

Neolithisation of Sava-Drava-Danube interfluve at the end of the 6600–6000 BC period of Rapid Climate Change: a new solution to an old problem

Katarina Botić

Institute of Archaeology, Zagreb, CR
kbotic@iarh.hr

ABSTRACT – *The idea of the Neolithisation of the Sava-Drava-Danube interfluve has undergone very little change since S. Dimitrijević's time. Despite their many shortcomings, new archaeological excavations and radiocarbon dates of Early Neolithic sites have provided us with new insight into the process of Neolithisation of this region. Using the recently published work by B. Weninger and L. Clare (Clare, Weninger 2010; Weninger et al. 2009; Weninger et al. 2014) as a starting point, the available radiocarbon and archaeological data are used to build up a time frame comparable to the wider region of Southeast Europe and climate conditions for specific period. The results fit the model of Neolithisation well (Weninger et al. 2014.9, Fig. 4), filling in the geographical gaps.*

IZVLEČEK – *Premise o neolitizaciji v medrečju Save, Drave in Donave se od časa S. Dimitrijevića niso veliko spremenile. Nova arheološka izkopavanja in radiokarbonski datumi zgodnjega neolitika so, kljub mnogim pomanjkljivostim, prinesli nove vpogled v proces neolitizacije na tem območju. Za osnovo pri interpretaciji smo uporabili nedavno objavljena dela B. Weningerja in L. Clarea (Clare, Weninger 2010; Weninger et al. 2009; Weninger et al. 2014), dosegljive radiokarbonske datume in arheološke podatke pa smo uporabili za izdelavo časovnega okvirja, ki je primerljiv s širšim območjem jugovzhodne Evrope in s klimatskimi pogoji za posamezna obdobja. Rezultati dobro ustrezajo uveljavljenemu modelu neolitizacije (Weninger et al. 2014.9, Fig. 4) ter zapolnjujejo geografske vrzeli v modelu.*

KEY WORDS – *Neolithisation; Starčevo culture; northern Croatia; flooding episodes; Rapid Climate Change (RCC)*

Introduction

The Early Neolithic of Sava-Drava-Danube interfluve, situated on the southern edge of the Carpathian basin, was marked by Starčevo culture. It first appeared in western Sarmatia and eastern Slavonia, spreading through Baranja and western Slavonia and further west along the Drava River sometime around or slightly after 6000 BC. Over 100 Starčevo culture sites are known today, but only a handful have been excavated, and even fewer properly published. Data from four sites are used in this paper: Sopot, Zadubravlje – Dužine, Slavonski Brod – Galovo and Virovitica – Brekinja (Fig. 1). The earli-

est radiocarbon dates can be attributed to features exhibiting the full so-called Neolithic package. The south-east to north-west direction of spread of Neolithisation can be observed through the available radiocarbon dates.

The first relative chronology of Starčevo culture for the region in question was determined by Stojan Dimitrijević (1969.40; 1979.237–238). This chronology is still in use, and no attempts have been made to challenge it or to attribute absolute dating to its phases¹.

¹ Kornelija Minichreiter added to it Linear C phase for the western Drava region (1992.54–55), but she concentrated more on internal chronologies of specific sites than on the absolute dating of Starčevo culture phases in general. The only exception is the attempt to date the white painted Linear A phase at Galovo site (Minichreiter 2007b) but without reference to the full problem of Neolithisation.

In recent years, new interdisciplinary studies appeared that enabled more complex analysis and offered different solutions to the problem of Neolithisation in the wider region from the Middle East, through south-east Europe and beyond. Whether they deal with possible climatic impact on Neolithisation from the climatological point of view (Perry, Hsu 2000; Migowski et al. 2006; Weninger et al. 2006; 2009; 2014; Kuper, Kröpelin 2006; Budja 2007; Clare et al. 2008; Gronenborn 2009; Berger, Guilaine 2009; Clare, Weninger 2010; Weninger, Clare 2011; Zielhofer et al. 2012; Reimer et al. 2013, etc.) or predominantly from the archaeological point of view (Jurić et al. 2001; Bonsall et al. 2002; Bonsall 2007; Bánffy et al. 2007; Borić, Dimitrijević 2007a; Bánffy, Sümegey 2012; Bánffy 2013a; Salisbury et al. 2013; Lespez et al. 2013; Gurova, Bonsall 2014; Krauß et al. 2014; Botić 2016, etc.), they offer answers to some very old questions on this subject.

Relative chronology of Starčevo culture in northern Croatia

The basic typological periodisation and relative chronology of Starčevo culture in northern Croatia was determined by Dimitrijević (1969.40; 1979.237–238) with very few later additions (Minichreiter 1992.54–55; Marković 1994.62–63). Dimitrijević separated Starčevo culture into seven phases: Monochrome, Linear A, Linear B, Girlandoid, Spiraloid A, Spiraloid B and the Final Ždralovi phase (1969.40; 1979.237–238). Kornelija Minichreiter later added Linear C phase (Minichreiter 1992.54–55), which she considers parallel to Spiraloid A phase in eastern Slavonia and Baranja. Zorko Marković's proposed chronological system was never accepted (Marković 1994.62–63)². No recent attempts have been made to further study the problem of the relative chronology of Starčevo culture, except Minichreiter's internal chronologies of the Zadubravlje – Dužine, Slavonski Brod – Galovo, and Pepelana sites (Minichreiter 1992; 2007a; 2007b; 2007c), although the problem of

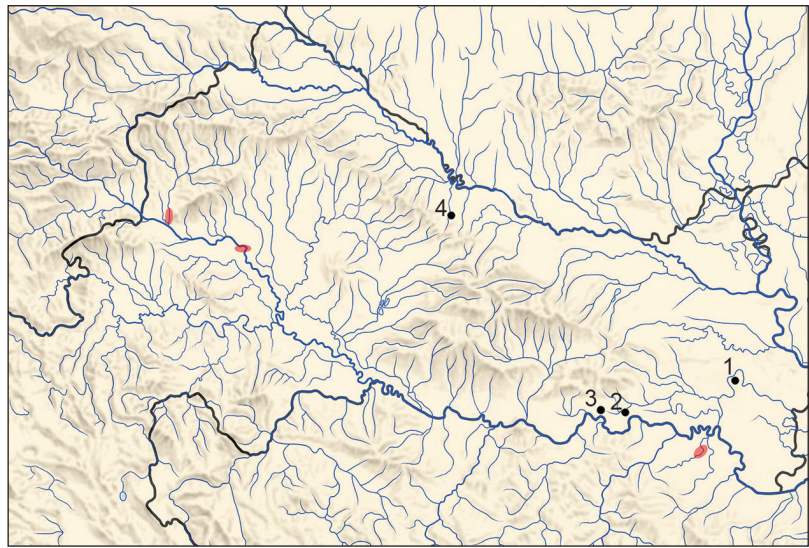


Fig. 1. Starčevo culture sites mentioned in the text: 1 Sopot; 2 Zadubravlje – Dužine; 3 Slavonski Brod – Galovo; 4 Virovitica – Brekinja. Sites of sub-fossil wood extraction mentioned in the text (from east to west): Oštra luka; Sava River near Rugvica; mouth of the Krapina River.

chronological sequences of these phases and their apparent parallel appearance in different regions still waits to be addressed.

An old problem

The process of Neolithisation of the Sava-Drava-Danube interfluvium has not been properly addressed since Dimitrijević's time. The development of early Neolithic Starčevo culture was observed by Minichreiter mostly in the light of new excavations carried out at the Pepelana, Zadubravlje and Galovo sites in terms of internal chronology (Krajcar Bronić, Minichreiter 2007; 2011; Minichreiter 2001; 2007a; 2007b; 2007c; 2010; Minichreiter, Botić 2010; Minichreiter, Krajcar Bronić 2006) but the process itself was not the focus of Minichreiter's research.

Dimitrijević presumed the existence of an initial Monochrome phase (Dimitrijević 1969) even describing pottery finds (Dimitrijević 1969.40; Minichreiter 1992.7–8), but sites containing finds from this presumed phase were never documented in northern Croatia (Minichreiter 1992.41, 54; 2007b.23), not even after the large-scale rescue excavations on highways, bypasses etc. carried out in the last 15 years. Dimitrijević's second presumed Linear phase (Dimitrijević 1969), more specifically Linear A (Dimitrijević 1979.237; Minichreiter 2007b.22–23),

² Phases are: Starčevo 1, Starčevo 2-A, Starčevo 2-B, Starčevo 3, Starčevo 4-A and Starčevo 4-B. His phases are parallel to Dimitrijević's.

was confirmed at the Slavonski Brod – Galovo site (*Minichreiter 2007a.16; 2007b*) where white painted pottery was found, and at the Zadubravlje site, which had no white painted pottery, although the coarse pottery shows characteristics of this phase (*Minichreiter 1992.35; 2007c.173*): the lack of channelled barbotine decoration and lack of biconical vessel forms. Dark painted Linear B phase (*Dimitrijević 1979.237*) was attested at both the Zadubravlje and Galovo sites, the latter exhibiting white and dark painted linear pottery in all three features mentioned by Minichreiter (*Minichreiter 2007b*)³. However, according to Dimitrijević (*1979.242–246*), barbotine and channelled barbotine decoration was introduced in the Linear B phase, which is absent from both of these sites, although some fragments with amorphous relief appliqués appear (*Minichreiter 1992.35, 69, 101, Tab. 19.1; 2007a.93*).

The last campaign at the Sopot site also provided some fragments of white painted pottery, although some fragments were found earlier scattered over the site out of context⁴. How and where the so-called Neolithic package reached northern Croatia and how that affected the Mesolithic way of life remain unanswered questions.

There is another problem concerning most of the new and some of the old archaeological excavations: most of the finds were never published. The same holds for the radiocarbon dates obtained from these excavations. They have not been published or are published without any actual context, or perhaps with just a short description of the feature they were collected from. Thus, the view of how and where the neolithisation started in this region is limited. Nevertheless, data available, although limited, can provide a basis for a new interpretation of the beginning of Neolithic in northern Croatia.

¹⁴C sequences of four sites

From over hundred Starčevo culture sites only six have been radiocarbon dated⁵ and only four of these sites have usable data⁶. From Sopot near Vin-

kovci (Fig. 1.1), Zadubravlje – Dužine (Fig. 1.2), Slavonski Brod – Galovo (Fig. 1.3), and Virovitica – Brekinja sites (Fig. 14) 37 radiocarbon dates are available, most of them from Galovo (Tab. 1)⁷. Reconstructing a time frame from a limited number of radiocarbon dates per site, the obvious difference in quantity from site to site, the limited information about the context from which the samples were taken, *etc.*, is methodologically questionable, but it is the only information available at the moment.

Sopot near Vinkovci (Fig. 1.1)

The Sopot site was systematically excavated from 1996 until 2008 in 13 campaigns (*Krznarić Škrivanko 2015.372*) although there were several previous excavations during the 20th century (*Krznarić Škrivanko 2015.371–372*). The excavations focused on a late Neolithic Sopot culture tell settlement, but during the last campaign in 2008: “*Dug into the pre-sterile layer (prehistoric humus), for the first time at Sopot, a structure was excavated which can be attributed to the Starčevo culture. Pit dwelling SU 519 was dated to the period between 6060 and 5890 BC.*” (*Krznarić Škrivanko 2015.378*) (Fig. 2)⁸. The pit was found on the easternmost side of the excavated area, very close to the summit of the settlement plateau (*Krznarić Škrivanko 2009.90*). The pottery from this pit was coarse, but according to the excavator, fragments of white painted pottery were discovered before, scattered over the site out of context⁹. These finds have not been published yet. The area excavated was 375m², several metres in depth (*Krznarić Škrivanko 2011.212; 2015.375*).

Three dates are available, from pit SU 519 (Beta 251910) and two pre-sterile soil layers SU 80 (Beta 251909) and 143 (Beta 251911) (Fig. 3; Tab. 1). All three dates group around 6000 BC or just slightly earlier. These are the oldest dates for Starčevo culture in northern Croatia so far. The existence of two layers into which the Starčevo feature was dug in may suggest one or more episodes of flooding sealing off the Starčevo layer, rather than being layers

3 Pits 9, 205, and 207.

4 See note 9.

5 Only the published data were taken into consideration, with the exception of one unpublished date from Galovo provided by Dr Kornelija Minichreiter, for which we are grateful.

6 Dates from Tomašanci – Palača site were published as a 5660–5300 BC range without details (*Balen, Gerometta 2011.84, note 2*) and for Belišće – Staro Valpovo site the date was published as 6400–5450 BC, a sample being taken from a male skeleton, but with no other information (*Šimić 2007a.34, note 4; 2007b.10; 2012.27*). Both sites were excluded from this paper.

7 Sopot 3 dates; Zadubravlje 8 dates; Brekinja 2 dates; Galovo 24 dates.

8 Krznarić Škrivanko (*2011.219*) mentions two layers (80 and 143) through which this structure was dug in. These two layers were detected over other areas at the site and contained sporadic Starčevo finds (*Krznarić Škrivanko 2009.90*).

9 M. Krznarić Škrivanko, personal communication.

of prehistoric humus. The next occupation level at this site appears almost 1000 years later during the late Neolithic Sopot culture¹⁰.

Zadubravlje – Dužine site (Fig. 1.2)

Rescue excavations on the site were carried out in 1989 and 1990. An area of 6200m² was excavated (Minichreiter 1992.31; 1993.93; 2001.203, Fig. 4). Several large and small pits were explored, comprising working and living areas, many post holes, several kilns and a well (Minichreiter 1992; 1993a; 2001). No white painted pottery was reported from this excavation, but dark painted linear motifs were found together with coarse pottery characteristic of Linear A phase (Minichreiter 1992.35, 103, Tab. 21; 2007c.173).

Eight radiocarbon dates are available from this site (Fig. 4; Tab. 1). The oldest date (Z-2924) comes from a sample taken from the well. It was probably taken from a larger beam or a trunk and may be considered old wood; it was not taken into further consideration in this paper. Most of the dates group between 5900 and 5600 BC (Fig. 4; Tab. 1) with one exception (Z-2925).

Slavonski Brod – Galovo site (Fig. 1.3)

The site is situated about 9 km west of the Zadubravlje – Dužine site. The excavations started in 1997 and are continuing. An area of around 3000m² yielded 11 large pits which are considered burial pits, pit-dwellings and working pits, one above ground struc-



Fig. 2. Pit-dwelling 519 during and after the excavation (after Krznarić Škrivanko 2009.91; 2015.378, Fig. 11).

ture (Minichreiter 2010; Minichreiter, Botić 2010. 107), several large fences, a large number of post holes and smaller pits¹¹. White painted pottery was found in pits 9, 205, and 207 (Fig. 5) although most of the painted pottery in all three pits exhibit dark motifs (Minichreiter 2007b). Here, as at Zadubravlje site, the coarse pottery corresponds to Dimitrijević's definition of Linear A phase (Dimitrijević 1979. 243).

At the end of its life, the site was covered with an 80cm layer of sediment indicating no later occupation except a late Bronze Age necropolis (Minichreiter 2007a.33–34).

Twenty-four dates are available from this site, but some should be excluded. Some samples may have been contaminated by water from flooding episodes¹², while others (Z-3586, Z-3584) may be consi-

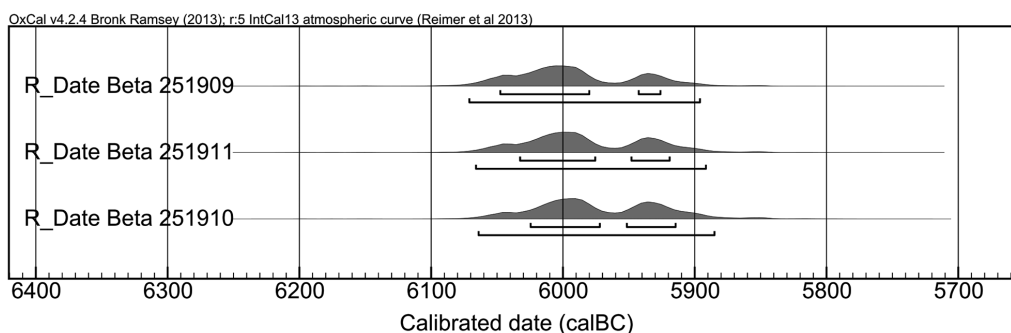


Fig. 3. Sopot ¹⁴C dates.

¹⁰ The oldest house SU 23 is dated to 6020±100 BP/5050–4780 BC (68.2%) (Z-3139) and 6010±100 BP/5040–4770 BC (66.35%) (Z-3140) (Krznarić Škrivanko 2011.211, Tab. 1).

¹¹ The last section excavated since 2010 was only published in short reports (Minichreiter 2011; 2012; 2013; 2014; 2015).

¹² Most probably samples Z-5043, Z-5044, Z-4879 and Z-4880. The site was damaged by clay extraction for a brick factory now closed, and there is a large hole to its north-east side. After heavy rains, water sometimes reaches the level of the site. Damage could have been done to unexcavated features with 80 cm of sediment already removed from their top. However, the oldest date from pit 323 (Z-4357) comes from the nearby southern area of the site, which could not have been affected by flood episodes. Further detailed analysis of the material from the southern pits is required.

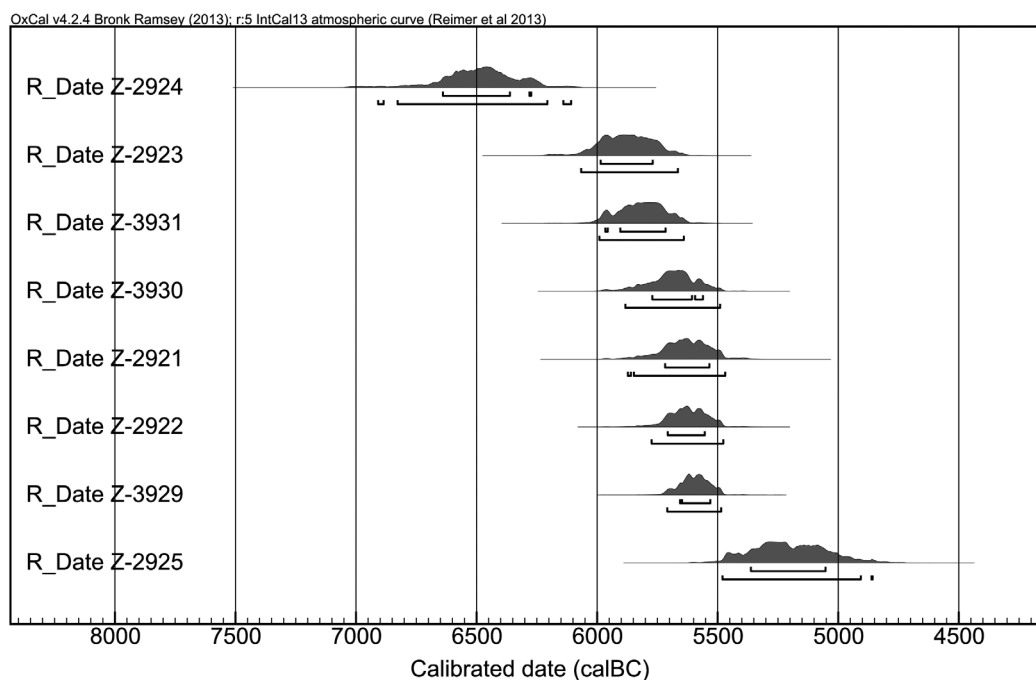


Fig. 4. Zadubravljje – Dužine ^{14}C dates.

dered old wood. Most of the dates group between 5800 and 5550 BC although a younger group of dates can be observed between 5500 and probably 5150 BC (Fig. 6). This group of dates belongs to the part of the feature (Z-3925, the youngest hearth from a pit 9 containing burials) or features (Z-3583, pit-dwelling 37; Z-2935 pit 15 containing male burial) situated on the north side of the site. However, if we consider the possible validity of the three oldest dates (Z-4357, Z-3586, Z-3584), then a third phase of the settlement can be added which would represent slightly younger phase than at the Sopot site and an almost parallel phase at Zadubravljje site.

Virovitica – Brekinja site (Fig. 1.4)

The site was excavated in 2005 on the future western Virovitica by-pass road. An area of 9000m² was explored, but Starčevo culture features were found only on 5400m². Merely the border area of the settlement was excavated, yielding a few partially explored features interpreted as working and residential areas. Most of the finds were fragments of coarse pottery with a barbotine surface. No painted pottery was found. The excavators date this site to the Spiraloïd B phase (Sekelj-Ivančan, Balen 2007).

Only two dates are available from this site (Fig. 7), but unfortunately no description of the context from which the samples were taken has been published. The dates confirm the late existence of this site, probably between 5500 and 5300 BC.

Time span of Starčevo culture in northern Croatia (Fig. 8)

Although scarce information about Starčevo culture sites is available, it is nevertheless possible to reach some preliminary conclusions about its time span:

- ❶ Sopot: So far, there are no traces of settlement at this site before 6060 BC (Beta 251909, Beta 251911, Beta 251910). After 5880 BC, early Neolithic life ends and life is renewed only a thousand years later.
- ❷ Zadubravljje – Dužine: The oldest date 6850–6100 BC from a wooden beam in the well (Z-2924) should not be taken into consideration as the oldest date for this settlement, but the date 6067–5666 BC (Z-2923) could indicate this first phase. The youngest date (Z-2925) corresponds to dates from the Virovitica – Brekinja site.
- ❸ Slavonski Brod – Galovo: The oldest date is from a small pit 323 from the south side of the excavated area (Z-4357) while the next two dates (Z-3586, Z-3584) are from the two wooden fences. These three samples group just after 6000 BC. The next group of dates is the largest, and groups between 5800 and 5550 BC. The three youngest dates (Z-3925, Z-3583, Z-2935) range from about 5500 to 5100 BC; these samples were taken from pits 9, 15 and 37 situated on the northern side of the site.

- ④ Virovitica – Brekinja: Two dates from this site belong to the period between 5500 and 5300 BC¹³.

It is worth noting that three of the sites, Sopot, Galovo, and Zadubravlje¹⁴, were at some point covered by one or several layers of sediment. These layers sealed off the sites for a considerable time: at Sopot, for about a thousand years, and at Galovo until the

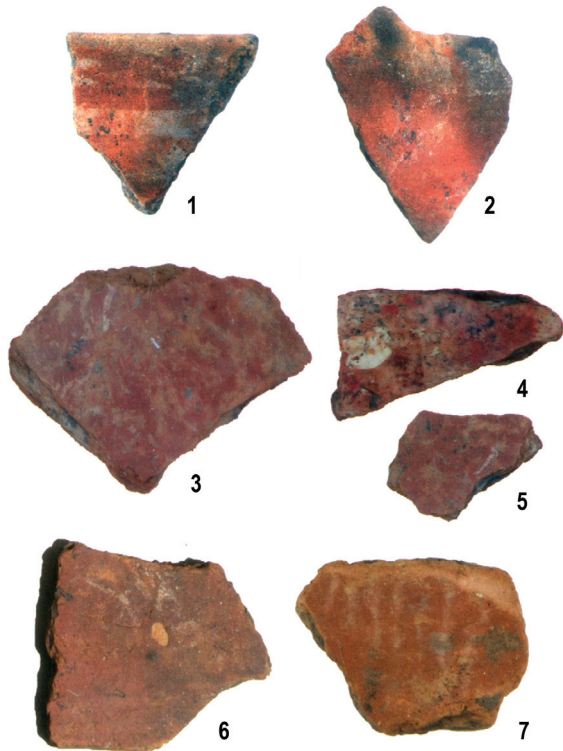


Fig. 5. Slavonski Brod – Galovo, white painted pottery. 1–2 working pit 205; 3–5 working pit 207; 6–7 pit 9 with 3 burials (modified after Minichreiter 2007b.31, Fig. 4).

end of the Bronze Age. Life at Zadubravlje site was never renewed.

The sum of all the usable dates from all four sites (Fig. 8) shows the existence of Starčevo culture in this area roughly between 6000 BC (or slightly earlier) and 5300 BC. Obvious problems with some dates make it impossible to firmly establish the boundaries of phases, but it is possible to establish a time frame for further discussion in this paper.

The overview of ¹⁴C dates provided by Bernhard Weninger *et alii* (2014) from central Anatolia to north-east Hungary (Fig. 9) can be complemented with the dates available for north Croatia, filling in the geographical gap. It is also clear that Neolithisation reached northern Croatia just after 6600–6000 BC, following after the Bulgarian and Romanian dates¹⁵, but before the Hungarian dates (*Hertelendi et al. 1995.242, Tab. 1*). On the territory of Serbia the oldest dates come from southern Serbia¹⁶, while the Iron Gates¹⁷ and Donja Branjevina site (*Budja 2009.127, Tab. 1, 129, Tab. 2; 2013.42, Fig. 1*)¹⁸ show very similar dates to those from northern Croatia.

New solution – RCC 6600–6000 as *terminus post quem*

For a new interpretation of the beginning of the Neolithic in northern Croatia, it is necessary to have a closer look at investigations of the Holocene climate fluctuations of the northern hemisphere. Recent palaeoclimate research has discovered the existence of a distinctly repetitive series of cooling ano-

13 During the preparation of this paper, new ¹⁴C dates were obtained for the Našice – Velimirovac, Arenda 1 site (situated north-west of Našice, near Velimirovac). A rescue excavation was carried out in 2011 on the Našice by-pass road. The dates obtained from charcoal samples from a single pit are: 6855±32 BP (DeA-8335) and 6704±39 BP (DeA-8336). However, low temperature combustion yielded 6822±23 BP and 6804±25 BP, showing better results. These are the oldest dates for the Drava region, predating most of the dates at Zadubravlje, half of the dates from Galovo (both in Sava region) and dates from Virovitica – Brekinja site situated further west. The pottery shows traces of black painted motifs on a red surface, the most similar to the Gírlanoid phase according to Dimitrijević (1969.36–37). Similar finds were collected at the Našice – Brick factory site (*Minichreiter 1992.16; 86, T. 4*) about 4km to the southeast. This is further confirmation of the somewhat later spread of Starčevo culture to the Dravina region. It is still an open question if flooding prevented the advance of the Neolithic to the west along Drava River.

14 K. Minichreiter, personal communication.

15 Similarity of the earliest radiocarbon dates across the Balkans from southern Bulgaria (Dzhuljanitsa, Kovačevo) to Transilvania (*Gurova, Bonsall 2014.100; Krauß et al. 2014*). See also absolute chronology data for the Starčevo-Criş cultural complex (*Luca et al. 2011; Biagi et al. 2005.44.Fig. 4; Biagi, Spataro 2005.38.Fig. 8a–b; 2008.342–343, Tab. 2*).

16 Blagotin by 6200 BC (*Whittle et al. 2002.107, 113; Bonsall 2007.55*).

17 Vlasac was occupied before and after the 8.2 ka event (*Borić et al. 2008.279.Fig. 22*), but at Lepenski Vir there is a gap between 7200 and 6300 BC; the range of dates for the phase with trapezoidal buildings is 6240–5845 BC, while the early Neolithic context has range of dates 6005–5798 BC (*Borić, Dimitrijević 2007a.67, 69*).

18 Dates clearly group before and after 6000 BC, forming a boundary connecting Grivac, Lepenski Vir, Padina before 6000 BC and the disappearance of this boundary after the 6000 BC, indicating two directions of spread of the Neolithic along important rivers: one through Divostin and along the Danube, north-west to Donja Branjevina, and the other to the north-east, along the Tisza and its tributaries to Pannonian Plain and Gura Baciului (*Draşovean 2007.69*).

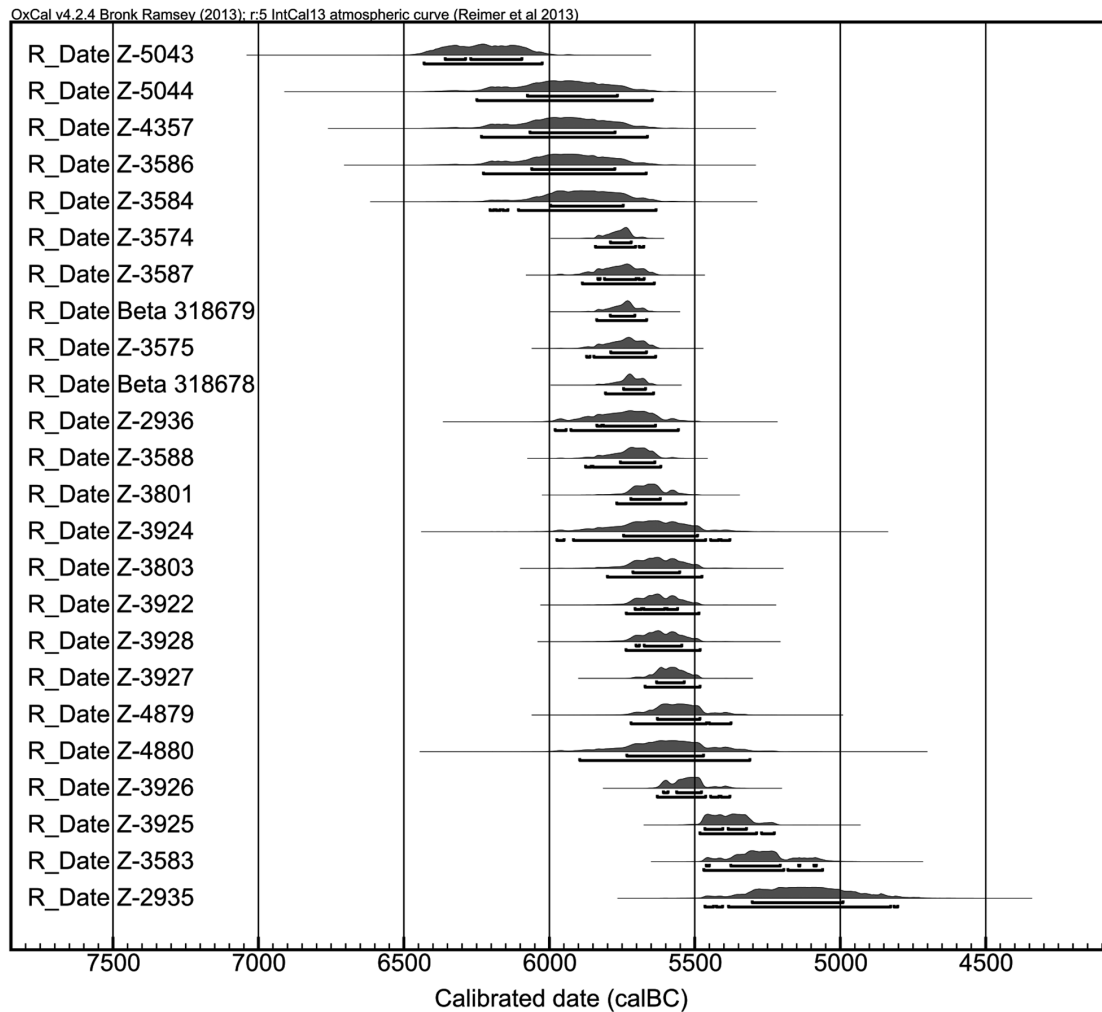


Fig. 6. Slavonski Brod – Galovo ^{14}C dates.

malies during the Holocene (Weninger et al. 2009; Weninger, Clare 2011.11) termed ‘Rapid Climate Change’ (RCC) events (Rohling et al. 2002; Mayewski et al. 1997; 2004; Clare et al. 2008; Weninger, Clare 2011.11; Budja 2015). The RCC intervals are: 9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000 and 600–150 BP, the most recent corresponding to the LIA (Mayewski et al. 2004; Budja 2007; Weninger et al. 2009; 2011; Clare, Weninger 2010). The main cause of these events, in addition to solar intensity weakening (Perry, Hsu 2000; Bond et al. 2001; Mayewski et al. 2004.244; Marino et al. 2009.3246), appears to have been a strengthening of atmospheric pressure gradients between Siberian (High), Iceland (Low) and the Azores (High), conditions supporting an influx of extremely cold air from the polar regions into Europe (Clare et al. 2008; Weninger et al. 2009; Clare, Weninger 2010; Weninger, Clare 2011; Weninger et al. 2014; Weninger, Harper 2015.478, Fig. 2; Benito et al. 2015.5). RCC events correlate with ice-rafted debris (IRD) events (Bond et al. 1997) although not entirely. Further-

more, the North Atlantic Oscillation (NAO) positive phases may have been connected to these cold events (Bout-Roumazielles et al. 2007.3212).

The most severe of these events was the 8.2 ka event (6600–6000 BC) (Alley et al. 1997; Magny et al. 2003; Alley, Ágústsdóttir 2005; Thomas et al. 2007; Clare et al. 2008; Gronenborn 2009; Marino et al. 2009; Weninger et al. 2009; Weninger et al. 2014) during which temperatures in the North Atlantic region dropped over the course of the subsequent 160 years (Thomas et al. 2007.75; Weninger et al. 2009.11). This cooling event was amplified between 8.2 and 8.0 ka calBP by the collapse of a remnant Laurentide ice-dome and subsequent drainage of large amounts of melt-water from the Hudson Bay into the North Atlantic (Bauer et al. 2004; Budja 2007.191; Marino et al. 2009.3246; Weninger et al. 2009.11–12; 2014.8; Weninger, Clare 2011.17) resulting in one of the most extreme climate anomalies of the entire Holocene (Weninger et al. 2014.10). Marine Core LC21 from the southeast Aegean to the east

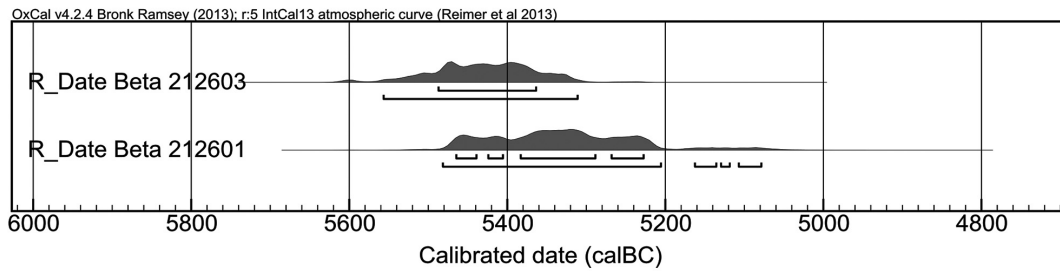


Fig. 7. Virovitica – Brekinja ^{14}C dates.

of Crete showed rapid sea-surface temperature variations resulting from the rapid movement of extremely cold air masses over the surface of the Aegean Sea over a distance of some 700km over short periods of time during winter and early spring (Weninger et al. 2009.10; 2014.10; Weninger, Harper 2015). Cold and dry air flowing rapidly over a warm ocean surface caused evaporation (Weninger et al. 2009.11), which in turn could have provoked intensive precipitation (Weninger et al. 2009.33). Similar cooling events were documented for the Adriatic Sea (Siani et al. 2013; Budja 2015.172). However, in Eastern Mediterranean periods of extreme drought were documented, such as the low levels of Dead Sea (Migowski et al. 2006; Budja 2007.194; Weninger et al. 2009.15–16) (Fig. 10.H), during which ‘flash-flood’ events would have had devastating results on the environment and human occupation (Weninger et al. 2009.33). Weninger et alii (2014. 14) distinguish two phases: an earlier phase at 6600–6200 cal BC (RCC only) and a later phase at 6200–6000 cal BC (RCC amplified by Hudson Bay impact).

Northern Africa was arid until 8500 BC, when an abrupt arrival of monsoon rains created savannah-like environmental conditions, which prompted the swift population of the area by 7000 BC; conditions changed back to arid after 5300 BC (Kuper, Kröpelin 2006.806.Fig 3). Nile River sediments record an enhanced riverine contribution between 8600 and 5500 calBP, indicating enhanced precipitation in north-east Africa (Magny, Combourieu Nebout 2013. 1449). The aridity in North Africa, southern Near East and Middle East is due to the reduced northward migration of the Intertropical Convergence Zone (ITCZ) in summer (Berger, Guilaine 2009.41). Southern Europe shows similar records, indicating that it should be integrated into the same climatic zone during the 8200 calBP event (Berger, Guilaine 2009.41).

In Europe during the 8.2 ka event, low latitudes were affected by colder and more arid conditions, especially in winter (Alley et al. 1997; Alley, Ágúst-

dóttir 2005; Berger, Guilaine 2009.35.Fig. 3). German oak tree-ring records show a distinct low (Fig. 11) (Alley, Ágústsdóttir 2005.1127; Budja 2007.192; Berger, Guilaine 2009.37; Weninger et al. 2014.15. Fig. 9), implying poor growing spring and summer conditions (Alley, Ágústsdóttir 2005.1127; Budja 2007.193; Berger, Guilaine 2009.37; Čufar et al. 2014.1275).

In southern-central Europe, pollen spectra show a sudden disappearance of *Corylus avellana* (hazel) and rapid expansion of *Pinus* (pine), *Betula* (birch) and *Tilia* (lime) and an invasion of *Fagus sylvatica* (beech) and *Abies alba* (fir). This change in vegetation is thought to relate to annual temperature decreasing by about 2–3°C and increased moisture availability. The rapid retreat of drought-adapted *Corylus* was probably caused by taller and longer-lived trees (*Pinus*, *Betula*, *Tilia*, *Quercus*, *Ulmus*, *Fragaria excelsior*, etc.) (Tinner, Lotter 2001; 2006; Budja 2007.194; Nafradi et al. 2015. 14, Dörfler 2013.322). Research conducted at Prokoško jezero in central Bosnia, the closest to our region of interest, showed similar trends: from 7360 BC until 5500 BC a distinct change occurred, when *Fagus* increased rapidly and became the dominant species in sub-alpine woodlands, closely followed by *Abies*, while *Corylus* greatly decreased; *Betula*, *Quercus* and *Tilia* values diminish, while *Carpinus orientalis* (oriental hornbeam) and *Picea* slightly increase (Dörfler 2013.325). The difference in vegetation is noted for north-western Greece (Rezina marshes – Willis 1992, and Boras Mountains – Lawson et al. 2005): the spread of thermophilic trees starts with *Quercus*, *Abies* and *Carpinus orientalis*, followed after some 1000 years by *Corylus* and *Ulmus*, and after another 1000 years by *Tilia* (Dörfler 2013.329). *Fagus* and *Abies* values are very low in the Rezina marshes (Dörfler 2013.329). In north-west Romania (Preluca Tiganului and Steregoiu) pollen-based analysis showed a drop of 1.5–2°C in mean annual temperature, 2–4°C in mean temperature of the coldest month, and an increase in mean temperature of the warmest month, while precipitation shows a de-

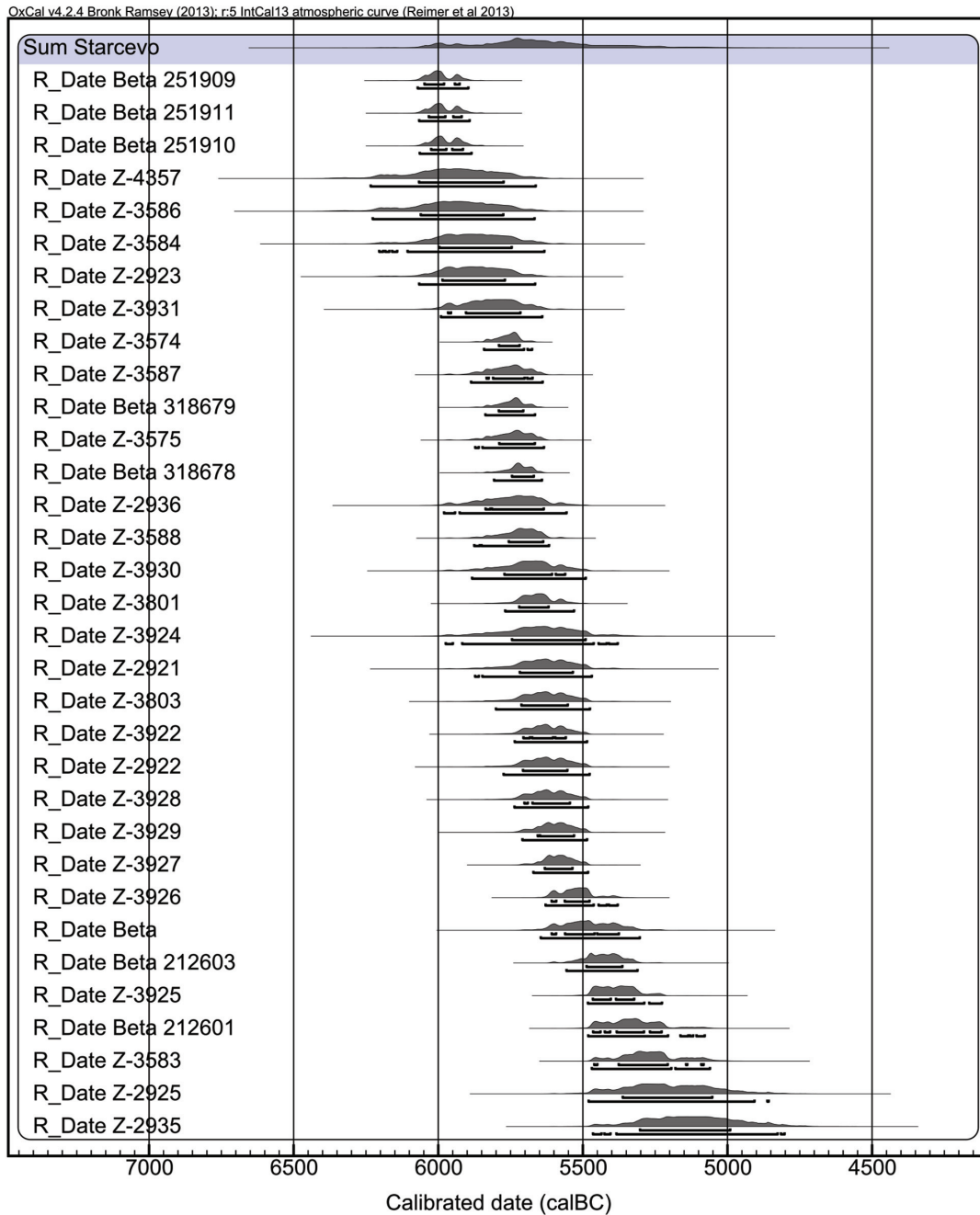


Fig. 8. Sum of ^{14}C dates for Starčevo culture in northern Croatia.

crease of about 200mm. This suggests an intensification of seasonality and continentality (Feurdean et al. 2008.500).

European mid-latitudes between 43° and 50°N underwent wetter conditions in response to cooling, while northern and southern latitudes were marked by drier climate (Magny et al. 2003.1593; Alley, Ágústsdóttir 2005.1128; Budja 2007.194; Berger, Guilaine 2009.37, 40.Fig. 6). Increasing cyclonic activity over mid-latitudes consecutive to a southward displacement of the Atlantic Westerly Jet and a strong thermal gradient between high and low lati-

tudes could have been the cause of hydrological tripartition of Europe (Magny et al. 2003.1592.Fig. 2, 1593–1594.Fig. 3; Budja 2007.194–195.Fig. 3; Berger, Guilaine 2009.41). Lake sediment and palaeobotanical records from Alpine region indicate cooler and wetter conditions between 8500 and 7800 cal BP (Haas et al. 1998; Bonsall et al. 2002.2; Magny et al. 2003.1592; Berger, Guilaine 2009. 37; Budja 2015.172) while wet winters and wet summers are documented in southern regions below 40°N (Budja 2015.172) marked by sea surface salinity lowering and reduced deep-sea convection during the sapropel S1 phase between 9.3 and 7.4 ka (Magny, Com-

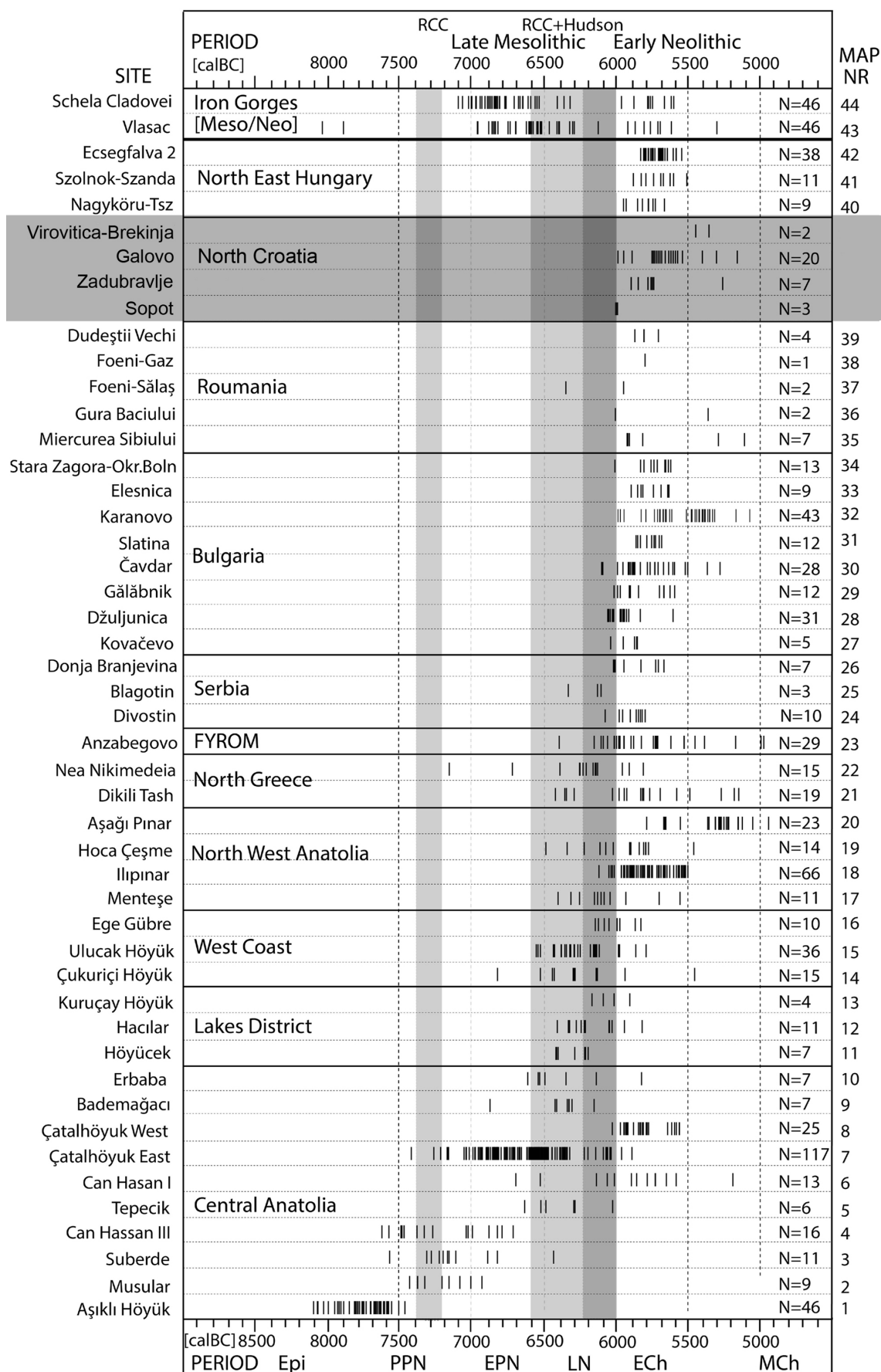


Fig. 9. Overview of ¹⁴C-ages (modified after Weininger et al. 2014.9.Fig. 4).

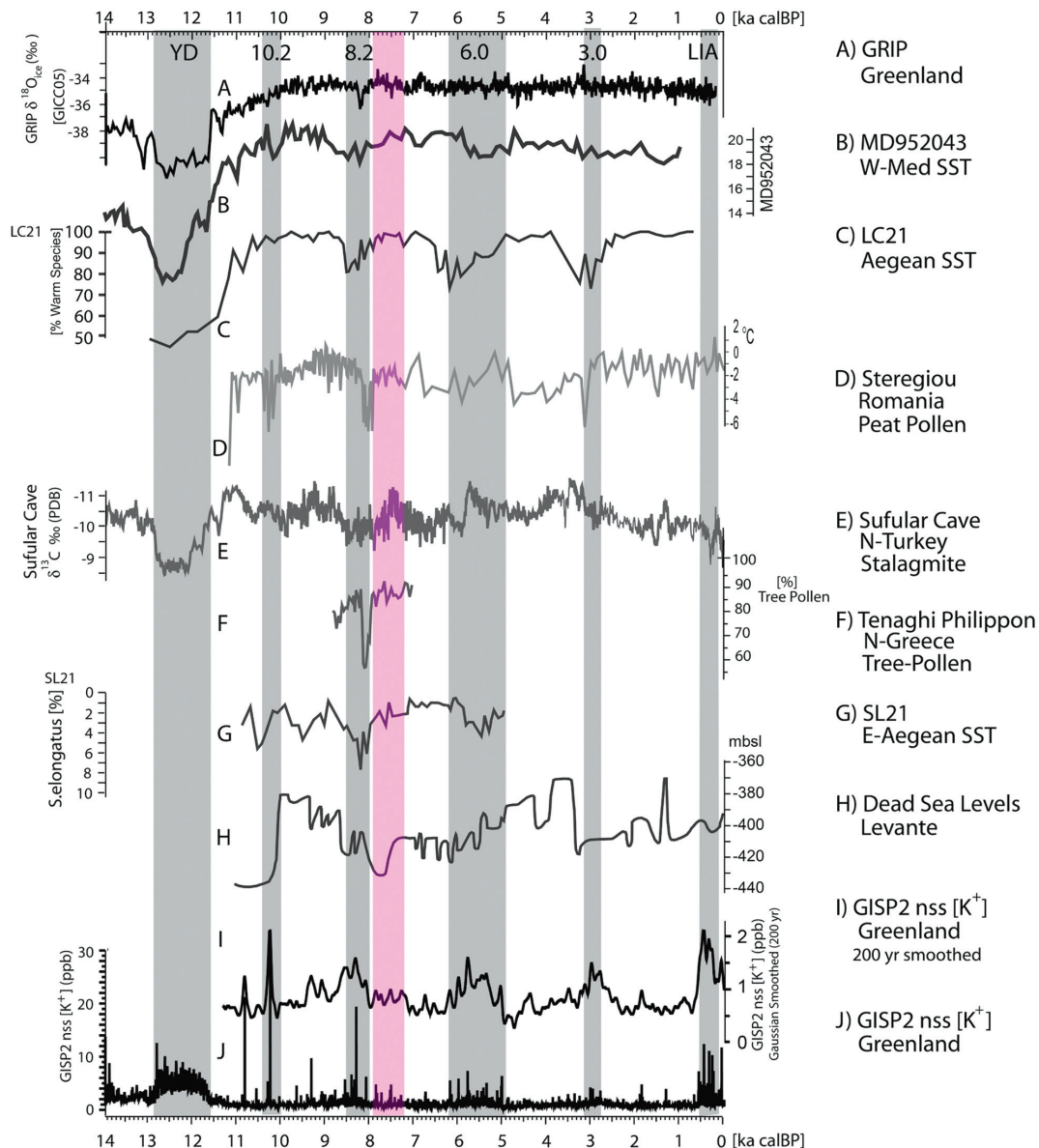


Fig. 10. Northern Hemisphere Palaeoclimate Records showing Holocene Rapid Climate Change (RCC). The purple line marks the duration of the early Neolithic in northern Croatia (modified after Weininger et al. 2014.11.Fig. 5).

bourieu Nebout 2013.1449; Siani et al. 2013.510). There is also evidence for a major period of flooding in several parts of Europe, *i.e.* central Europe (fluvial episode associated with a massive accumulation of tree trunks in the Rhine Valley between 8500 and 8000 cal BP – *Berger, Guilaine 2009.37–38*), Britain, the Danube delta and specifically the French Alps between 8250 and 7950 BP (*Bonsall et al. 2002.4*). A recent study by Gerardo Benito *et alii* (2015) combines more than 2000 ^{14}C and OSL dated

flood units from 12 regions in Europe and North Africa (*Benito et al. 2015.2, Fig. 1*), but unfortunately this study does not include data from regions between the Alps and the Black Sea including the entire Carpathian basin¹⁹. Studies have shown that intensive runoffs of the Po, coastal Italian, Apennine and Albanian rivers may have had an impact on lowering salinity during the middle part of the Holocene in the south Adriatic Sea (*Magny, Combourieu Nebout 2013.1449; Siani et al. 2013.505*).

¹⁹ It is, however, interesting to note an increase in flooding after the 8.2 ka event, first in temperate European regions and slightly after in Mediterranean regions (*Benito et al. 2015.4, Fig. 3*). These flood episodes in both regions correspond to IRD 5b, *i.e.* to the period between 5700 and 5100 cal BC (*Gronenborn 2009.100; Benito et al. 2015.4.Fig. 3*), adding to our understanding of climatological conditions during the early Neolithic in northern Croatia and especially during its end.

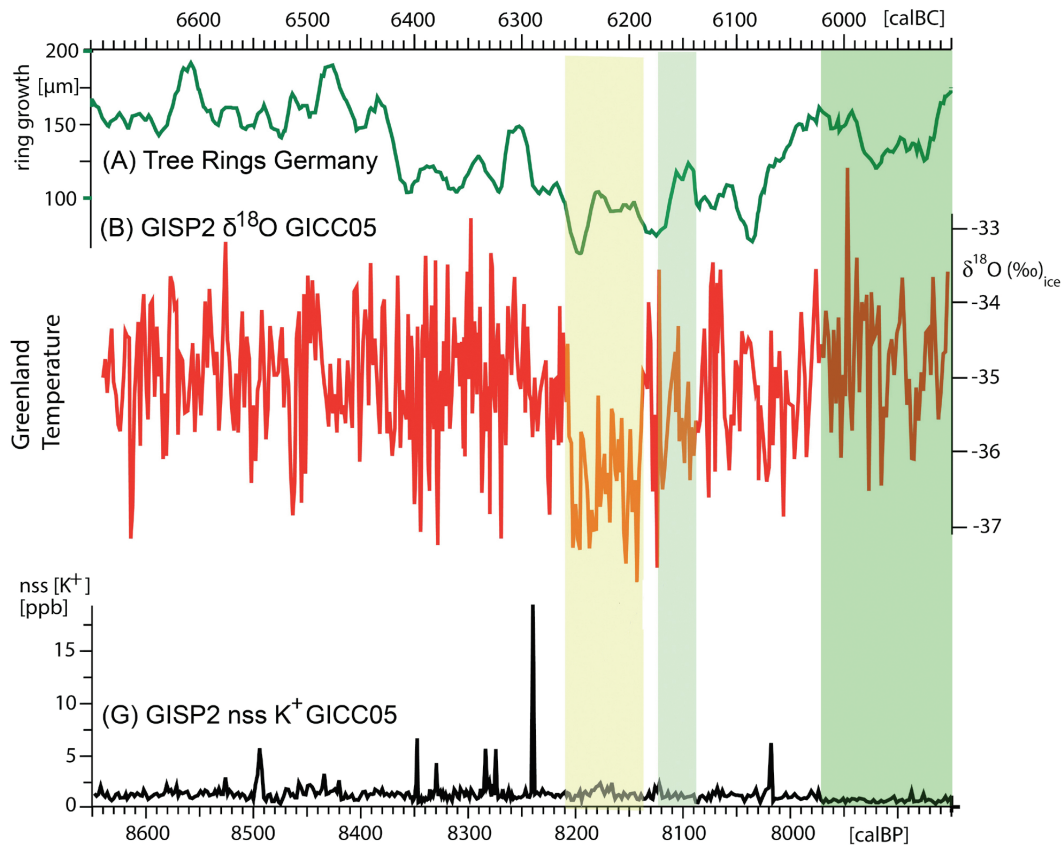


Fig. 11. Timing and structure of the 8.2 ka calBP event on a global scale. The relevant time frame for the beginning and duration of early Neolithic in northern Croatia is marked in darker green (modified after Weninger et al. 2014.15.Fig. 9).

The end date for the 8.2 ka event (Weninger et al. 2014) falls at 6000 BC, or slightly before. The available radiocarbon dates from the early Neolithic period from the Sava-Drava-Danube interfluvies fall within the same time range. Thus, the end of the RCC 6600–6000 BC can be taken as a *terminus post quem* for the appearance of the early Neolithic in this region. It is important to stress that the full 'Neolithic package' is present at all the above-mentioned sites²⁰.

Discussion

Several studies published in the last 15 years or so (Perry, Hsu 2000; Migowski et al. 2006; Weninger et al. 2006; 2009; 2014; Kuper, Kröpelin 2006; Budja 2007; Clare et al. 2008; Gronenborn 2009; Berger, Guilaine 2009; Clare, Weninger 2010; Weninger, Clare 2011; Zielhofer et al. 2012; Reimer et al. 2013, etc.) were dedicated to the observation of the

8.2 ka event impact on Neolithisation processes with some regard to archaeological evidence from the Middle East across the Eastern Mediterranean, northern Africa, and southern and central Europe. Others (Jurić et al. 2001; Bonsall et al. 2002; Bonsall 2007; Bánffy et al. 2007; Borić, Dimitrijević 2007a; Bánffy, Sümegy 2012; Bánffy 2013a; Salisbury et al. 2013; Lespez et al. 2013; Gurova, Bonsall 2014; Krauß et al. 2014; Botić 2016, etc.) take the archaeological context more into consideration but recognise the possible climatic influence on Neolithisation process from the Middle East to central Europe or at least deal with ecological/environmental conditions that could have enabled or prevented the spread of Neolithisation at specific point in time. These studies seem to indicate a halt in Neolithisation advances caused by the 8.2 ka event, which led to unfavourable conditions across certain European regions, mainly the Carpathian basin and other regions of temperate Europe.

²⁰ At the Sopot site, only a partial pit was excavated, but it contained coarse pottery and an altar (Krzynarić Škrivanko 2015.Fig. 12). White painted fragments were collected at similar depths across the site, but out of context and radiocarbon dates come from teeth (Krzynarić Škrivanko 2011.223, Tab. 3), although it is not clear if the teeth are from animals and if they are from domesticated species.

Eszter Bánffy and Pál Sümegei (2012) discuss the role of the Central European-Balkan Agro-Ecological Barrier (CEBAEB)²¹ in the Carpathian Basin as a zone of interaction between immigrant farming communities and the local forager population, although the reasons for the existence of the barrier were manifold: the climatic conditions on the southern side of the boundary were favourable, but the soil was sandy and unsuitable for long-term settlement and crop cultivation (Bánffy, Sümegei 2012.59), especially given the limited agricultural knowledge of immigrant communities adapted to different conditions in south-eastern Europe; the specific climatic conditions in Carpathian Basin due to the basin effect (Bánffy, Sümegei 2012.59) which could trigger a unique transformation in vegetation and soil types; wet habitats and sandy ridges more suitable for a Mesolithic population based on hunting and foraging (Bánffy, Sümegei 2012.60) etc. The German oak tree-ring record²² (Fig. 11) shows another low between 6000 and 5900 BC, possibly indicating unfavourable climate conditions such as excess of precipitation that could have caused large-scale and unpredictable floods (Bonsall et al. 2002; Bonsall 2007) representing impenetrable barriers, although their intensity could have been less pronounced than in the previous 8.2 ka period. However, some of the barriers recognised, such as the one in the Kálcso area and Tolna Sárköz region (the southern Danube region in Hungary), are difficult to explain using ecological/environmental arguments (Bánffy 2013b). Borić (2011) does not see the gap in the settlement of the area between the late Mesolithic and early Neolithic in the Iron Gates gorge; gaps can be seen at certain sites, while others were settled during that time. Borić also does not agree with Bonsall (Bonsall et al. 2002; Bonsall 2007) that large-scale floods were the reason for discontinuity of occupation of sites, but considers different economic strategies to be the reason for that. It is also clear in the Iron Gates gorge that Early/Middle Neolithic

(5950/5900–5500 BC) settlements are at least to a point situated in different environments and on different soils (such as Aria Babi) (Borić 2011.183).

The question is whether some kind of ecological barrier existed in the Sava-Drava-Danube interfluvium, influencing the emergence and spread of Neolithisation in this region or whether this spread was dictated by some other reasons, such as in the Tolna Sárköz region. So far, specific environmental analysis compared with archaeological data has not been done for the Sava-Drava-Danube region, and only circumstantial data are available which might give an insight into the climatic conditions of this region during the Neolithic. In a recently published paper (Pearson et al. 2014) two sub-fossil wood samples are of interest for the region discussed here. Samples 25 from Oštra Luka near Orašje and 151 from the mouth of Krapina River near Zagreb yielded very interesting dates (Fig. 12–13). The date for sample 25 from Oštra Luka is almost identical to three dates from Sopot (Fig. 3) and the date for sample 151 from the Krapina River coincides with the beginning of flood episodes (Benito et al. 2015.4, Fig. 3c), which in turn coincide with IRD 5b (Bond et al. 2001.2131, Fig. 2; Gronenborn 2009.99, Fig. 2; Benito et al. 2015.4, Fig. 3b). As the extreme flooding in spring 2014 showed, extremely high precipitation in the central Bosnian mountain region can provoke extreme episodes of flooding of the Vrbas, Bosna and lower flow of the Sava rivers. This scenario may have happened around 6000 BC or slightly after; debris could have sealed off the Sopot site for the next 1000 years^{23,24}.

Interestingly, in the Prokoško jezero pollen record, a significant drop in the *Corylus* record and a rapid increase of *Fagus* are noted around 6000 BC (Dörfler 2013.322, Fig. 11). This episode could have been provoked by increased precipitation.

21 CEBAEB: an ecological-palaeoecological-mathematical model based on the combination of archaeological and the palaeoenvironmental evidence (Bánffy, Sümegei 2012.57–58).

22 The positive correlation between tree-ring widths and amount of summer precipitation in different months, the ambiguous effect of summer temperatures (Čufar et al. 2014.1268). The sub-regional climatic signal should be taken into consideration because there is clear evidence that the eastern part of the Sava-Drava-Danube interfluvium shows a different climatic signal from the western part (Čufar et al. 2014.1272, Fig. 3).

23 The date for sample 151 from Krapina river may indicate climatic conditions just before the appearance of the Našice – Velimirovac, Arenda 1 site in Drava region (see note 13). The Krapina and Drava rivers respond to increased precipitation in pre-Alpine region, while the lower flow of Sava river responds to precipitation in the central Balkan region. Quite often, floods of the Krapina, Drava, Kupa and upper flow of the Sava rivers do not correspond to floods in the lower flow of Sava river because of this dual source of excess precipitation.

24 As mentioned above, this is all circumstantial evidence; nevertheless, the closeness of dates is striking. Bearing in mind that Starčevo culture was more extensive and more intensive presence in western Hungary can only be documented from around 5700–5550 cal BC (Bánffy 2013a.17), this circumstantial evidence carries even more weight. In this respect, the temporal map of the spread of Neolithisation from the Middle East to Europe (Gronenborn 2014) needs to be modified.

The early Neolithic in Sava-Drava-Danube interfluvium shows all the characteristics of full Neolithic package. White painted motifs on some fragments from the Galovo and Sopot sites suggest the earliest Linear A phase, although these fragments are accompanied by fragments with black painted motifs. The percentage of both white and black painted pottery is very low in the overall amount of pottery from all sites. There is a difference of opinion as to whether a Monochrome phase of early Neolithic existed throughout south-east Europe preceding the 'developed' Neolithic (Stojanovski et al. 2014:24): Lolita Nikolova (2007:91) puts Hoca Çeşme 4-3, Krajnitsi 1, Divostin 1, Koprivets 1, Dzhulyunitsa, and Smurdesh 1 sites in this phase, dating it to 6300-6200/6100 cal BC, while Krauß (2011) argues that the amount of painted pottery during the whole early Neolithic in south-eastern Europe is notably below 10%, and that painted pottery was present from the very beginning in this region²⁵. This latter can be applied to Sava-Drava-Danube region: the amount of painted pottery is well below 10% at observed sites and it is already present in the earliest dated sites. So far, no traces of Starčevo Monochrome phase have been found in our observed region (Minichreiter 1992:54; 2007b:23). Nevertheless, some sites in the Balkans were attributed to that earliest Monochrome phase: Krajnici, Koprivec and Poljanica-platoto in Bulgaria; Divostin, Donja Branjevina and Grivac in Serbia; Pešterica, Rudnik and Grnčarica in the Republic of Macedonia (Krauß 2010:41; Stojanovski et al. 2014), Foeni-Sălaş and Gura Baciului in Romania (Draşovean 2007:70, Fig.2-4; Luca, Suciş 2007:79; Krauß 2010:36).

The question of the transition from late Mesolithic to early Neolithic is also open for discussion for Sava-Drava-Danube region, because no Mesolithic sites are yet known from eastern Slavonia, which may be the result of later floods covering earlier sites or the state of current research. In the surrounding areas, the best-preserved and explored sites exhibiting the transition from Mesolithic to Neolithic are situated in the area of the Iron Gates (Krauß 2014:194). There, among other periods, the Late Mesolithic (c. 7400-6200 cal BC) and Transformation period/Early Neolithic (c. 6200/6300-6000/5950 cal BC) can be distinguished (Borić 2011:161). There are several well-documented Mesolithic sites in this region: Hajdučka

Vodenica, Icoana, Kula, Ostrovul Banului, Ostrovul Corbului, Ostrovul Mare, Padina, Schela Cladovei, Velesnica, and Vlasac (Borić 2011:163, Tab. 2; Borić et al. 2014). In the Transformation/Early Neolithic period only Hajdučka Vodenica, Padina and Vlasac show uninterrupted occupation, while new sites appear: Ajmana, Alibeg, Lepenski Vir²⁶ and Stubica (Borić, Dimitrijević 2007a:69, Tab. 2; Borić et al. 2008:279; Borić 2011:163, Tab. 2; Borić et al. 2014)²⁷. In the following Early/Middle Neolithic (c. 5900-5500 BC) occupation continues in Ajmana, Hajdučka Vodenica, Icoana, Lepenski Vir, Padina, Schela Cladovei, Velesnica, and Vlasac and new sites appear: Ari Babi, Cuina Turcului, Donje Butroke, and Lepenski Abri (Borić 2011:163, Tab. 2).

In southern Banat, a part of the Iron Gates region, only two sites are known: Hoţu Cave, near Steierdorf (Anina) and Băile Herculane-Hoţilor Cave (Krauß 2014:195). These sites are situated a few kilometres north of the Iron Gates in the hilly parts of the southern Carpathians, while in the northern part of the Banat, the Mesolithic is as yet unknown (Krauß 2014:195-196). In Bačka, Mesolithic sites are documented at Hajdukovo close to Subotica and at Bačka Palanka, west of Novi Sad; the sites are located exclusively on the banks of the alluvial plains of the rivers (Krauß 2014:196). In Transdanubia, the Regöly 2 site was recently explored, but there are some older finds from the vicinity of Győr, from the Sárét bog, Csór-Merítőpuszta, next to the village of Nádasdladány and from a sand dune on the flood plain of the Kapos River at Kapshomok (Krauß 2014:196). In Alföld, excavations were carried out at two sites in the Szódliged/Vác area, together with intensive survey in the Jászság area. The sites at Szódliged are situated close to the Danube and are compared to Iron Gates sites by the excavators (Krauß 2014:201). Extensive surveys were carried out in Jászság Basin, the large flood plain between the upper Tisza and Danube rivers, and two Mesolithic sites were found: Jászberény I and Jásztelek I (Krauß 2014:201-202). Five more sites from the Alföld have been mentioned in the literature, some of them situated on the sandy dunes of the floodplains or close to major rivers (Krauß 2014:212). In the Sathmar district of north-west Romania Ciumeşti II site is also situated on a dune (Krauß 2014:212).

25 In Dzhulyunitsa, the oldest layer contains black painted pottery, while only the second layer presents white painted pottery (Krauß et al. 2014; Dzhanfvezova et al. 2014). It is also clear from a preliminary archaeometric study (Dzhanfvezova et al. 2014) that all the pottery was locally made and that the presumed south-eastern imports do not exist.

26 For the non-existent Late Mesolithic period at Lepenski Vir (see Borić, Dimitrijević 2007b:51, Tab. 2; 2007b:69, Tab. 2; Borić 2011:169).

27 Note the change in view of the Mesolithic-Neolithic transition at Vlasac in papers by Borić et al. (2008:279; 2014).

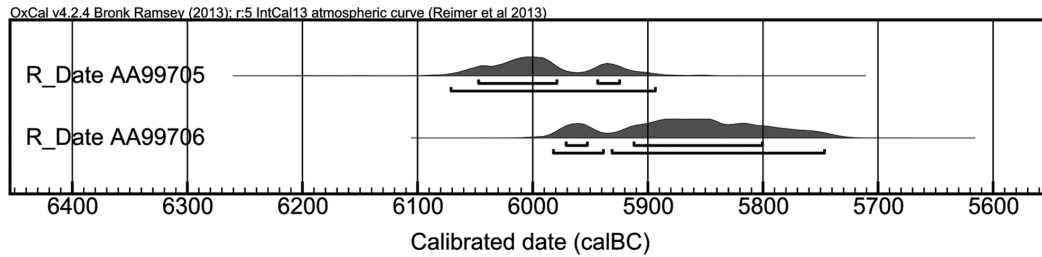


Fig. 12. ^{14}C dates for two sub fossil samples: AA99705 = sample 25 and AA99706 = sample 151 (after Pearson et al. 2014.S54, Tab. 2).

Maria Gurova and Clive Bonsall (2014), comparing known data for Upper Palaeolithic and Late Mesolithic sites in the Balkans, show the peripheral distribution of latter sites within the Balkans. In their assessment, most of the sites are located within 50km of the sea or the Danube. One of the reasons for Mesolithic peripheral site distribution could have been the change in vegetation cover – from semi-desert steppe and forest-steppe ecosystems to a major expansion of temperate forest during the early Holocene. Dense forests protected animals, thus reducing hunting productivity and they have also “posed significant challenges for inter-group communication and participation in viable mating networks” (Gurova, Bonsall 2014.98). Edible plants in temperate forest ecosystems are found on the forest margins, such as upland tree lines, recently burned areas or along sea, lake and river shores. Aquatic resources became an essential substitute for the lack of animal biomass (Gurova, Bonsall 2014.97–98).

Bearing in mind the specific site positions on dunes near large rivers or at elevations near floodplains, the change in resources due to the change in the environment and appearance of dense temperate forests, it is clear that the lack of Mesolithic sites in the Sava-Drava-Danube region, specifically eastern Slavonia, was partially due to environmental change at

the beginning of the Holocene. The only large river in this area is the Danube, while the Sava and Drava plains experienced regular seasonal flooding, but were also covered by dense forests. Mesolithic settlements can nevertheless be expected on the high right margin of the Danube and Đakovo-Vinkovci loess plateau. However, intensive occupation of these regions from the Late Neolithic to modern times reduces the hope of finding surviving Mesolithic sites.

Conclusion

The appearance of the early Neolithic, *i.e.* Starčevo culture in the Sava-Drava-Danube interfluvium can be placed around 6000 BC or just slightly before, as current research and radiocarbon dates show. The earliest dates and finds come from the Sopot site situated in the south-eastern part of Slavonia. After a short period of settlement during this initial Neolithic phase, an episode of flooding probably sealed off the site for the next 1000 years. Shortly after the abandonment of Sopot site, the Zadubravlje and Galovo sites situated in the Sava valley to the west were settled. Both sites show traces of flooding, which was probably the reason why both sites were abandoned and never resettled (except for the late Bronze Age necropolis at the Galovo site). Most of the dates from Zadubravlje and Galovo group after 5850 BC,

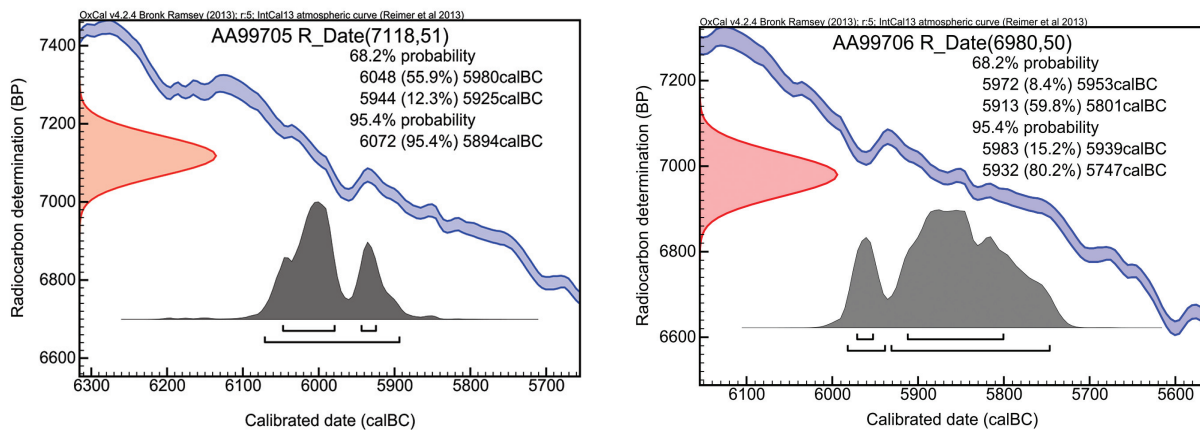


Fig. 13. ^{14}C dates for two sub-fossil samples: AA99705 = sample 25 and AA99706 = sample 151. OxCal v4.2.4 (Bronk Ramsey et al. 2013); IntCal 13 atmospheric curve (Reimer et al. 2013).

although two older dates, slightly younger than the Sopot dates, come from the Zadubravlje site and four dates from the Galovo site. The youngest group of dates can be observed at the Galovo and Virovitica – Brekinja sites (with one date from Zadubravlje) starting after 5500 BC. The end of Starčevo culture can be expected before 5100 BC. Radiocarbon dates also indicate the north-western spread of Starčevo culture to the Drava valley around 5750 BC and later.

Taking climatological/ecological data into consideration, the beginning of Starčevo culture can be linked to the end of the 6600–6000 BC period of Rapid Climate Change (8.2 ka cal BP) but it cannot be expected earlier than 6100 BC. Similarly, the end of Starčevo culture can be linked to the 7.1 ka calBP event (5300–5100 BC).

There is circumstantial evidence of climatic instability in this region, *i.e.* excess of precipitation that can probably be linked to flooding responsible for sealing off the Sopot site and for the unfavourable conditions prior to the Drava region settlement around 5750 BC.

The white painted pottery found at Sopot and Galovo sites shows the connection to other regions of south-east Europe in the Neolithisation process. This connection is also visible in available radiocarbon dates. Weninger *et alii* (2014.6) give the best summary of the process: “*The moment the Neolithic left the Aegean basin, which appears to have occurred not earlier than 6100 cal BC, it apparently took little more than 100 years to become established at sites in Serbia, Bulgaria, and Romania, and little more than around 200 years even to have reached the Pannonian Basin.*”

Although the climate was not the primary reason for cultural change, and in some cases played almost no role in it (Budja 2015; Flohr *et al.* 2015), it is worth noting that radiocarbon dates from early Neolithic sites of the Sava-Drava-Danube interfluvium fit well between documented RCC periods; further archaeo-

logical, geoarchaeological and palaeoenvironmental research is needed to firmly establish a cultural, climatological and environmental connection. The term archaeological climatology or archaeoclimatology, introduced by Fabian Welc (2016) describing a sub-discipline within geoarchaeological science, can be applied to this future interdisciplinary research.

Epilogue

During spring 2016, a small scale geoarchaeological survey in eastern Slavonia was conducted by Zagreb Institute of Archaeology and the Institute of Archaeology, Cardinal Stefan Wyszyński University in Warsaw with the cooperation of the Faculty of Geology, University of Warsaw. The survey consisted of geological sampling and a geophysical survey and was conducted at, among other places, at Slavonski Brod – Galovo and Sopot sites. At the Galovo site, a core of 9m was taken, while at the Sopot site the depth of the core was 3.6m. Magnetic susceptibility preliminary results show an episode of drought followed by an episode of extreme wetter conditions just at the end of life at the Galovo site, while the cultural layer at Sopot site was sealed off by a pronounced wet episode. The interchange of dry and extremely wet conditions can be compared to the eastern Mediterranean periods of extreme drought during which ‘flash-flood’ events occurred (Weninger *et al.* 2009. 33). The full results of this survey will be published in the future.

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Site	Lab code	Material and context	¹⁴ C Age (BP)	δ ¹³ C/ ¹² C (‰)	cal BC (2σ)	Reference
Sopot	Beta 251909	tooth from SU 80 (sq. J25): layer before sterile ground	7120±50	-20.0	6072–5897	Krznarić Škrivanko 2011.215, Tab. 3
Sopot	Beta 251911	tooth from SU 143 (sq. J37): layer before sterile ground	7110±50	-19.7	6067–5892	Krznarić Škrivanko 2011.215, Tab. 3
Sopot	Beta 251910	tooth from SU 519 (sq. K35): pit-dwelling	7100±50	-20.5	6065–5886	Krznarić Škrivanko 2011.215, Tab. 3; Burić 2015.145, Tab. 2
Zadubravlje – Dužine	Z-2924	charcoal from well 11 (sq. C/19; 3.90–4.10m depth)	7620±140		6850–6100	Obelić et al. 2002.620; Krajcar Bronić et al. 2002.18; Minichreiter, Krajcar Bronić 2006.14, Fig. 5; Minichreiter 2001.207; Krajcar Bronić 2011.183,185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-2923	charcoal from south-east part of the pit-dwelling 10 (sq. D-E/15)	6995±115		6067–5666	Obelić et al. 2002.620; Krajcar Bronić et al. 2002.18; Minichreiter, Krajcar Bronić 2006.14, Fig. 5; Minichreiter 2001.205; Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-3931	charcoal from working pit 19 – workshop for stone tools and weapons production (sq. D/11)	6919±102		5991–5641	Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-3930	charcoal from working pit 12 that contained several kilns (sq. A/20-A/21)	6770±110		5884–5491	Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-2921	charcoal from pit-dwelling 6 (sq. A/14-A/15)	6710±115		5873–5470	Obelić et al. 2002.620; Krajcar Bronić et al. 2002.18; Minichreiter, Krajcar Bronić 2006.14, Fig. 5; Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-2922	charcoal from southwest part of the pit-dwelling 9 (sq. A/18)	6705±95		5775–5477	Obelić et al. 2002.620; Krajcar Bronić et al. 2002.18; Minichreiter, Krajcar Bronić 2006.14, Fig. 5; Minichreiter 2001.203; Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-3929	charcoal from the south pit-dwelling 10 (sq. E/15)	6673±75		5710–5486	Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Zadubravlje – Dužine	Z-2925	charcoal from working pit 12 (sq. A/20–21)	6260±130		5481–4858	Obelić et al. 2002.620; Krajcar Bronić et al. 2002.18; Minichreiter, Krajcar Bronić 2006.14, Fig. 5; Minichreiter 2001.204; Krajcar Bronić 2011.185, Fig. 5; Krajcar Bronić, Minichreiter 2011.47, Fig. 3
Slavonski Brod – Galovo	Z-5043	charcoal from burial pit 2013, sq. J/6a	7358±114		6431–6025	Minichreiter 2013.27 (only partial date published; BP age first published here)

Tab. 1. Starčevo culture ¹⁴C dates in northern Croatia. OxCal v4.2.4 (Bronk Ramsey et al. 2013); IntCal 13 atmospheric curve (Reimer et al. 2013).

Site	Lab code	Material and context	¹⁴ C Age (BP)	$\delta^{13}\text{C}/^{12}\text{C}$ (‰)	cal BC (2 σ)	Reference
Slavonski Brod – Galovo	Z-5044	charcoal from burial pit 2013, sq. J/6a	7076±158		6250–5647	<i>Minichreiter</i> 2013.27 (only partial date published; BP age first published here)
Slavonski Brod – Galovo	Z-4357	charcoal from a small pit 323 (sq. J/10-a,b, I/10-c,d) under the hearth SU 1681 (sq. J/10-b)	7067±152		6234–5664	<i>Minichreiter, Botić</i> 2010.120, Fig. 14; <i>Krajcar Bronić, Minichreiter</i> 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-3586	charcoal from the western cult structure 89 (sq. F/12-d)	7060±150		6227–5668	<i>Minichreiter, Krajcar Bronić</i> 2006.8, Fig. 2; <i>Minichreiter</i> 2007a.192, Fig. 1; <i>Krajcar Bronić, Minichreiter</i> 2007.716; <i>Minichreiter, Botić</i> 2010.120, Fig. 14; <i>Krajcar Bronić</i> 2011.182, 184, Fig. 4; <i>Krajcar Bronić, Minichreiter</i> 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-3584	charcoal from the western cult structure 149 (sq. E/11-a)	7000±140		6205–5634	<i>Minichreiter, Krajcar Bronić</i> 2006.8, Fig. 2; <i>Minichreiter</i> 2007a.192, Fig. 1; <i>Krajcar Bronić, Minichreiter</i> 2007.716; <i>Minichreiter, Botić</i> 2010.120, Fig. 14; <i>Krajcar Bronić</i> 2011.182, 184, Fig. 4; <i>Krajcar Bronić, Minichreiter</i> 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-3574	charcoal from pit-dwelling 205/kiln 752 (sq. I/13a,c)	6875±35		5842–5676	<i>Minichreiter, Krajcar Bronić</i> 2006.8, Fig. 2; <i>Minichreiter</i> 2007a.192, Fig. 1; <i>Krajcar Bronić, Minichreiter</i> 2007.716; <i>Minichreiter, Botić</i> 2010.120, Fig. 14; <i>Krajcar Bronić</i> 2011.182, 184, Fig. 4; <i>Krajcar Bronić, Minichreiter</i> 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-3587	charcoal from the western cult structure 389 (sq. G/12-a)	6865±65		5887–5640	<i>Minichreiter, Krajcar Bronić</i> 2006.8, Fig. 2; <i>Minichreiter</i> 2007a.192, Fig. 1; <i>Krajcar Bronić, Minichreiter</i> 2007.716; <i>Minichreiter, Botić</i> 2010.120, Fig. 14; <i>Krajcar Bronić</i> 2011.182, 184, Fig. 4; <i>Krajcar Bronić, Minichreiter</i> 2011.46, Fig. 2
Slavonski Brod – Galovo	Beta 318679	charcoal from SU 2243 (sq. I/6b), fill of the burial pit	6860±40	–24.8	5838–5666	<i>Minichreiter</i> 2012.20 (only partial date published; BP age first published here)
Slavonski Brod – Galovo	Z-3575	charcoal (loom beam) from pit-dwelling 205 (sq. I/13a)	6850±60		5873–5635	<i>Minichreiter, Krajcar-Bronić</i> 2006.8, Fig. 2; <i>Minichreiter</i> 2007a.192, Fig. 1; <i>Krajcar Bronić, Minichreiter</i> 2007.716; <i>Minichreiter, Botić</i> 2010.120, Fig. 14; <i>Krajcar Bronić</i> 2011.182, 184, Fig. 4; <i>Krajcar Bronić, Minichreiter</i> 2011.46, Fig. 2
Slavonski Brod – Galovo	Beta 318678	charcoal from kiln SU 258 (sq. I/13-b,d) in pit-dwelling SU 205	6840±40	–23.8	5808–5642	first published here

Tab. 1. continue

Site	Lab code	Material and context	¹⁴ C Age (BP)	$\delta^{13}\text{C}/^{12}\text{C}$ (‰)	cal BC (2 σ)	Reference
Slavonski Brod – Galovo	Z-2936	charcoal from kiln 032, pit-dwelling 9 (sq. C/3), contains 3 skeletal burials	6835±110		5981–5557	<i>Obelić et al. 2002.616; Krajcar Bronić et al. 2002.18; Minichreiter, Krajcar Bronić 2006.8, Fig. 2; Minichreiter 2007a.192, Fig. 1; Krajcar Bronić, Minichreiter 2007.716; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3588	charcoal from pit-dwelling 155 (sq. G/13a)	6820±70		5876–5618	<i>Minichreiter, Krajcar Bronić 2006.8, Fig. 3; Minichreiter 2007a.192, Fig. 1; Krajcar Bronić, Minichreiter 2007.716; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3801	charcoal from a kiln SU 181 (sq. G/12-a, G/13-b) in pit 155	6750±70		5769–5531	<i>Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3924	charcoal from a burial pit 9 (sq. C/4)	6726±147		5975–5380	<i>Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3803	charcoal from pit-dwelling 207, bottom near the kiln 794 (sq. H/13-d), PU548	6710±100		5801–5476	<i>Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3922	charcoal at the bottom of a working pit 291 (sq. K/11-a)	6709±82		5736–5486	<i>Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3928	charcoal from pit-dwelling 153 (sq. E/13d)	6700±86		5737–5482	<i>Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-3927	charcoal from pit-dwelling 108 (sq. G/11c)	6659±61		5672–5483	<i>Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2</i>
Slavonski Brod – Galovo	Z-4879	burial pit 2243, sq. I/6b	6620±102		5720–5376	<i>Minichreiter 2012.19–20 (only partial date published; BP age first published here)</i>
Slavonski Brod – Galovo	Z-4880	burial pit 2243, sq. I/6b	6600±162		5896–5311	<i>Minichreiter 2012.20 (only partial date published; BP age first published here)</i>

Tab. 1. continue

Site	Lab code	Material and context	¹⁴ C Age (BP)	$\delta^{13}\text{C}/^{12}\text{C}$ (‰)	cal BC (2 σ)	Reference
Slavonski Brod – Galovo	Z-3926	charcoal from hearth near the kiln SU 31 in burial pit 9 (sq. C/4)	6567±66		5630–5380	Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-3925	charcoal from a burial pit 9 (sq. B/3)	6398±67		5483–5227	Krajcar Bronić et al. 2010.495, Fig. 3; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-3583	charcoal from pit-dwelling 37 (sq. b/10-c)	6300±80		5470–5061	Minichreiter, Krajcar Bronić 2006.12, Fig. 4; Minichreiter 2007a.192, Fig. 1; Krajcar Bronić, Minichreiter 2007.716; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2
Slavonski Brod – Galovo	Z-2935	charcoal from pit-dwelling 15 (sq. D/2), contains 1 skeletal burial	6185±130		5466–4803	Obelić et al. 2002.616; Krajcar Bronić et al. 2002.18; Minichreiter 2007a.192, Fig. 1; Krajcar Bronić, Minichreiter 2007.716; Minichreiter, Botić 2010.120, Fig. 14; Krajcar Bronić 2011.182, 184, Fig. 4; Krajcar Bronić, Minichreiter 2011.46, Fig. 2
Virovitica – Brekinja	Beta 212603	charcoal	6470±70		5557–5312	Sekelj-Ivančan, Balen 2007.24
Virovitica – Brekinja	Beta 212601	charcoal	6350±80		5482–5079	Sekelj-Ivančan, Balen 2007.24

Tab. 1. continue

