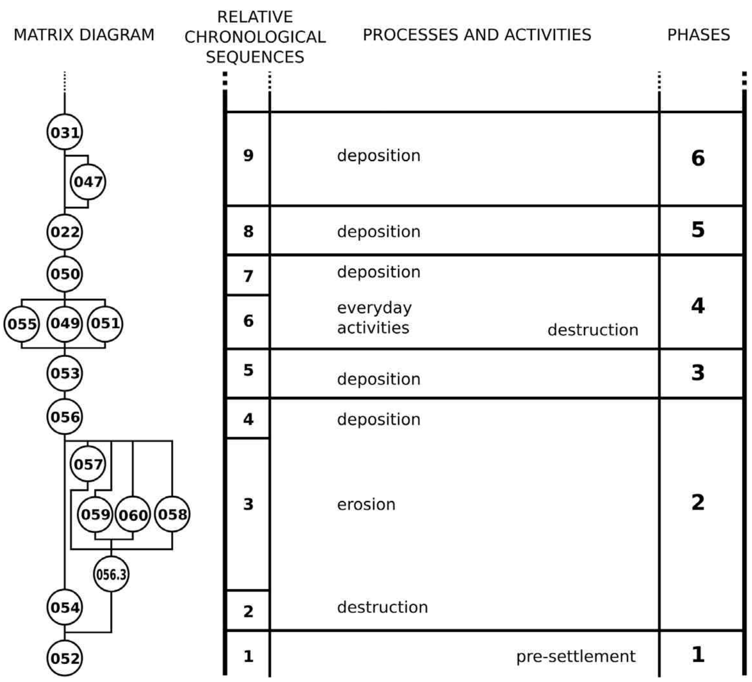

Fig. 1. Stratigraphic sequence and sequence of Neolithic settlement phases in Moverna vas (**Budja 1993(1994).Fig. 5*****).***

in five contiguous bounded phases that follow each other sequentially in the OxCal model. Phases are thus modelled without the possibility of temporal overlap between them. While the dates on carbonised residue on pottery are good, supposedly randomly distributed, samples from within individual settlement phases, this cannot be said of the charcoal dates, as their ages could be significantly older than the events of their deposition within the context, *i.e.* individual settlement phases. ^{14}C dates on charcoal are thus not fully incorporated into our model and are included only as *termini post quos* (*Bayliss* et al. *2011.56–58*). This means that they do not represent random samples from within the individual settlement phases and only constrain the dates for their endings, not their beginnings. One recently obtained ^{14}C date (Poz-48537) was also not incorporated into the model, because it was produced on a sample from older, non-stratigraphic excavations. A correlation of sections from two excavations (non-stratigraphic in 1984 and stratigraphic in 1988) allows us to situate the mentioned sample either within the 4th or the 5th settlement phase, which is in agreement with the probability distribution of this date.

The results of the chronological modelling presented in Figure 2 allows us to estimate the start and end dates of individual phases, the dates of the boundaries between them and the durations of individual phases, as well as the Neolithic settlement as a whole. The model has a good agreement index (115%) and the same holds for individual ^{14}C dates, except for one date (Poz-21404) from the 6th settlement phase, which seems to be too old and was thus excluded from the analysis. A sherd belonging to the same vessel as the inconsistent date was replicated (Poz-48534) in the newest ^{14}C series. It is in good agreement with the model so it seems that the first date on this vessel is erroneous. Our results are consistent with the interpreted sequence of settlement phases at the site. The oldest phase at the settlement, *i.e.* the 2nd settlement phase, starts in 4937–4801 calBC (68.2% probability). It is followed in 4649–4550 calBC (68.2% probability) by the 3rd settlement phase. This phase is objectified in the stratigraphic sequence by a thin layer with very few finds, and was probably formed by natural processes with very little anthropogenic activity. One date on pottery residue from this phase shows that some activity was present, as its age is clearly discerned from the ages of dates from the previous 2nd and following 4th settlement phases. On the basis of our present data, we cannot say if this isolated activity was preceded or followed by any gap in occupation. The dates of 4th and 5th settlement phases are tightly clustered, but we were able to separate them in our model on the basis of relative chronological information. The 4th settlement phase follows a lull of activity represented by the previous settlement phase in 4498–4419 calBC (68.2% probability) and is soon followed by the 5th settlement phase in 4426–4376 calBC (68.2% probability). The groupings of dates in these two settlement phases show that this was a period of high anthropogenic activity. The last Neolithic 6th settlement phase follows the 5th in 4389–4350 calBC (68.2% probability) and ends in 4324–4225 calBC (68.2% probability).

The Neolithic occupation at the site lasted for 512–703 years (68.2% probability). The estimated durations of individual settlement phases show that the oldest 2nd settlement phase is of the longest duration (Fig. 3). It probably lasted two to three centuries or more (178–365 years (68.2% probability)). Of shorter but still significant duration is the 3rd settlement phase (73–204 years (68.2% probability)). The disproportionately long duration of this phase when compared to the thinness of its deposit and lack of archaeological finds is an additional argument suggesting that this phase was a period of low activity. The durations of the following, well-dated 4th (0–78 years (68.2% probability)) and 5th settlement phases (0–42 years (68.2% probability)) are very brief and can be measured in terms of human generations. The last Neolithic 6th settlement phase lasted about more or less a century (38–161 years (68.2% probability)).

Beyond the mere relative sequence of Neolithic settlement phases in Moverna vas, our results not only provide more precise dates, but also durations. This allows us to better interpret the anthropogenic activity at the site and separate periods of low activity from periods of high activity. The oldest 2nd settlement phase at the site can now be dated from the 49th to 47th centuries calBC and thus represents the oldest well documented Neolithic activity in continental Slovenia. The low activity of the 3rd settlement phase can be dated to the 46th century calBC and the first half of the 45th century calBC, while a period of high activity in the 4th settlement phase is dated to the 45th and that of the 5th settlement phase to the first half of the 44th century calBC. The 6th and last Neolithic settlement phase can be dated to the 44th and 43rd centuries calBC. Interestingly, the end of the Neolithic settlement phases in Moverna vas around 4300 calBC is contemporary with the

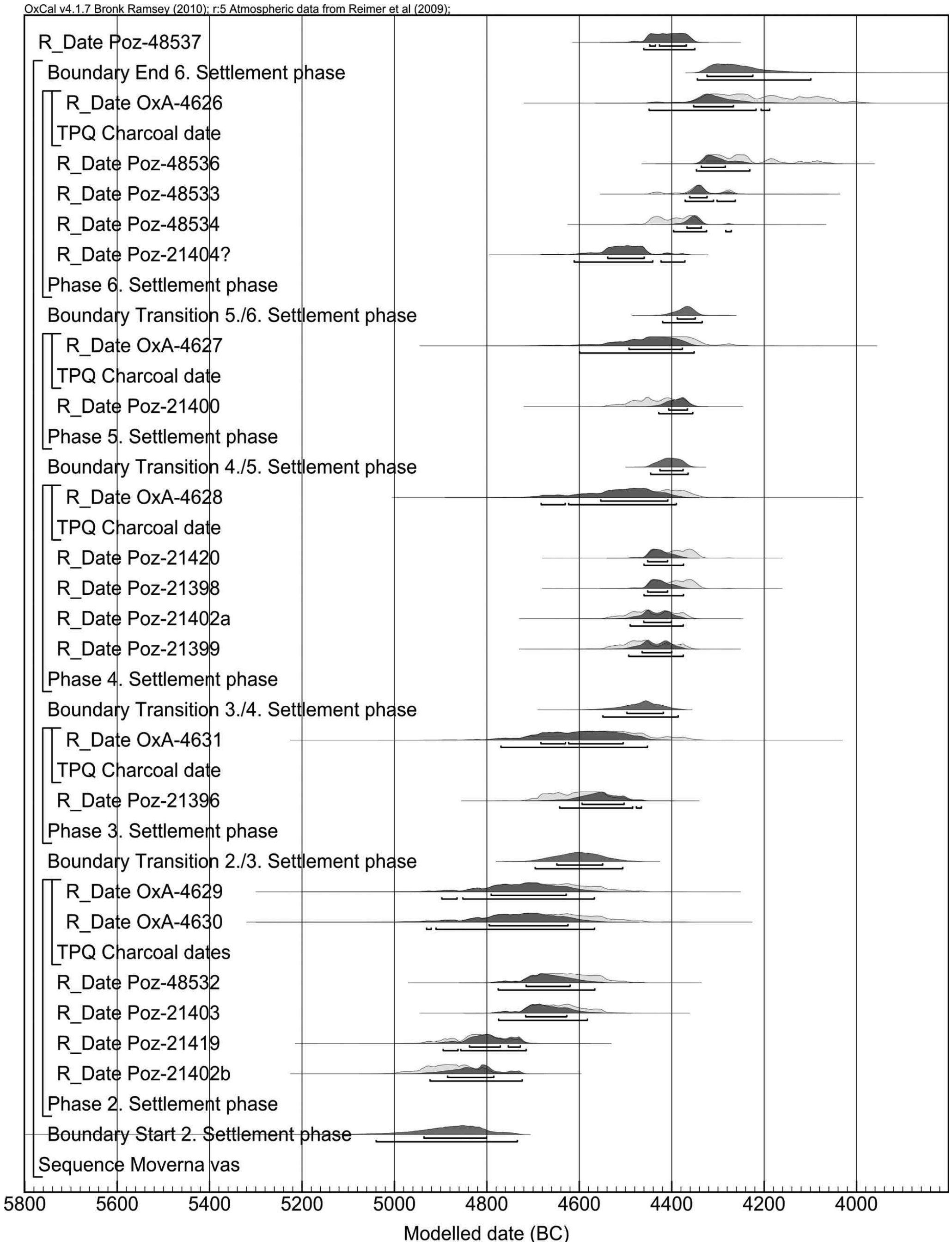

Fig. 2. Chronological model of Moverna vas settlement phases.

proposed beginning of the Eneolithic Lasinja culture in a broader spatial framework (*Balen 2008.22; Guštin 2005.14, Fig. 4; Oross* et al. *2011.182; Ruttkay 1996; Somogyi 2000*). Precisely dated settlement phases in Moverna vas also mean that its pottery assemblages are well constrained on the calendar time frame and can thus be more usefully compared with those from other ^{14}C dated or undated sites. Moverna vas, with its long stratigraphic and typological sequence, is a unique reference point in relation to other Neolithic and Eneolithic sites in Slovenia. The calendar chronology of its settlement phases is useful as an indirect calendar dating reference for other archaeological sites with comparable material.

Analyses of pottery from individual settlement phases in Moverna vas showed considerable changes in typology and technology between the 6th and the undated 7th settlement phases (*Tomaž 1997*). These changes are traditionally considered as marking the transition between the Neolithic and Eneolithic (Lasinja) cultures. Additional dates are needed from younger Eneolithic settlement phases in Moverna vas

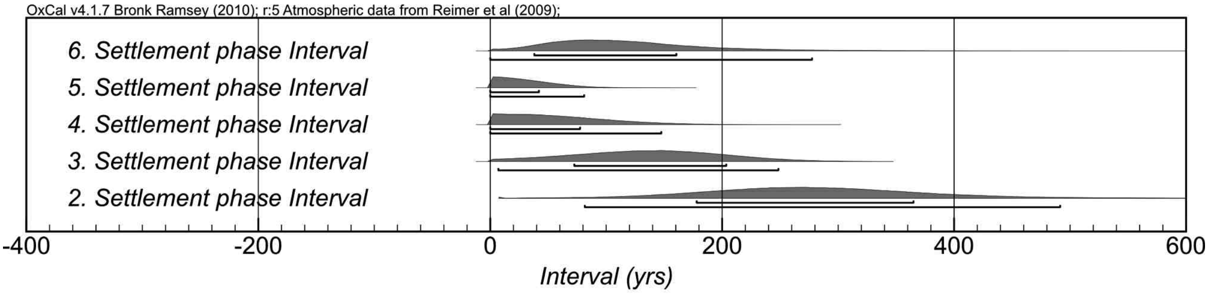

Fig. 3. Estimated duration of settlement phases in Moverna vas.

in order to date younger activities and to constrain the date of the supposed transition between the Neolithic and Eneolithic at the site. We will then be able to show whether similar typological and technological changes appear simultaneously at different sites, as is expected from a relative chronological viewpoint, or if the picture is more complicated. On the basis of the present chronological model of the Neolithic settlement phases in Moverna vas, we can at least put forward a *terminus post quem* date for the boundary between 6th and 7th settlement phases and associated typological changes of pottery at this site to around 4349–4257 calBC (68.2% probability). This is an age estimate for the end of the 6th settlement phase in our model (Fig. 2).

The Sava group of the Lengyel culture

In this case study, ^{14}C dates from sites associated with the Sava group of the Lengyel culture are modelled within a bounded phase in order to limit the inevitable scatter of individual dates and estimate the period in which this pottery type was produced. This Neolithic cultural group was recently defined on the basis of typological and technological analyses of pottery and comparison of sites discovered in new rescue excavations in Central Slovenia. It was synchronised with phase II of the Lengyel culture and roughly dated to the 1st half of the 5th millennium calBC, or from 4800 to 4500 calBC (*Guštin 2005.14–16*). ^{14}C dates from three sites allows us to model the period when this type of pottery was in use, while activities within individual sites cannot be dated precisely because there are no vertical stratigraphic sequences which would allow us to constrain the ^{14}C dates. Twenty dates are available from the site at Čatež-Sredno polje, excluding three significantly younger dates (*ibid.* Fig. 2). Measurements were performed in Leibnitz-Labor in Kiel. The Dragomelj site provides us with four dates measured by Beta Analytic in Miami (*Turk, Svetličič 2005.69; Turk 2010.43*). One date is again significantly younger and thus excluded. Two additional dates are available from Resnikov prekop, one older and less precise measurement from Zagreb (*Srdoč* et al. *1977. 472*) and one measured in Heidelberg (*Čufar, Korenčič 2006.Tab. 2*).

As presented in the introduction to Bayesian modelling, the underlying assumption of a bounded phase used in this model is that ^{14}C samples are randomly distributed within a period of activity. In our case, this period of activity is represented by the production of a specific variety of pottery, while our available ^{14}C dates act as random samples from within this activity. In this, our model is slightly biased, as ^{14}C dates are available from only three sites, and the majority comes from only one (Čatež-Sredno polje). Nevertheless, the results of our model represent the current state of research. Another problem affecting the results of the model is that all the ^{14}C dates were taken from charcoal samples, so the old wood effect has to be taken into account. Because of this problem, our estimated date for the start of the modelled period of activity is not reliable and should probably be younger, while our estimate for the end of this period should be close to the true value.

The results of the model are presented in Figure 4. The model has a good agreement index (74.4%), with only the oldest date from Čatež-Sredno polje being inconsistent. This was expected, due to the possibility of the old wood effect of the charcoal dates. The estimated beginning of the Sava group of the Lengyel culture is dated to 4786–4731 calBC (68.2% probability), but due to the old wood effect, we can expect it to be later. The end of this period is dated to 4582–4530 calBC (68.2% probability). Pottery associated with this cultural group was produced in the 48th, 47th and early 46th centuries calBC, for an estimated duration of 161–268 years (68.2% probability).

Concerning all the available ^{14}C dates from Slovenia, two major clusters of probability distribution appear. The one dating to the 48th–46th century calBC (Fig. 4) comprises sites of the Neolithic Sava group of the Lengyel culture, while the second dated to 44th and 43rd centuries calBC comprises the first sites of the Eneolithic Lasinja culture, as well as sites still attributed to the Neolithic (Fig. 5). There is a lack of dated sites in the 45th millennium calBC, with the exception of two dates from two sites in the Prekmurje region (Bukovnica and Murska Sobota-Nova Tabla; see Fig. 11). It cannot be determined whether this gap in the calendar sequence is the result of research orientation or real settlement patterns. The time difference between the two clusters of dates, *i.e.* between the end of the Sava group phase and the beginning of the Lasinja culture sites, the chronological modelling of which is presented below, is 150–233 years (68.2% probability).

The contemporaneity of Neolithic and Eneolithic sites in Slovenia

We now turn to the series of available ^{14}C dates from the second half of the 5th millennium calBC. This period is characterised in traditional relative cultural chronology by the transition from Neolithic to Eneolithic (Lasinja) cultures, which are viewed as temporally exclusive, following each other sequentially with no temporal overlap. We present three chronological models together and try to show that a temporal overlap is possible, or at least synchronicity between differently chronologically and culturally classified sites in Slovenia.

Ajdovska jama in southeastern Slovenia is a cave site where human burials were discovered within two thin layers (stratigraphical units 44 and 43). There is evidence of a funerary ritual in which the deceased were supposedly exposed in the right cave shaft to putrefy before they were finally buried (*Horvat 2009.28–29*) in the cave. Many radiocarbon dates from the burial contexts were measured on charcoal and cereal grain by the Ruđer Bošković Institute in Zagreb, but these dates are old and have large standard deviations. They are not used in the chronological modelling, as new and much more precise AMS ^{14}C dates on human bones have been obtained (*Bonsall* et al. *2007. Tab. 1*). Together with the publication (*ibid.* Fig. 5), 10 ^{14}C dates were modelled within two bounded contiguous phases that correspond to the two stratigraphic layers from which the dates originate. The results show that burial deposition began after 4340–4286 calBC (68.2% probability), lasted for only 0–62 years (68.2% probability) and ended before 4295–4235 calBC (68.2% probability). These precise estimates show that people were buried in Ajdovska jama for only about two generations or less, some time in the second half of the 44th century and the first half of the 43rd century calBC. Ajdovska jama is the only Neolithic site in Slovenia where human burials have been discovered and is dated to the period in which the transition between the Neolithic and Eneolithic is expected, while the pottery assemblage associated with the human burials is supposedly Neolithic in terms of typology and technology (*Horvat 2009.25*).

In North-eastern Slovenia, we have a series of ^{14}C dates from sites with pottery assemblages that have been attributed to the Eneolithic Lasinja culture on the basis of their typological and technological analysis and inter-site comparisons. We consider only dates that fall within the second half of the 5th millennium calBC. All the available dates from Lasinja culture sites refer to charcoal, so we need to take the old wood effect into account. Dates are available from four sites attributed to Lasinja culture. The Sodolek and Malečnik sites provide only one ^{14}C date each. Eight dates measured in Miami are available from supposedly Lasinja culture features from Ormož-Hardek (*Žižek 2006.130*), but three had to be excluded from the model because they appear erroneously too old or too young. From Turnišče-Gorice (*Plestenjak 2010.156–161*) five dates are available, but two must again be excluded because they are significantly younger and fall outside the range proposed for Lasinja culture. They are erroneous or date younger occupations of the site. The significant dates from Turnišče-Gorice were measured in Kiel and in Waikato Radiocarbon Dating Laboratory. Dates are modelled as a bounded phase of activity similarly to the modelling of the Sava group of the Lengyel culture described above. With the assumption of a random distribution of samples, we try to limit the scatter of probability distributions and estimate the date for the beginning of pottery production associated with the Lasinja culture in Slovenia. The beginning of the Lasinja culture estimated on the basis of our model is expected to be 4384–4337. As all of the ^{14}C dates are on charcoal, this estimate should probably be set later.

The chronological modelling of the settlement phases at Moverna vas presented in the first case study allowed us to estimate the beginning of the 6th settlement phase after 4389–4350 calBC (68.2% probability) and its end to 4324–4225 calBC (68.2% probability). This last Neolithic settlement phase can thus be compared with the dates for the Lasinja culture sites and Ajdovska jama burials. As shown by pottery analyses at Moverna vas, crucial typological

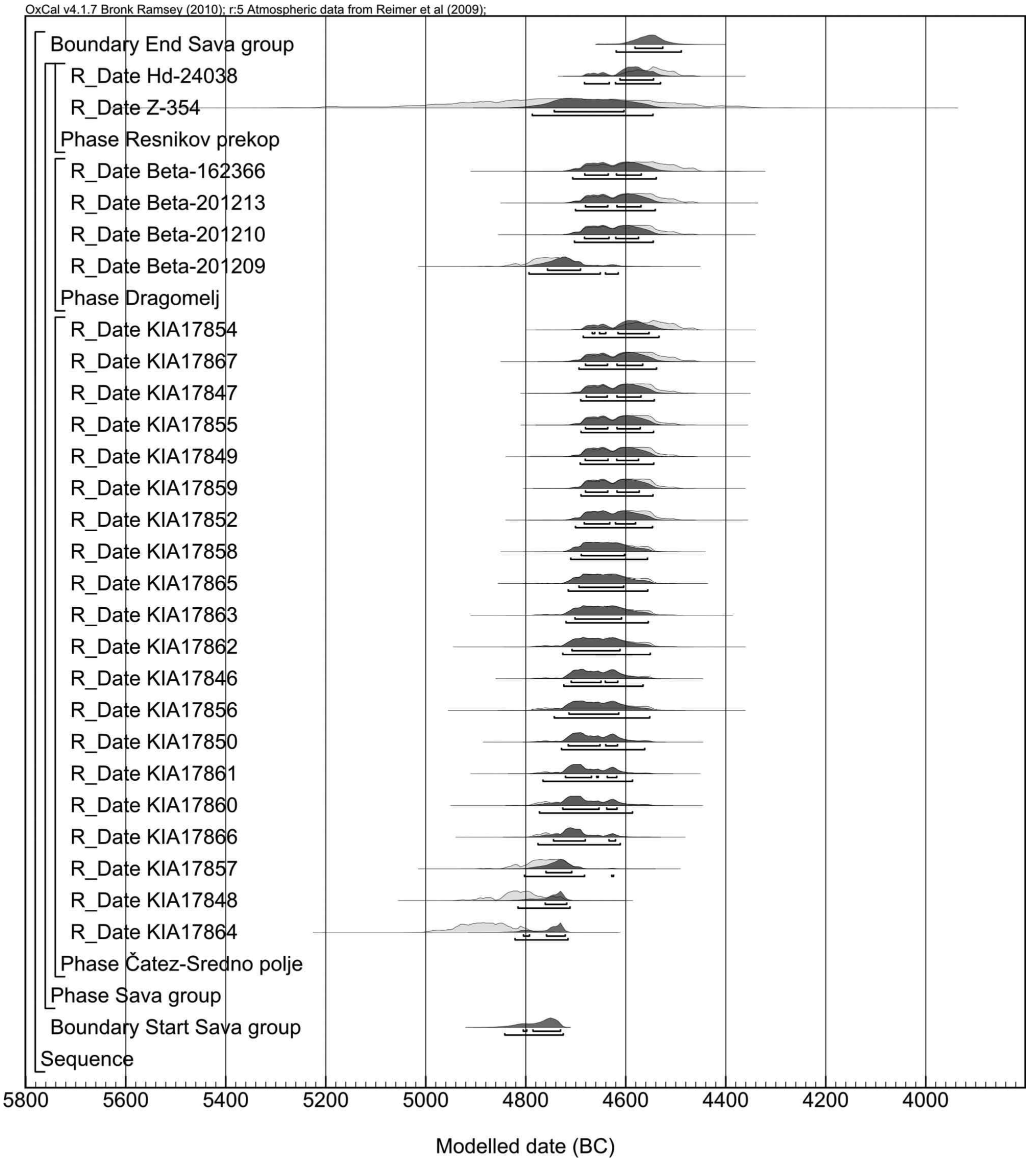

Fig. 4. Chronological model of the Sava group of the Lengyel culture in Slovenia.

and technological changes in pottery connected with the appearance of the Lasinja culture are attested for this site no earlier than the next, undated 7th settlement phase.

A comparison of the results of three different chronological models (Ajdovska jama burials, Lasinja culture sites and the last Neolithic settlement phase at Moverna vas) on the Figure 5 shows that all the modelled dates are grouped tightly together within the 44th and 43rd centuries BC. There seems to be a significant temporal overlap between Neolithic (burials at Ajdovska jama and last Neolithic settlement phase in Moverna vas) and Eneolithic (Lasinja culture) sites. On the basis of the calculated difference between the end of burial activity in Ajdovska jama and the start of Lasinja culture this overlap lasted for about a century or so (50–135 years (68.2% probability)); the same holds for the overlap between the 6th settlement phase at the Moverna vas and Lasinja culture sites (29–148 years). Interestingly, the calculated difference between the start of both the 6th settlement phase in Moverna vas and Lasinja culture is close to zero (–23–47 years (68.2% probability). This means that at the time when sites with pottery attributed to the Eneolithic Lasinja culture were being founded, pottery in Moverna vas was still being produced in more or less traditional 'Neolithic' ways, with changes coming a century or so later. Even if we consider the overlap as being partly the product of the old wood effect on the Lasinja culture dates, the demonstrated tight grouping of dates in our models show that it must be assumed that both Ajdovska jama and the 6th settlement phase in Moverna vas and Lasinja culture sites were contemporary. Thus sites with Neolithic pottery tra-

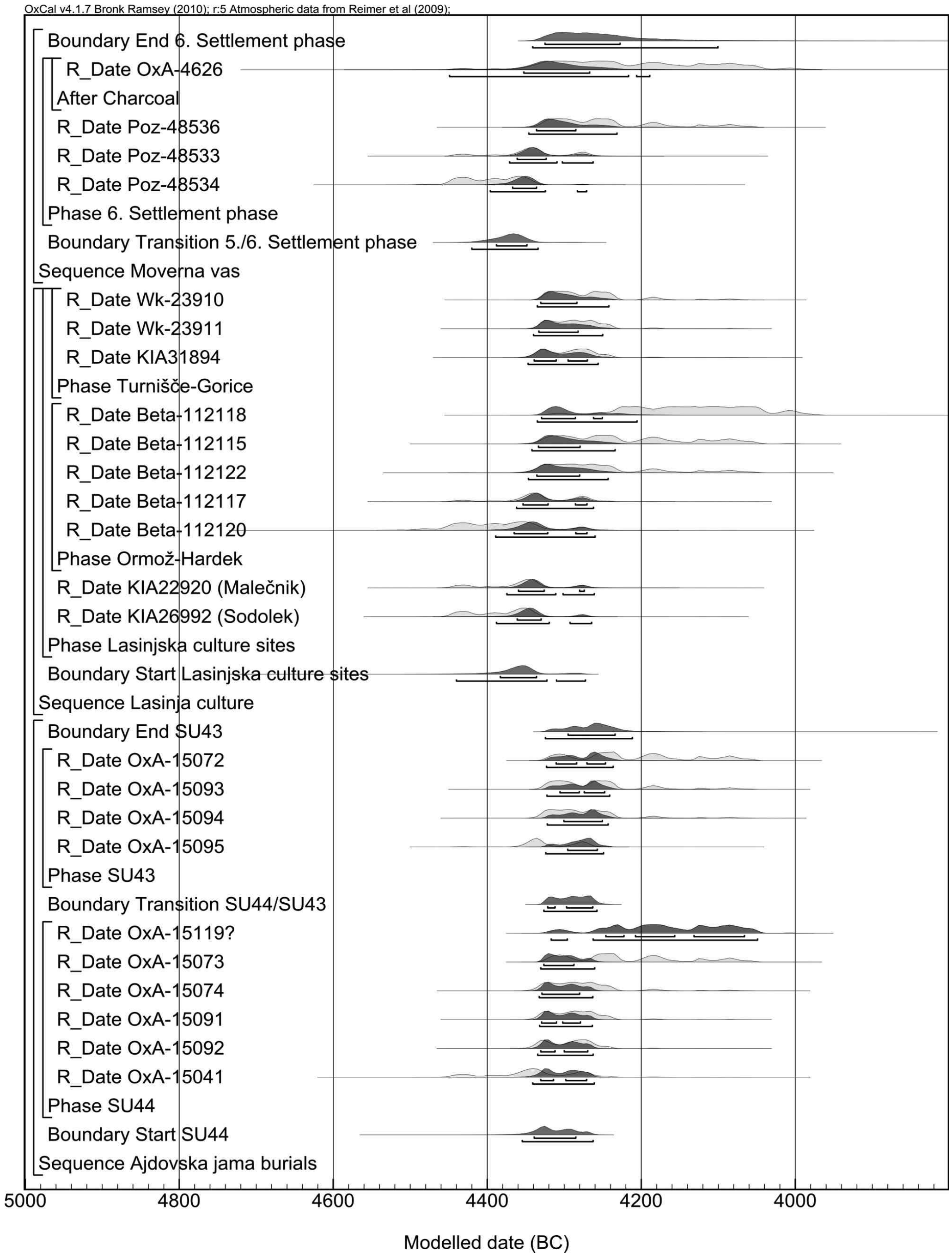

Fig. 5. Comparison of chronological models of Ajdovska jama burial activity, 6th settlement phase in Moverna vas and Lasinja culture sites in Slovenia.

ditions and sites with Eneolithic pottery types seem to be contemporary.

Our results show that the calendar time-scale temporal patterning of pottery assemblages is more complicated than relative chronologies suppose. It has to be pointed out that ascription of sites to different periods and cultures is highly dependent on the excavator's experience and viewpoint concerning pottery typology, the comparison of pottery assemblages and relative chronological schemes. The pottery assemblage from Ajdovska jama, for example, although interpreted by the excavator as having Neolithic traditions and dated to the "*Pre-Lasinja period*" (*Horvat 2009.25*), was also used to show similarities in pottery typology with sites attributed to the Eneolithic Lasinja culture (*e.g. Plestenjak 2010. 35*). It seems that the contradictions between the relative chronology and the calendar chronology are more products of inconsistencies of interpretation between different researchers. More cases of researchers disagreeing on the attribution of sites to Neolithic or Eneolithic Lasinja culture can be found in a recent article by Milena Horvat (*Horvat 2009*). Inconsistencies in relative chronology can be considered a product of the assumptions underlying the time concepts of temporal exclusiveness and sequential order of relative chronological blocks. This is not the place to argue about whether a site should be considered Neolithic or Eneolithic. The interpretations of the excavators were simply used and compared to the results of calendar chronology to show that there are some problems of interpretation concerning the relative chronological schemes, which have to be addressed in the future. Calendar chronology allows the independent dating of pottery assemblages and sites irrespective of their relative-chronological and cultural attribution and will help to clarify these chronological problems and the underlying concepts of time.

In addition to similar traits in pottery typology (*Horvat 2009*) and period attribution to the Neolithic 6th settlement phase at Moverna vas and burial contexts in Ajdovska jama dated to this time frame have another thing in common. They are both situated in southeastern Slovenia, while all of the relevant Lasinja culture sites lie in northeastern Slovenia. For this reason, we should perhaps also consider regional differences in the appearance of pottery traits associated with the beginning of the Eneolithic period. Additional data is needed to present evidence for or against this proposition. Other observation we wish to put forward is the fact that at Moverna vas, with a long stratigraphic and typological sequence (*Tomaž 1997*), pottery forms and decorations change gradually within Neolithic settlement phases, while on Lasinja sites, where there is no continuity from the Neolithic, pottery forms and decoration appear as novel. This perhaps contributes to the inconsistency of chronological attribution to the Neolithic (continuity of pottery typology) versus Eneolithic (novel pottery typology) periods between different excavators.

The time scale of our models is no longer several centuries, as was possible to achieve in the past, but several decades or spans of a few generations. Using such precision, we have to be careful about our conclusions, as we have reached the limit of the ^{14}C dating method. We have to attend more closely to the shape of the calibration curve and its 'plateaus', which presents an obstacle even when ^{14}C dates are well constrained by archaeological data. One such plateau is present in the time frame of the 44th and 43rd centuries calBC that we deal with in this section and this has an effect on the probability distributions of ^{14}C dates and, eventually, on our conclusions.

Sequence of houses at Vinkovci-Sopot

Recently, new radiocarbon dates from the eponymous tell-site of the Sopot culture – Vinkovci-Sopot in the Slavonian region in Croatia – have been published, together with some archaeological information concerning the superposition of houses, some of which have been ^{14}C dated (*Krznarić Škrivanko 2011*). Published ^{14}C dates were measured on charcoal and animal tooth samples at the Ruđer Bošković Institute in Zagreb, Croatia and Beta Analytic laboratory in Miami, USA. Activity connected to individual superposed houses is mostly dated by one or rarely two charcoal samples found on house floors. Because most of the dates are on 'long-lived' charcoal there is a possibility that the ages of ^{14}C samples are significantly older than house activities, and because few dates on 'short-lived' animal teeth do not date the same contexts, the extent of this time difference cannot be estimated. Despite these problems, the publication of ^{14}C dates from Vinkovci-Sopot together with some contextual archaeological information provides an opportunity to model the calendar chronology of the site in OxCal and constrain the dates of individual houses based on prior archaeological data.

We have modelled the calendar chronology of the settlement on the basis of description of stratigraphic relations published together with ^{14}C data. Relations were described only in text format so we decided to show relevant stratigraphic relations, used in our model, on Figure 6. Period of occupation of the settlement was modelled within two bounded overlapping phases. Within the first ('Starčevo culture occupation'), a phase of sterile layers (SU80 and SU143) is followed in a sequence by a date for the only Starčevo pit-house discovered so far at the site (SU519). Followed by a supposed gap of occupation, the second bounded phase ('Sopot culture occupation') is separated into three unrelated phases that correspond to two different locations on the site ('South-West', 'Plateau') and one phase that contained dated contexts not mentioned in the text ('Other'). Within the 'South-West' phase, we nested the following sequence: a phase connected to house SU23 (house SU23 and its rubble SU6 in a sequence, and neighbouring layer SU21 unrelated to this sequence) followed by two phases, each containing ^{14}C dates of house SU20 and SU11, respectively. Unrelated to the sequence, but still within the 'South-West' phase is house SU53. Within the Plateau phase there are two sequences of houses, both followed in a sequence by one of the channels (SU222) that destroyed the youngest horizon of houses at this part of the site. Within this broader sequence, one sequence represents a series of three (SU255, SU235 and SU207) and the other of two houses (SU301 and SU183a). Unrelated to this sequence of houses and a channel, but still within the Plateau phase, are one house (SU403) and the rubble of another house (SU332). Within the Other phase, two dates from the channel fills (SU238 and SU405), dates on two houses without a context number and a date from a layer (SU24) are modelled as unrelated. These contexts are not mentioned in the description, but their ^{14}C dates have also been published.

The model has been run in OxCal, and the results allowed us to constrain the dates for those houses which are in a sequence. Results are presented on Figure 7. The model has a good agreement index (111.4) and all of the standardised likelihoods (^{14}C dates) passed the 60% threshold for accepting the agreement as good. It has to be pointed out, however, that two dates were excluded from the model (Z-2826 and Z-3868), as their ages are considerably older than others from the same contexts (SU11 and SU183a) and also considerably older than other dates for the Sopot culture occupation at the site. The ^{14}C dates on sterile layers and the only Starčevo culture pit-house are almost contemporary and we can date the beginning of the 'Starčevo culture' occupation to around 6000 calBC. We do not have any other dated contexts attributed to this culture, so we cannot model the duration of its occupation, but we calculated the time difference between the end of the Starčevo culture occupation (based on available date) and the start of the Sopot culture occupation to be 966–1157 years (68.2% probability). The Starčevo culture occupation part of the model is not presented in Figure 7. The Sopot culture occupation of the site lasted for 661–871 years (68.2% probability), from 4936–4816 calBC to 4191–4046 calBC (68.2% probability). The sequence of houses above the ditch in the southwestern part of the site is the longest, as it contains both the oldest and youngest dated house (SU23 and SU11, respectively).

On the basis of the 'Order' function in OxCal, we can determine the most probable temporal order of the dated houses in the settlement. The oldest is house SU23, constructed above the ditch in the southwestern part of the tell in the 49th century calBC. It is followed by the houses on the Plateau in the following order: SU255, SU207, SU301, SU183a. These houses were constructed from the 48th to the 45th century calBC. These houses are followed in a sequence by channel SU222, which destroyed the youngest horizon of houses at this part of the site; but there is a gap of 326–473 years (68.2% probability) between the last dated house, SU183a, and channel SU222. This gap is only partly filled by the sequence in the southwestern part of the site, where house SU20 was constructed long after (430–595 years (68.2% probability)) house SU23 in the 43rd century calBC, followed by house SU11 in the same, or probably the next, century. This last dated house in the 'South-West' could be contemporary with the channel that destroyed the last houses on the Plateau. The modelled sequence of dated houses from different parts of the site shows two continuities of occupation in which the houses follow each other in relatively quick succession. The first continuity is represented by houses SU23, SU-

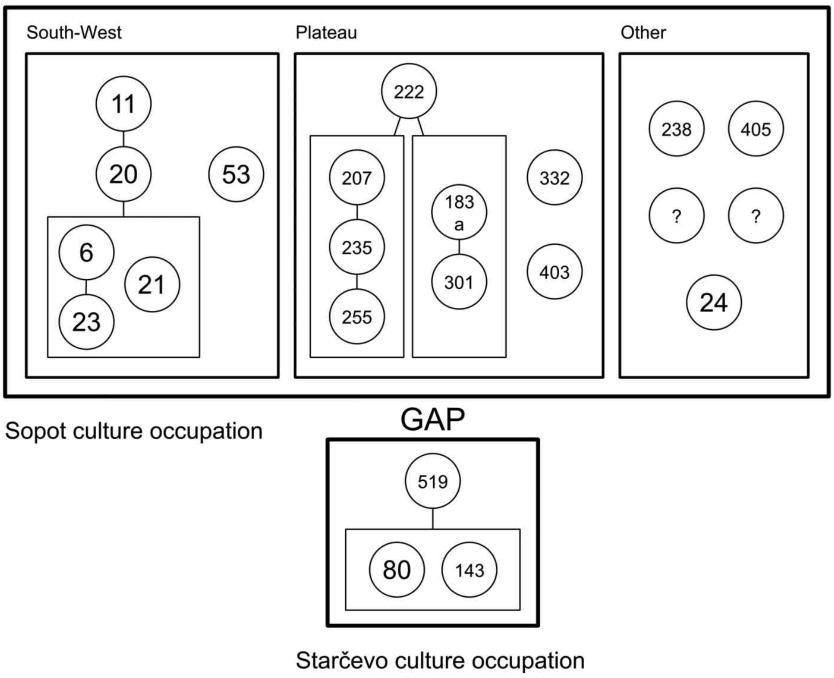

Fig. 6. Diagram of relationships of ^{14}C dated contexts in Sopot-Vinkovci (On the basis of the description in **Krznarić Škrivanko 2011***).*

255, SU207, SU301 and SU183a, built in the course of some two and a half centuries from the 49th till 46th century calBC. This continuity is followed by the already mentioned gap of about three centuries from the 46th till 44th century; a continuous sequence is then resumed with houses SU20 and SU11 in the 43rd and 42nd centuries calBC. The reason for the gap in our model could be due to the lack of ^{14}C dated houses and contextual archaeological data, as some unsequenced and thus less precise dates (for houses SU53, SU403 and layer SU24) also cover this period. On the other hand, however, if the sequence of houses in the 'South West' with houses SU23, SU20 and SU11 is complete as presented by Maja Krznarić Škrivanko (*2006.12–14, Fig. 2*), this gap is realistic.

Houses SU255, SU207, SU301 and SU183a from the Plateau are presented together with house SU11 from the 'South West' as belonging to the youngest phase of settlement in an article by Krznarić Škrivanko (*2006.12*). According to the results of our model, however, the houses were constructed four to five centuries before the end of the settlement, *i.e.* channel SU222 that, according to the excavator, destroyed the youngest horizon of houses in this part of the site (*Krznarić Škrivanko 2011.213*). Although these houses are perhaps the latest in the stratigraphic sequence, they are quite early in the calendar chronology of the site. After the gap in the calendar sequence of houses, they are followed in the southwestern part of the site by the youngest houses, SU20 and SU11.

Houses SU23, SU20 and SU11 above the ditch from southwestern part of the tell, the dates of which are constrained well within a sequence, have a pottery assemblages attributed to individual typological phases of the Sopot culture (*Krznarić Škrivanko 2006*). This allows us to check the consistency between the typological relative chronology and ^{14}C data and to propose dates when changes in typology happened.

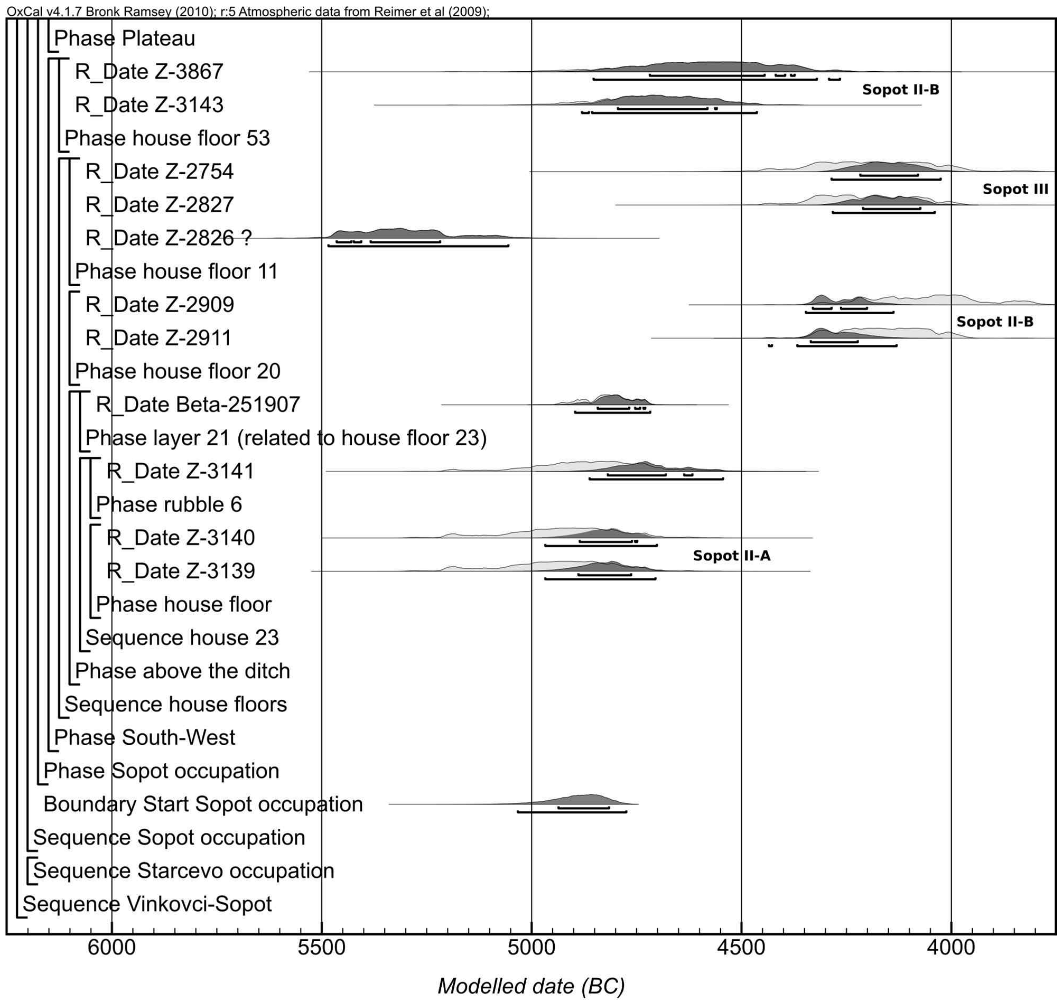

Fig. 7. Chronological model of the Sopot-Vinkovci tell site (typological phase attribution of individual dated houses is labelled).

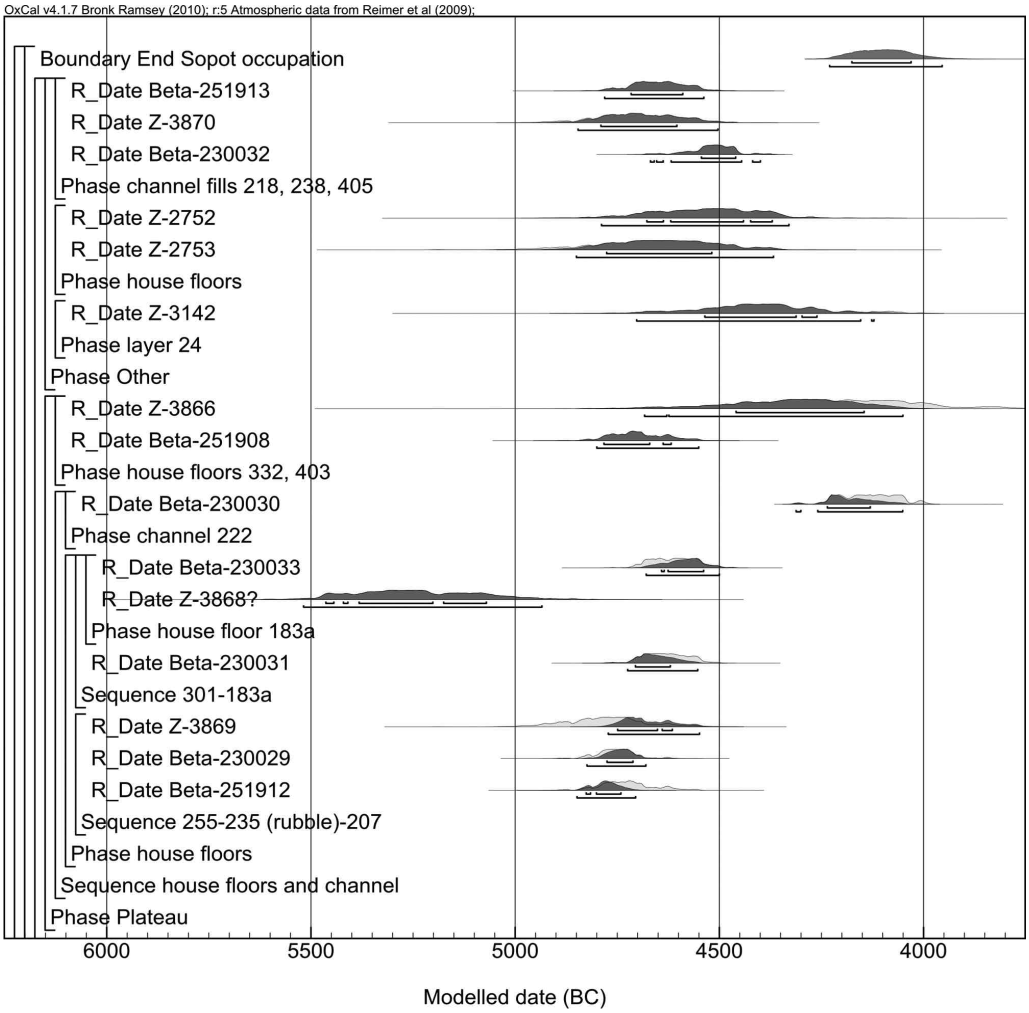

Fig. 7. (continued)

There seem to be no inversions of typological phases when the calendar chronology and typological attribution of pottery from the sequenced houses are compared (Fig. 7, labelled dates). Houses SU20 and SU53, with pottery attributed to typological phase II–B, are both dated after house SU23, with pottery attributed to phase II–A and before house SU11, with pottery attributed to phase III; so the relative chronological order of these typological phases of Sopot culture is consistent with the ^{14}C data, at least at the eponymous Sopot-Vinkovci site, according to the available ^{14}C dates and archaeological data. This is not surprising, as the separation of typological phases of the Sopot culture except for the oldest phase was largely based on material from Sopot-Vinkovci (*Dimitrijević 1979; Krznarić Škrivanko 2002*).

On the basis of our model, we can propose the dating of individual typological phases of the Sopot culture in Vinkovci-Sopot and compare it to the calendar chronology proposed by Obelić *et al.* (*2004*). The authors of this article used an informal approach of visual inspection of 68.2% probability ranges pertaining to the summed probabilities of all ^{14}C dates belonging to individual typological phases from different sites. In our model, the well constrained dates for house SU23 with pottery attributed to typological phase II–A represent a *terminus post quem* for the end of this phase, probably in the 48th century calBC. This date agrees with the proposed age for the end of typological phase II–A around 4770 calBC presented by Obelić *et al.* (*2004.Tab. 3*). The dates for houses SU53 and SU20 with pottery attributed to phase II–B can be used to date this phase approximately from the 48th to the 43rd century calBC. This again agrees well with the time range of 4800–4250 calBC proposed by Obelić *et al.* (*2004.Tab. 3*).

The continuation of the sequence above the ditch is represented by house SU20, with pottery attributed to typological phase II–B, followed by house SU11, with pottery attributed to typological phase III. If only simple calibration is performed, then probability distribution of ^{14}C dates of these two houses overlap. Archaeological data on the superposition of these two houses allow us to constrain their dates within a sequence and counter the broad scatter of probability distributions due to the shape of the calibration curve in the latter 5th millennium BC. This precise dating now allows us to estimate the age of the event when the typological shift from phase II–B and III can be expected at the Vinkovci-Sopot site. This is achieved in OxCal by entering additional date parameter in the model between the dates for houses SU20 and SU11 in a sequence. The program then estimates the age of this date as constrained in the model to 4287–4162 calBC (68.2% probability) (Fig. 8).

It must be pointed out that this age estimate is meaningful only if a sharp typological change in pottery production is realistic. In the theoretical discussion at the outset of this paper, we argued that the classification of material culture within relative chronological schemes of temporally limited and exclusive units that follow one after another can produce artificially homogenous and unchanging periods separated by relatively rapid typological changes. This is unrealistic, as pottery types are expected to change gradually. Much more meaningful are the other results of our model, namely, the precise constrained dates of individual houses and their sequences, together with estimated durations of occupation. Nevertheless, an age estimate for the boundary between the typological phases II–B and III of the Sopot culture at the Vinkovci-Sopot eponymous tell-site will be used in the following section as an argument for the contemporaneity of the Sopot and Lasinja cultures.

Contemporaneity of Sopot and Lasinja cultures

As argued in the theoretical discussion, archaeological cultures are still today represented as internally stable, time-constant entities that follow each other sequentially, meaning that there should be no temporal overlap between them. Figure 9 (*Minichreiter, Marković 2011.Fig. 2*) shows that in the Slavonian region of Croatia, where the Vinkovci-Sopot site is situated, phases III and IV of the Sopot and Lasinja cultures are expected to follow each other in such a sequential order. By using the results of the Vinkovci-Sopot model and chronological modelling of available dates for the Lasinja culture from Slavonia, we can check the consistency between the relative and calendar chronology and try to show that this relative cultural sequence is flawed.

In the section above, we presented the estimated date for the transition between typological phases II–B and III of the Sopot culture at the eponymous Vinkovci-Sopot site, where it is well constrained in a sequence of houses, the pottery of which has been attributed to individual typological phases. From the Slavonian region, we also have ^{14}C dates from several Lasinja culture sites excavated before the construction of a highway between Đakovo and Osijek (*Balen 2008.Tab. 1; Minichreiter, Marković 2011. Fig. 2*), which are situated about 30km from Vinkovci-Sopot. The Lasinja culture dates will be modelled as a bounded phase of activity. As mentioned in the introduction to Bayesian modelling, a bounded phase with a beginning and end assumes that the ^{14}C samples represent a random sample of dates within a period of activity, in our case the production of the Lasinja culture pottery type. This assumption is often used in order to limit the statistical scatter of the ^{14}C measurements, especially when the calibration curve is almost horizontal, as in our case.

On the Figure 10 we present our well constrained date for the transition between typological phases Sopot II–B and III in Sopot-Vinkovci, together with ^{14}C dates for the Lasinja culture sites (Tomašanci-Palača, Jurjevac-Stara Vodenica, Đakovački Selci-Pajtenica and Beketinci-Bentež). The estimated date for the start of the Lasinja culture on the basis of the ^{14}C dates for sites attributed to this culture is 4423–4256 calBC (68.2% probability), while our estimated date for the transition between the typological phases of Sopot II–B and III is 4287–4162 calBC (68.2% probability). After calculating the time difference between these estimates, we can say that the transition between Sopot II–B and III is 50–196 years (68.2% probability) younger than the date for the start of Lasinja culture, and on the basis of the 'Order' func-

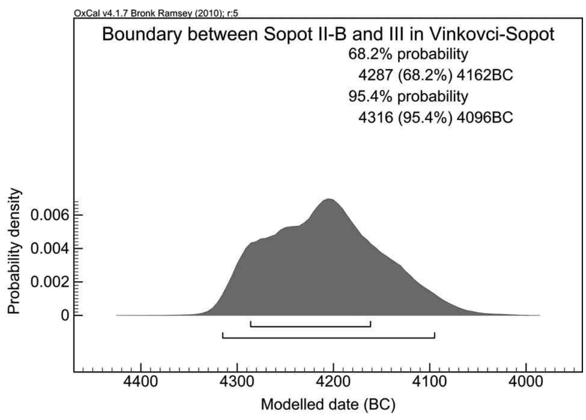

Fig. 8. Estimated age of the boundary between the II–B and III typological phases of Sopot culture as constrained by the Sopot-Vinkovci model.

tion in OxCal the probability of it being older are negligible. If our constrained date represents the start of the Sopot III typological phase, then according to the relative sequence, we should have additional time reserved for the duration of this typological phase before the start of Lasinja culture, especially since in the relative chronological scheme (Fig. 9) there is a whole cultural block (Sopot IV typological phase, defined by *Marković 1994*) between the end of Sopot III and start of Lasinja culture. Our results, on the contrary, show a significant temporal overlap between the two cultures and provide a good argument for this cultural sequence being flawed.

Discussion

The chronological models presented show how it is possible to constrain the dates of prehistoric activities for individual archaeological sites and how to overcome the inevitable scatter of ^{14}C dates of typological phases and archaeological cultures at the regional scale. By comparing calendar with typological and cultural sequences, we showed some inconsistencies and contradictions in relative chronological schemes. These will now be discussed within a broader temporal and spatial framework, together with synchronicities of different cultural sequences.

On Figure 11 we present a diagram in which we correlate calendar chronologies and some cultural sequences from Central and Southeastern Europe. It has to be pointed out, that only a selection of archaeological cultures are presented on the diagram, so cultural sequences from individual regions are not complete. The diagram was produced on the basis of Bayesian ^{14}C chronological models and simple group calibrations as well as the calibrations of single ^{14}C dates. For larger ^{14}C data sets from individual sites or archaeological cultures estimates of their calendric time spans are presented on the basis of results of Bayesian analysis, while for single or few ^{14}C dates calibrated ranges within a 68.2% probability are presented. Boundaries between typological phases of some archaeological cultures are marked with the aid of median values of estimated boundary dates. Left part of the diagram shows calendar time-scale positions of Slovenian sites on the basis of available ^{14}C dates (*Bonsall* et al. *2007.Tab. 1; Čufar, Korenčič 2006. Tab. 2; Guštin 2005.Fig. 2, 3; Plestenjak 2010.156, 160; Turk, Svetličič 2005.69; Turk 2010.43; Žižek 2006.Fig. 2*) and the long calendar sequence for Moverna vas, presented in our first case study (*Budja 1993(1994).Fig. 5; Žibrat Gašparič 2008.Fig. 5.1*). From Croatia, we present our results of the chronological modelling of the eponymous Vinkovci-Sopot site (*Krznarić Škrivanko 2011.Tab. 1*) and the chronology of the Sopot culture proposed by Bogomil Obelić *et al.* (*2004.Tab. 1*). The Lasinja culture span in Croatia is also presented (*Balen 2008.Tab. 1; Minichreiter, Marković 2011.Tab. 1; Bekić 2006.22, 95*). We show also the results of the Bayesian chronological modeling of the eponymous Vinča-Belo brdo site from Serbia, produced by Dušan Borić (*2009.Tab. 7*). From Austria, the results of the Bayesian modelling of the relative chronology of the Moravian-Eastern-Austrian group of the Lengyel culture (MOG) are presented (*Stadler, Ruttkay 2007*) as well as a span of Kanzianberg-Lasinja culture (*Ruttkay 1996.47*). From Moravia, in the Czech Republic, we produced a similar modelling of the relative chronology of Moravian painted ware culture (MMK) from the available dates (*Kuča* et al. *2009a.Tab. 1; 2009b. 319, 320; 2010.157*), while one date is available for the Jordanów culture (*Pavelčik 2002.Tab. 2*). From Hungary, the overlapping phases of Transdanubian Linear Pottery Culture (TLPC), Sopot and Early Lengyel cultures are presented (*Bronk Ramsey* et al.

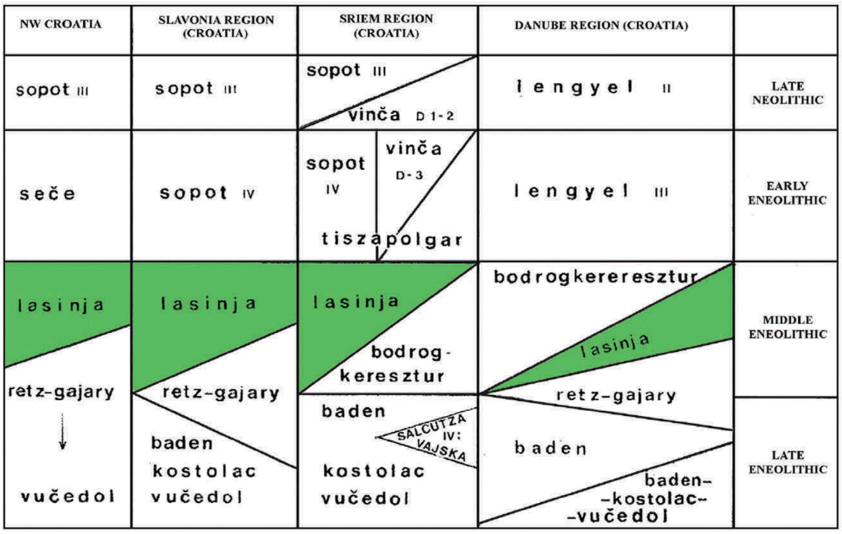

Fig. 9. Relative chronological scheme showing (among others) the temporally exclusive cultural sequence of Sopot III, Sopot IV and Lasinja cultures in Slavonia, Croatia. (*Minichreiter, Marković 2011.Fig. 2*).

1999; Horvath, Kalicz 2003.20; Barna 2007.367; Kalicz et al. *2007.44, 45*), as well as spans for phase III of the Lengyel culture (*Ehrich 1992.353; Hertelendi 1995.105–111; Ilon 2004.Sl. 26*) and Balaton-Lasinja culture (*Ehrich 1992.353; Kalicz 1995.41; Figler* et al. *1997.Tab. 2; Oross* et al. *2010.Tab. 1*). From Slovakia, the span of the settlement in Svodín is presented (*Němejcová-Pavúková 1995.168*) and that of the Ludanice culture from Jelšovce (*Görsdorf 1995.205, 206*).

The second settlement phase in Moverna vas represents the oldest well documented and ^{14}C dated Neolithic activity in continental Slovenia, and its beginning in 49th century calBC can be dated to before the appearance of the Lengyel culture in a broader spatial framework (Lengyel culture in Hungary and Slovakia, MOG in Austria and MMK in Moravia). The second settlement phase is also synchronous with the transition between the C and D typological phases of Vinča culture and the II–A typological phase of the Sopot culture as constrained by the Bayesian chronological modelling of the site at Vinkovci-Sopot. It is also synchronous with the later part of the Sopot culture and Formative and Early phases of the Lengyel culture in the Transdanubian region of Hungary. On the basis of culturally mixed deposits and the temporal overlap of ^{14}C dates between Transdanubian Linear Pottery culture and Sopot culture on one and Sopot and Lengyel culture on the other hand, the possibility that individual archaeological cultures lived contemporaneously in the same region has been proposed (*Barna 2007; Kalicz* et al. *2007*). This argument is problematic, because it is based on the assumption that differently culturally attributed pottery was produced by different people. The authors themselves acknowledge that differently classified pottery shows many similarities and is hard to differentiate (*Barna 2007.371*). The cultural attribution of pottery thus seems to be more

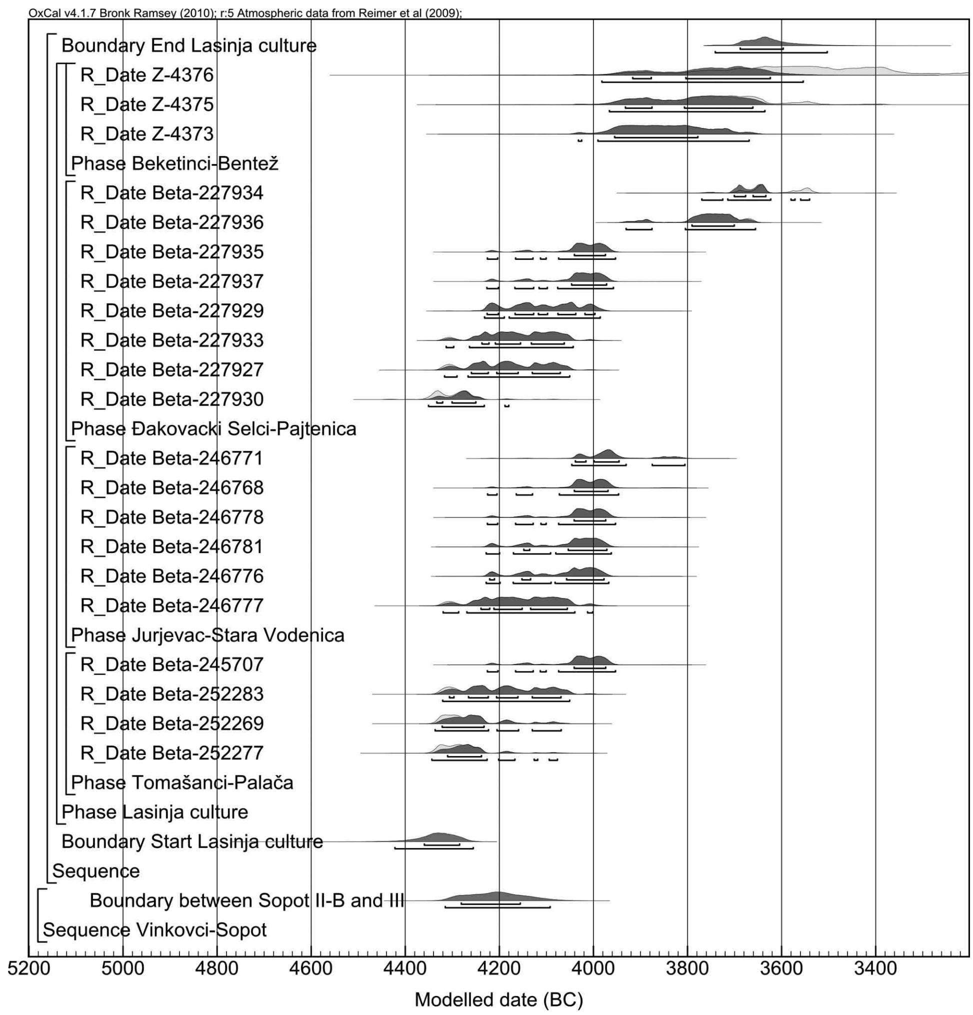

Fig. 10. Comparison of the estimated age of the boundary between the II–B and III typological phases of Sopot culture and chronological model of Lasinja culture in Slavonia, Croatia. (*Minichreiter, Marković 2011.Fig. 2*).

the result of the experiences and decisions of archaeologists rather than something pertaining to real patterns of material culture.

The sites of the Sava group of the Lengyel culture in Slovenia, dated from the 48th to the 46th century calBC also partly fit this temporal framework, but not with certainty because of the possibility of the old wood effect on the charcoal dates from these sites. The Sava group is contemporaneous with the early typological phases of MOG, *i.e.* formative phase Ia0 and phases Ia and Ib, which is also postulated on the basis of a typological comparison of pottery (*Tomaž 2010.180*). The general appearance of Lengyel culture in different regions is dated to around 4800 calBC (*Stadler, Ruttkay 2007*). The sites of the Sava group of the Lengyel culture are also contemporary with the older sequence of houses at Vinkovci-Sopot and with typological phases II–A and partly II–B of the Sopot culture.

The lull in activity at Moverna vas in the third settlement phase and the end of the Sava group in Slovenia are synchronous with the end of a long calendar sequence on Vinča-Belo brdo and thus probably also with the overall Vinča cultural sequence. This period can be dated to the 46th century and the first half of the 45th century calBC. Interestingly, the gap in the sequence of superposed ^{14}C dated houses at Vinkovci-Sopot can also be dated to this period. In Southeastern European periodisation, the end of Vinča culture marks the beginning of the Eneolithic. Also contemporaneous are the IIa typological phase of MOG and MMK in Austria and Moravia, respectively, and the beginning of phase III of Lengyel culture in Hungary. These typological phases of Lengyel culture are represented as the Earliest Eneolithic phase in traditional periodisations (*Pavúk 2000*), with the exception of Austria, where the term Eneolithic is not used. The transition from the Neolithic to Eneolithic in the traditional relative periodisation can be dated to around the middle of the 5th millennium calBC.

After the end of the Sava group of the Lengyel culture in Central Slovenia, a gap of some two centuries appears in the radiocarbon sequences before the beginning of the Lasinja culture, dated on the basis of sites in north-eastern Slovenia. Well constrained dates for the 4th and 5th settlement phases in a continuous stratigraphic sequence at Moverna vas date the period of high activity on the site to the second half of the 45th century and the first half of the 44th century calBC. This period is synchronous with later typological phases of the Lengyel culture. In the 44th and 43rd centuries calBC we pointed out the contemporaneity of sites attributed to the Neolithic (the Ajdovska jama cave site and the 6th settlement phase at Moverna vas) and Eneolithic or Lasinja culture (sites in North-eastern Slovenia). The overall appearance of Lasinja culture and other related cultures of the so-called Epilengyel cultural horizon (Kanzianberg-Lasinja in Austria, Balaton-Lasinja in Hungary, Ludanice in Slovakia and Jordanów in Czech Republic) can probably be dated to around 4300 calBC or earlier. The beginning of Lasinja culture around 4300 calBC has also been proposed by other researchers (*Balen 2008.22; Guštin 2005.14, Fig. 4; Oross* et al. *2011.182; Ruttkay 1996; Somogyi 2000*).

Conclusion

The case studies presented here show different possibilities of modelling calendar chronologies with the aid of a Bayesian statistical framework implemented in the widely available OxCal calibration program. While this approach enables the dating of archaeological deposits and sites irrespective of their periodic or cultural attribution, it is far from an independent dating method, as the accuracy and understanding of our archaeological information and assumptions are crucial to the production of realistic models. On the other hand, ^{14}C sampling at archaeological sites needs careful planning in order to obtain relevant samples whose relation to archaeological events of interest is understood. We must bear in mind that Bayesian modelling of archaeological chronologies is only a heuristic tool; it does not provide final or absolute results. Our calendar chronologies will change as new data becomes available and as we decide to model them in different ways. Our results are only a first glimpse into what can be achieved with Bayesian modelling of calendar chronologies.

In Moverna vas, the stratigraphic and typological sequence of Neolithic settlement phases was provided with precise dating of pottery assemblages from within these phases as well as with their durations. On the basis of the estimated duration of individual settlement phases, the depth of layered deposits and abundance of material within them, we proposed that the 3rd settlement phase was a period of low anthropogenic activity, while the opposite is true of the 4th and 5th settlement phases. The end of Neolithic occupation at the site corresponds well with the proposed beginning of the Eneolithic Lasinja culture in neighbouring regions, while the Lasinja sites in Slovenia seem to be at least partly contempora-

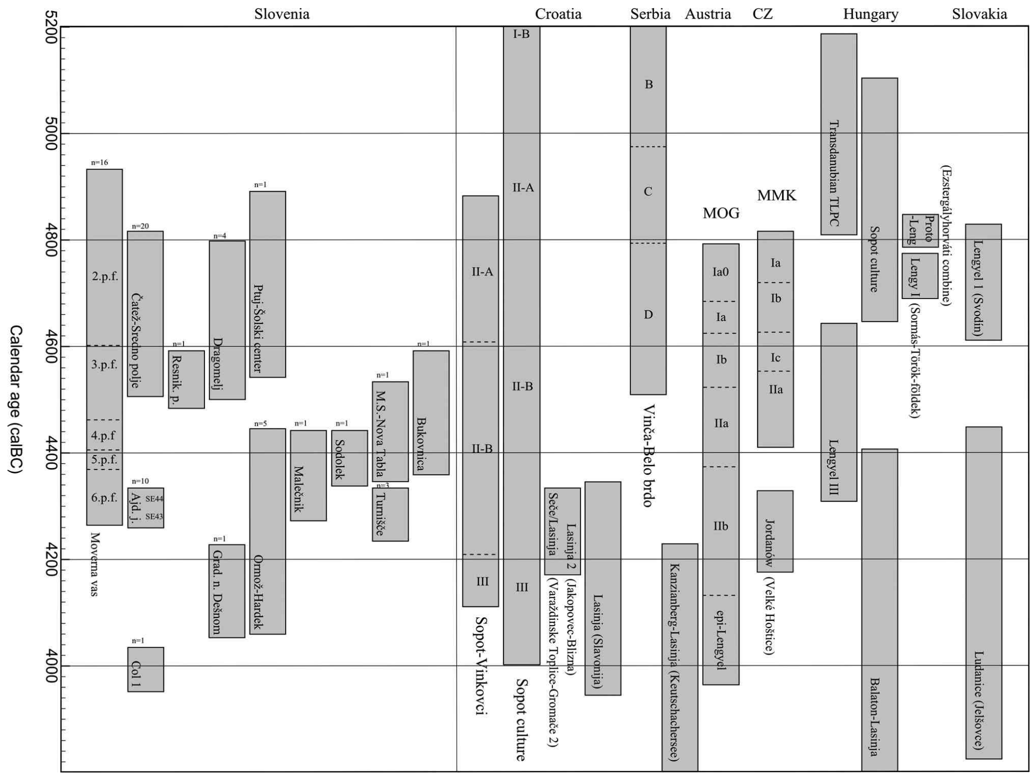

Fig. 11. Diagram of the correlation between calendar and cultural sequences. The cultural sequences of some archaeological cultures as well as individual sites from Central and Southeastern Europe are shown.

neous with the last Neolithic settlement phase in Moverna vas.

^{14}C dates from sites attributed to the Sava group of the Lengyel culture in Central Slovenia were used to provide an estimated calendar date for the beginning and end of this cultural group and an estimate of its duration. We pointed out two clusters of ^{14}C dates from Slovenia, one belonging to this group and the other to Lasinja sites in North-Eastern Slovenia (besides ^{14}C dates from Ajdovska jama cave site). A significant temporal gap can be discerned between these two clusters in the middle of the 5th millennium calBC.

By comparing the calendar chronology model of human burials discovered in Ajdovska jama cave and the calendar chronology of the last Neolithic settlement phase in Moverna vas with the chronological model for the Lasinja sites in North-Eastern Slovenia, we exposed inconsistencies in cultural attribution of contemporaneous sites. Sites that are contemporary according to their ^{14}C dates are interpreted by different researchers as belonging to different periods and archaeological cultures. We also considered the possibility that differences in the periodical and cultural attribution of pottery assemblages from contemporary sites could be the result of regional differences in the appearance of pottery traits associated with different periods and archaeological cultures.

The complex calendar chronology model of the Vinkovci-Sopot tell-site, which utilises the available ^{14}C dates and archaeological data about the superposition of houses, allowed us to date individual houses precisely and propose the most probable order in which they were constructed. The ^{14}C dated and sequenced houses were built within two continuous periods separated by a gap. With the aid of information on the typological attribution of the pottery assemblages from some sequenced houses, we were able to estimate the age of the event when the boundary between the II–B and III typological phases of the Sopot culture can be expected at the Vinkovci-Sopot site.

This event, dated to around 4200 calBC, is considerably later than the appearance of the Lasinja sites in the same region in Croatia. Unlike the relative cultural schemes which present Sopot III and Lasinja culture as not only temporally exclusive, but also separated by another Sopot IV typological phase, our results provide a good argument for a temporal overlap between them and for an inconsistency in the relative chronological scheme of archaeological cultures.

Despite the problematic theoretical nature of chronology, it is crucial to archaeological practice. Bayesian modelling of calendar chronologies is a way to bridge the gap between chronology and theoretical discussions concerning the experience and flow of time, issues of social construction of time, of memory and forgetting and the nature of the past in the past. Particular events that happened in the past can now be assigned to specific centuries and even spans of decades and we can start thinking in terms of human generations and lifetimes. The people who participated in these events are no longer timeless and faceless, but particular people in particular places and particular times.

ACKNOWLEDGEMENTS

This research was partly supported by the Slovenian Research Agency, Research Programme 'Arheologija (P6–0247–0581)' and the Research Project 'Archaeologies of hunter-gatherers, farmers and metallurgists: cultures, populations, palaeo-economies and climate (J6–4085–0581)'. My research is carried out within the Junior Researcher Programme funded by the Ministry of Education, Science, Culture and Sport, Republic of Slovenia. I would like to thank dr. Bernhard Weninger (Institut für Ur- und Frühgeschichte, Universität zu Köln), who reviewed parts of this paper and provided some crucial suggestions, which helped in clarifying my ideas. Finally, I am very grateful to prof. dr. Mihael Budja for his continuous encouragement in my research.

∴

References

Ashmore P. J. 1999. Radiocarbon dating: avoiding errors by avoiding mixed samples. *Antiquity 73(279): 124–130*.

Bailey G. N. 2007. Time perspectives, palimpsests and the archaeology of time. *Journal of Anthropological Archaeology 26: 198–223*.

Balen J. 2008. Apsolutni datumi sa zaštitnih istraživanja na prostoru Slavonije kao prilog poznavanju kronologije srednjeg eneolitika. *Vjesnik Arheološkog muzeja u Zagrebu 41: 17–35*.

Barna J. P. 2007. A New Site of the Lengyel culture in Sormás-Török-földek (County Zala, South-western Transdanubia). Preliminary report. In J. K. Kozłowski, P. Raczky (eds.), *The Lengyel, Polgár and related cultures in the middle/late Neolithic in Central Europe*. Polska Akademia Umiejętności, Kraków: 365–380.

Bayliss A., Bronk Ramsey C., van der Plicht J. and Whittle A. 2007. Bradshaw and Bayes: Towards a Timetable for the Neolithic. *Cambridge Archaeological Journal 17:1 (suppl.): 1–28*.

Bayliss A., van der Plicht J., Bronk Ramsey C., McCormac G., Healy F. and Whittle A. 2011. Towards generational time-scales: the quantitative interpretation of archaeological chronologies. In A. Whittle, F. Healy and A. Bayliss (eds.), *Gathering Time. Dating the Early Neolithic Enclosures of Southern Britain and Ireland*. Oxbow Books, Oxford: 16–60.

Bekić L. 2006. *Zaštitna arheologija u okolici Varaždina. Arheološka istraživanja na autocesti Zagreb – Goričan i njezinim prilaznim cestama*. Ministarstvo kulture RH. Zagreb.

Blackwell P. G., Buck C. E. 2003. The Late Glacial human reoccupation of north-western Europe: new approaches to space-time modelling. *Antiquity 77: 232–239*.

Bonsall C., Horvat M., McSweeney K., Masson M., Higham T. F. G., Pickard C. and Cook G. T. 2007. Chronological and dietary aspects of the human burials from Ajdovska cave, Slovenia. *Radiocarbon 49(2): 727–740*.

Borić D. 2009. Absolute dating of Mettalurgical innovations in the Vinča Culture of the Balkans. In T. K. Kienlin, B. W. Roberts (eds.), *Metals and Societies. Studies in Honour of Barbara S. Ottaway*. Universitätsforschungen zur prähistorischen Archäologie, Bonn: 191–245.

Bronk Ramsey C. 1995. Radiocarbon calibration and analysis of stratigraphy: The OxCal program. *Radiocarbon 37(2): 425–430*.

1998. Probability and dating. *Radiocarbon 40(1): 461–474*.

2008. Radiocarbon dating: revolutions in understanding. *Archaeometry 50(2): 249–275*.

2009. Bayesian analysis of radiocarbon dates. *Radiocarbon 51(3): 337–360*.

Bronk Ramsey C., Pettitt P. B., Hedges R. E. M. and Hodgins G. W. L. 1999. Radiocarbon dates from the Oxford AMS system: Archeometry Datelist 2. *Archeometry 41(1): 197–206*.

Budja M. 1993(1994). Neolithic Studies in Slovenia: An Overwiev. *Atti della Societa per la Preistoria e Protostoria della Regione Friuli Venezia Giulia 8: 7–28.*

Chazan M. 1995. Conceptions of time and the Development of Paleolithic Chronology. *American Anthropologist 97(3): 457–467.*

Childe G. V. 1929. *The Danube in Prehistory*. Oxford University Press, Oxford.

Čufar K., Korenčič T. 2006. Raziskave lesa z Resnikovega prekopa in radiokarbonsko datiranje. In A. Velušček (ed.), *Resnikov prekop. Resnikov prekop, najstarejša koliščarska naselbina na Ljubljanskem barju*. Opera Instituti Archaeologici Sloveniae 10, ZRC Publishing, Ljubljana: 123–127.

Dimitrijević S. 1979. Sjeverna zona. In A. Benac (ed.), *Praistorija jugoslavenskih zemalja II: Neolitsko doba*. Centar za Balkanološka Ispitivanja, Sarajevo: 229–360.

Ehrich R. W. (ed.). 1992. *Chronologies in Old World Archaeology. Third edition. Vol. II*. The University of Chicago Press. Chicago.

Figler A., Bartosiewicz L., Füleky Gy. and Hertelendi E. 1997. Copper Age Settlement and the Danube Water System: A Case study from North-Western Hungary. In J. Chapman, P. Dolukhanov (eds.), *Landscapes in Flux: Central and Eastern Europe in Antiquity*. Colloquia Pontica 3: 209–230.

Görsdorf J. 1995. Datierung von Menschenknochen aus dem Gräberfeld Jelšovce. In J. Pavúk, J. Batora (eds.), *Siedlung und Gräber der Ludanice-gruppe in Jelšovce*. Archeologický ústav SAV, Nitra: 205–206.

Guštin M. 2005. Savska skupina Lengyelske kulture. In M. Guštin (ed.), *Prvi poljedelci. Savska skupina Lengyelske kulture*. Annales Mediterranea, Koper: 7–22.

Hertelendi E. 1995. 14Carbon dating of Zalaszentbász-Szőlőhegyi mező 1992–93. In B. M. Szőke (ed.), *Archaeology and Settlement history in the Hahót basin, Southwest Hungary. From the Neolithic to the Roman Age*. Antaeus 22. Communicationes ex Instituto Archaeologico Academiae Scientiarum Hungaricae, Budapest: 105–108.

Horvat M. 2009. Prvi prebivalci v Posavju. In J. Barachini (ed.), *Ukročena lepotica. Sava in njene zgodbe*. Javni zavod za kulturo, šport, turizem in mladinske dejavnosti, Sevnica: 25–35.

Horváth L., Kalicz N. 2003. Excavation of a Neolithic site at Petrivente (Zala county). *Archaeological Investigations in Hungary 2001: 5–29.*

Ilon G. 2004. *Szombathely őskori településtörténetének vázlata: avagy a római kor előtt is volt élet (Outline of the Pre-historic Settlement of Szombathely: or life before the Roman age)*. Oskorunk 2. Vas Megyei Múzeumok, Szombathely.

Kalicz N. 1995. Die Balaton-Lasanja-Kultur in der Kupferzeit Südost-und Mitteleuropas. *Neuere Daten zur Siedlungsgeschichte und Chronologie der Kupferzeit des Karpatenbeckens*. Inventaria Praehistorica Hungariae 7. Magyar Nemzeti Múzeum. Budapest.

Kalicz N., Kreiter E. and Tokai Z. M. 2007. Die Rolle der Sopot-Kultur in der Entstehung der Lengyel-Kultur auf Grund der Neuen Ausgrabungen in Südwestungarn. In J. K. Kozłowski, P. Raczky (ed.), *The Lengyel, Polgár and related cultures in the middle/late Neolithic in Central Europe*. Polska Akademia Umiejętności, Kraków: 29–47.

Krznarić Škrivanko M. 2002. Peta i šesta sezona sustavnog istraživanja gradine Sopot. *Obavijesti Hrvatskog arheološkog društva 34(2): 36–45.*

2006. Istraživanja na Sopotu. In A. Tomaž (ed.), *Od Sopota do Lengyela*. Annales Mediterranea, Koper: 11–19.

2011. Radiokarbonski datumi uzoraka sa Sopota. Panonski prapovijesni osviti. *Zbornik radova posvećenih Korneliji Minichreiter uz 65. obljetnicu života*. Institut za Arheologiju, Zagreb: 209–225.

Kuča M., Trampota F., Kazdová E., Prokeš L., Petřík J., Kolář J. and Fajkošová Z. 2009a. Kyjovice (okr. Znojmo) Sutny. *Přehled výzkumů 51: 315–318.*

Kuča M., Přychistal A., Schenk Z., Škrdla P. and Vokáč M. 2009b. Lithic raw materials procurement in the Moravian Neolithic: the search for extra-regional networks. In M. Budja (ed.), *16th Neolithic Studies. Documenta Praehistorica 36: 313–326.*

Kuča M., Škrdla P. and Nývltová Fišáková M. 2010. Příspěvek k absolutní chronologii mladšího stupně Lengyelské Kultury ve středním Pomoraví. *Slovacko 52: 153–160.*

Lucas G. 2005. *The Archaeology of Time*. Routledge. New York.

Marković Z. 1994. *Sjeverna Hrvatska od neolita do brončanog doba. Problem kontinuiteta stanovništva i kulture sjeverne Hrvatske od ranog neolita do početka brončanog doba*. Muzej grada Koprivnice. Koprivnica.

Minichreiter K., Marković Z. 2011. Architecture of Lasinja culture settlements in the light of new investigations in northern Croatia. In M. Budja (ed.), *18th Neolithic Studies. Documenta Praehistorica 38: 333–343.*

Müller J. 2009. Dating the Neolithic: Methodological premises and absolute chronology. *Radiocarbon 51(2): 721–736*.

Němejcová-Pavúková V. 1995. *Svodín. Band 1. Zwei Kreisgrabenanlage der Lengyel-Kultur*. Comenius University in Bratislava. Bratislava.

Obelić B., Krznarić Škrivanko M., Marijan B. and Krajcar Bronić I. 2004. Radiocarbon dating of Sopot Culture sites (Late Neolithic) in eastern Croatia. *Radiocarbon 46(1): 245–258*.

Oross K., Marton T., Whittle A., Hedges R. E. M. and Cramp L. J. E. 2010. Die Siedlung der Balaton-Lasinja-Kultur in Balatonszárszó-Kis-erdei-dűlő. In J. Šuteková, P. Pavúk, P. Kalábková and B. Kovár (eds.), *Panta Rhei. Studies in chronology and cultural development of South-Eastern and Central Europe in earlier prehistory presented to Juraj Pavúk on the occasion of his 75. birthday*. Comenius University in Bratislava, Bratislava: 161–187.

Paynter R. 2002. Time in the Valley. Narratives about Rural New England. *Current Anthropology 43(4): 85–101*.

Pavelčík J. 2002. Neolithikum und Äneolithikum in Nordmähren und Schlesien (Troppauer Gebiet) im Lichte der 14C-Daten. *Preistoria Alpina 37: 333–336*.

Pavúk J. 2000. Epilengyel/Lengyel IV als kulturhistorische Einheit. *Slovenská archeológia 48: 1–26*.

Plestenjak A. 2010. *Gorice pri Turnišču*. Zbirka Arheologija na avtocestah Slovenije 12. Zavod za varstvo kulturne dediščine Slovenije. Ljubljana.

Reimer P. J., Baillie M. G. L., Bard E., Bayliss A., Beck J. W., Blackwell P. G., Bronk Ramsey C., Buck C. E., Burr G. S., Edwards R. L., Friedrich M., Grootes P. M., Guilderson T. P., Hajdas I., Heaton T. J., Hogg A. G., Hughen K. A., Kaiser K. F., Kromer B., McCormac F. G., Manning S. W., Reimer R. W., Richards D. A., Southon J. R., Talamo S., Turney C. S. M., van der Plicht J. and Weyhenmeyer C. E. 2009. IntCal09 and Marine09 radiocarbon age calibration curves, 0–50,000 years cal BP. *Radiocarbon 51(4): 1111–1150*.

Renfrew C. 1973. *Before Civilization. The Radiocarbon Revlution and Prehistoric Europe*. Jonathan Cape. London.

Ruttkay E. 1996. Zur Chronologie der Kanzianiberg-Lasinja-Gruppe. *Archäologie Österreichs 7(2): 43–48*.

Shanks M., Tilley C. 1987. *Social Theory and Archaeology*. Polity Press. Cambridge.

Somogyi K. A. 2000. Balaton-Lasinja kultúra leletanyaga Somogy megyében. *Communicationes Archaeologicae Hungaricae: 5–48*.

Srdoč D., Sliepčević A., Obelić B. and Horvatinčić N. 1977. Rudjer Bošković Institute radiocarbon measurements IV. *Radiocarbon 19(3): 465–475*.

Stadler P., Ruttkay E. 2007. Absolute Chronology of Moravian-Eastern-Austrian Group (MOG) of Painted Pottery (Lengyel Culture) based on new Radiocarbon Dates from Austria. In J. K. Kozłowsky, P. Raczky (eds.), *The Lengyel, Polgár and related Cultures in the Middle/ Late Neolithic in Central Europe*. Polska Akademia Umiejętności, Kraków: 117–146.

Thomas J. 1993. Discourse, Totalization and 'The Neolithic'. In C. Tilley (ed.), *Interpretative Archaeology*. Berg, Oxford: 357–394.

Tomaž A. 1997. Tehnološka raziskava lončenine iz Moverne vasi v Beli Krajini. *Poročilo o raziskovanju paleolita, neolita in eneolita v Sloveniji 24: 113–142*.

2010. *Neolitska keramika iz najdišča Čatež-Sredno polje: prispevek k poznavanju neolitskega obdobja v osrednji Sloveniji*. Unpublished PhD thesis. University of Primorska, Koper.

Turk P. 2010. Priložnosti in pasti. Radiokarbonske datacije iz neolitske naselbine v Dragomlju. *Argo 53(1): 41–43*.

Turk P., Svetličič, V. 2005. Neolitska naselbina v Dragomlju. In M. Guštin (ed.), *Prvi poljedelci. Savska skupina Lengyelske kulture*. Annales Mediterranea, Koper: 65–79.

Whittle A., Bayliss A. and Healy F. 2008. The Timing and Tempo of Change: Examples from the Fourth Millenium cal. BC in Southern England. *Cambrige Archaeological Journal 18(1): 65–70*.

Whittle A., Healy F. and Bayliss A. 2011a. *Gathering Time. Dating the Early Neolithic Enclosures of Southern Britain and Ireland*. Oxbow Books. Oxford.

Whittle A., Healy F. and Bayliss A. 2011b. Gathering time: causewayed enclosures and the early Neolithic of southern Britain and Ireland. In A. Whittle, F. Healy and A. Bayliss (eds.), *Gathering Time. Dating the Early Neolithic Enclosures of Southern Britain and Ireland*. Oxbow Books, Oxford: 1–15.

Žibrat Gašparič A. 2008. *Strukturna analiza neolitske keramike in lončarske tehnologije*. Unpublished PhD thesis. University of Ljubljana, Ljubljana.

Žižek I. 2006. Eneolitska naselbina Hardek. In A. Tomaž (ed.), *Od Sopota do Lengyela*. Annales Mediterranea, Koper: 129–140.

Appendix

Site	Lab Code	Age (BP)	SD (±a)	Material	Stratigraphic Context	Typo-chronological scheme	Reference
Ajdovska jama	OxA-15041	5485	50	human bone	44	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15072	5365	31	human bone	43	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15073	5369	31	human bone	44	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15074	5416	35	human bone	44	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15091	5421	30	human bone	44	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15092	5436	30	human bone	44	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15093	5389	30	human bone	43	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15094	5405	31	human bone	43	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15095	5471	31	human bone	43	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Ajdovska jama	OxA-15119	5340	36	human bone	44	Neolithic	*Bonsall* et al. 2007.*Tab.1*
Čatež-Sredno polje	KIA17846	5804	30	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17847	5747	32	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17848	5935	31	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17849	5751	33	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17850	5811	30	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17852	5758	33	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17854	5718	32	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17855	5750	31	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17856	5806	42	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17857	5888	36	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17858	5782	30	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17859	5752	30	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17860	5828	36	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17861	5820	30	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17862	5797	40	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17863	5791	37	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17864	5992	36	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17865	5787	33	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17866	5839	30	charcoal		Sava group	*Guštin 2005.Fig. 2*
Čatež-Sredno polje	KIA17867	5737	39	charcoal		Sava group	*Guštin 2005.Fig. 2*
Dragomelj	Beta-162366	5730	50	charcoal		Sava group	*Turk, Svetličič 2005.69*
Dragomelj	Beta-201209	5870	40	charcoal		Sava group	*Turk 2010.43*
Dragomelj	Beta-201210	5750	40	charcoal		Sava group	*Turk 2010.43*
Dragomelj	Beta-201213	5740	40	charcoal		Sava group	*Turk 2010.43*
Turnišče-Gorice	KIA31894	5435	35	charcoal		Lasinja	*Plestenjak 2010.156*
Turnišče-Gorice	Wk-23910	5396	30	charcoal		Lasinja	*Plestenjak 2010.160*
Turnišče-Gorice	Wk-23911	5416	30	charcoal		Lasinja	*Plestenjak 2010.156*
Malečnik	KIA22920	5503	38	charcoal		Lasinja	*Guštin 2005.Fig. 3*
Moverna vas	OxA-4626	5390	80	charcoal	031.4 (6. phase)	Neolithic	*Budja 1993(1994).Fig. 5*
Moverna vas	OxA-4627	5580	80	charcoal	022 (5. phase)	Neolithic	*Budja 1993(1994).Fig. 5*
Moverna vas	OxA-4628	5640	80	charcoal	050.2 (4. phase)	Neolithic	*Budja 1993(1994).Fig. 5*
Moverna vas	OxA-4629	5830	80	charcoal	057 (2. phase)	Neolithic	*Budja 1993(1994).Fig. 5*
Moverna vas	OxA-4630	5830	90	charcoal	056.3 (2. phase)	Neolithic	*Budja 1993(1994).Fig. 5*
Moverna vas	OxA-4631	5720	90	charcoal	053 (3. phase)	Neolithic	*Budja 1993(1994).Fig. 5*
Moverna vas	Poz-21396	5750	40	pottery residue	053.1 (3. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21398	5550	40	pottery residue	050.2 (4. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21399	5630	40	pottery residue	050.1 (4. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21400	5610	40	pottery residue	022.1 (5. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21402a	5620	40	pottery residue	050.1 (4. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21402b	5990	40	pottery residue	050.2/056 (2. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21403	5800	40	pottery residue	planum 7 (2. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*

Site	Lab Code	Age (BP)	SD (±a)	Material	Stratigraphic Context	Typo-chronological scheme	Reference
Moverna vas	Poz-21404	5670	40	pottery residue	031.4 (6. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21419	5940	40	pottery residue	planum 7 (2. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-21420	5550	40	pottery residue	050.2 (4. phase)	Neolithic	*Žibrat Gašparič 2008.Fig. 5.1*
Moverna vas	Poz-48532	5780	50	pottery residue	056.1 (2. phase)	Neolithic	first published here
Moverna vas	Poz-48533	5490	40	pottery residue	031.4 (6. phase)	Neolithic	first published here
Moverna vas	Poz-48534	5540	40	pottery residue	031.3 (6. phase)	Neolithic	first published here
Moverna vas	Poz-48536	5390	40	pottery residue	031.4 (6. phase)	Neolithic	first published here
Moverna vas	Poz-48537	5580	40	pottery residue	planum 6 (4. or 6. phase)	Neolithic	first published here
Ormož-Hardek	Beta-112115	5380	50	charcoal		Lasinja	*Žižek 2006.Fig. 2*
Ormož-Hardek	Beta-112117	5480	40	charcoal		Lasinja	*Žižek 2006.Fig. 2*
Ormož-Hardek	Beta-112118	5300	50	charcoal		Lasinja	*Žižek 2006.Fig. 2*
Ormož-Hardek	Beta-112120	5530	60	charcoal		Lasinja	*Žižek 2006.Fig. 2*
Ormož-Hardek	Beta-112122	5410	50	charcoal		Lasinja	*Žižek 2006.Fig. 2*
Sodolek	KIA26992	5524	37	charcoal		Lasinja	*Guštin 2005.Fig. 3*
Beketinci-Bentež	Z-4373	5057	81			Lasinja	*Minichreiter, Marković 2011.Fig. 2*
Beketinci-Bentež	Z-4375	4954	108			Lasinja	*Minichreiter, Marković 2011.Fig. 2*
Beketinci-Bentež	Z-4376	4787	168			Lasinja	*Minichreiter, Marković 2011.Fig. 2*
Jurjevac-Stara Vodenica	Beta-246768	5200	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Jurjevac-Stara Vodenica	Beta-246771	5160	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Jurjevac-Stara Vodenica	Beta-246776	5240	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Jurjevac-Stara Vodenica	Beta-246777	5330	50	bone		Lasinja	*Balen 2008.Tab. 1*
Jurjevac-Stara Vodenica	Beta-246778	5210	40	tooth		Lasinja	*Balen 2008.Tab. 1*
Jurjevac-Stara Vodenica	Beta-246781	5230	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227927	5350	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227929	5270	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227930	5450	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227933	5330	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227934	4840	40	bone		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227935	5210	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227936	4970	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Đakovački Selci-Pajtenica	Beta-227937	5220	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Tomašanci-Palača	Beta-245707	5210	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Tomašanci-Palača	Beta-252269	5400	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Tomašanci-Palača	Beta-252277	5420	40	charcoal		Lasinja	*Balen 2008.Tab. 1*
Tomašanci-Palača	Beta-252283	5360	50	charcoal		Lasinja	*Balen 2008.Tab. 1*
Vinkovci-Sopot	Z-3139	6020	100	charcoal	23	Sopot II-A	*Krznarić Škrivanko 2011.Tab. 1*

Site	**Lab Code**	**Age (BP)**	**SD (±a)**	**Material**	**Stratigraphic Context**	**Typo-chronological scheme**	**Reference**
Vinkovci-Sopot	Z-3140	6010	100	charcoal	23	Sopot II-A	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3141	5960	100	charcoal	6	Sopot II-A	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2752	5675	120	charcoal		Sopot II-B	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2753	5790	125	charcoal		Sopot II-B	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2909	5220	100	charcoal	20	Sopot II-B	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2911	5330	90	charcoal	20	Sopot II-B	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3143	5840	100	charcoal	53	Sopot II-B	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2754	5360	130	charcoal	11	Sopot III	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2826	6339	99	charcoal	11	Sopot III	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-2827	5380	98	charcoal	11	Sopot III	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3142	5550	130	charcoal	24	Sopot	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3866	5415	195	charcoal	332	Sopot	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3867	5715	155	charcoal	53	Sopot	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3868	6295	135	charcoal	183a	Sopot	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3869	5900	75	charcoal	207	Sopot	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Z-3870	5840	80	charcoal	238	Sopot	*Krznarić Škrivanko 2011.Tab. 1*
Vinkovci-Sopot	Beta-230029	5880	40	charcoal	235	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-230030	5300	40	charcoal	222	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-230031	5780	40	charcoal	301	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-230032	5680	40	charcoal	218	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-230033	5760	40	charcoal	183a	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251907	5940	40	tooth	21	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251908	5840	50	tooth	403	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251909	7120	50	tooth	80	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251910	7100	50	tooth	519	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251911	7110	50	tooth	143	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251912	5860	50	tooth	255	Sopot	*Krznarić Škrivanko 2011.Tab. 2*
Vinkovci-Sopot	Beta-251913	5800	50	tooth	405	Sopot	*Krznarić Škrivanko 2011.Tab. 2*