CLIMATIC INFLUENCES ON APPEARANCE AND DEVELOPMENT OF NEOLITHIC CULTURES IN SOUTHERN OUTSKIRTS OF CARPATHIAN BASIN

Katarina Botić

Institute of Archaeology, Ljudevita Gaja 32, HR-10000 Zagreb, Croatia, e-mail: kbotic@iarh.hr

Abstract

Southern outskirts of Carpathian basin, namely the region between Sava, Drava and Danube rivers, have specific climate conditions today partially influenced by geological structure and geographical position. In this region Neolithic Starčevo and Sopot cultures are observed. Radiocarbon dates for Neolithic cultures are used to build a time frame which is compared with climate proxies, especially with Holocene rapid climate events (8.2, 5.9 and 4.2 ka), to draw a conclusion on when and how these cultures developed in southern regions of Carpathian basin. Lacking firm geoarchaeological data the results are not conclusive but can provide some insight on how the climate may have directly and indirectly influenced development of Neolithic and beginning of Eneolithic period in the region.

Key words: northern Croatia, Slavonia, Neolithic, Starčevo and Sopot cultures, rapid climate events (8.2, 5.9 and 4.2 ka).

INTRODUCTION

Attempts of absolute dating of Neolithic cultures in southern regions of Carpathian basin, i.e. the Slavonia region of northern Croatia, haven‘t been very successful so far. The main problem is the inconsistency in collecting and interpreting radiocarbon data, often used to date structures and not the remains of material culture. When dates are published and attempts made to firmly connect them with certain phases of known Neolithic cultures, some problems are not detected or are simply ignored (Obelić et al., 2004; Minichreiter and Krajcar Bronić, 2006; Minichreiter, 2007; Krajcar Bronić and Minichreiter, 2007; Krznarić Škrivanko, 2011; Sraka, 2012).

In this paper we are giving an alternative way of narrowing down the possible absolute dating of Neolithic cultures in this region. Sums of radiocarbon dates for two main Neolithic cultures (Starčevo and Sopot) are used as a time frame which is in turn compared to climate proxies and data available from close by regions that already underwent detailed analysis. Although this method is questionable, there is no other geoarchaeological data available yet for the region under observation here. The conclusions, although methodologically questionable, are still sufficiently interesting and open up a new perspective to the archaeological context.

Southern outskirts of Carpathian basin, the region observed in this paper, in geographical sense covers the region between Sava, Drava and Danube rivers (Fig. 1). In geopolitical sense, it is the north-east part of Croatia, i.e. Slavonia and Syrmia region. Drava and Sava rivers flank it from the north and south while Danube river makes its eastern border. Those rivers represent quickest communication routs but they were also source of great annual flooding of the plain\(^1\), put under control only at the end of the 19th c. by melioration. The floods influenced the Neolithic way of life, especially the choice of settlement positions. By observing these positions, it is possible to come to the conclusion how the flooding and underground water levels changed over time. The water levels depend heavily on the amount of precipitation in the wider region even today, making this region very sensitive to it. Slavonia region has a specific geological structure (Fig. 2) which enabled permanent settlement of populations from the beginning of Neolithic onwards. Drava and Sava rivers make alluvial plains, both running from the pre Alpine region towards the east. Sava runs slower than Drava, making it easier to cross. Drava was running faster until the hydro power plants were built on it in the 20th c. and it was more difficult to cross in prehistoric times. Both rivers enter Danube river which makes a sharp turn to the east after coming from the north through Pannonian plain. Drava has a lower level of the

\(^1\) The wider region is full of rivers, like Vrbas, Bosna, Drina, Kupa etc. that added to the flooding. Melting of snow in the Alps as well as in the Balkan mountains were additional source of flooding. In 2014 the excessive precipitation in central Balkan region provoked heavy flooding and mudslides in middle and lower flows of the rivers including lower flow of Sava river (Pearson et al., 2014). The damage was horrifying.
waters and is slowed down by high Danube waters, making a wetland near its mouth called Kopački rit (Burić and Težak Gregl, 2009). Banks of Sava and Drava rivers are low but Danube’s right bank is much higher than its left bank – in some parts more than 30 m. Between Sava and Drava Holocene alluvial plains there is a Pleistocene loess ridge (Haase et al., 2007: Fig. 1, Fig. 9 – here, the area in question is marked as containing loess derivatives only but see detailed map in Bačani et al., 1999; Burić and Težak Gregl, 2009) known as Đakovo-Vinkovci plateau (Bačani et al., 1999). Loess and its derivatives cover app. 35.7% of Croatia’s total surface area, in some areas reaching thickness of up to 30 m (Galošić, 2005; Galošić et al., 2009; Burić and Težak Gregl, 2009). It makes extremely fertile zone exploited from the beginning of agriculture in the Neolithic. The alluvial plains regularly flooded were exceptionally good for growth of penduculate oak (Quercus rubra), while regions west and south of Slavonia are still covered by sessile oak (Quercus petraea) (Pearson et al., 2014).

Recently, the work on collection of subfossil samples for multimillennial tree-ring chronology started. The samples are taken from Sava, Bosna, Vrbas, Kupa and Krapina rivers as well as some archaeological sites (Pearson et al., 2014). This chronology, when finished, will not only present excellent method of dating but will provide much needed climatological data. Climatological studies of Čufar et al. (2014) indicated potential to cross-match material from Croatia with oak growth in the wider region (Pearson et al., 2014). They identified common climatic controls of oak growth at sites in Austria, Hungary, Slovenia, Croatia and Serbia, from 45.00° to 48.00°N latitude and from 13.14° to 21.63°E longitude (Pearson et al., 2014). Čufar et al. (2008) have also constructed an oak tree-ring chronology spanning the period AD 1456-2003 for Slovenia but Croatian chronology already shows potential for time span of several millennia (Pearson et al., 2014).

Continental Croatia has a temperate continental climate today. The climate is modified by the maritime influence of the Mediterranean, which is stronger in the area south of the Sava River than in the north, and which weakens towards the east (Zaninović 2008). Although there is no significant difference in mean annual air temperature between Zagreb in the west and Osijek in the east, gradual decrease in mean annual precipitation can be observed (Zaninović 2008). Area of our interest has on average 300 mm less mean annual precipitation. Eastern part of Slavonia is showing microclimate conditions today but we don’t have available data for the past.

RELATIVE CHRONOLOGY OF NEOLITHIC CULTURES IN NORTHERN CROATIA

Dating of Neolithic cultures in northern Croatia, even after decades of investigation, is not sufficiently precise. The foundation for relative chronology of Neolithic cultures was given by Stojan Dimitrijević in the 1960’s and 1970’s. It suffered very little change since and it is still in use today.

The beginning of Neolithic in northern Croatia was marked by appearance and development of Starčevo culture which was divided by S. Dimitrijević into 6 phases with one additional final phase: Monochrom, Linear A, Linear B,
Fig. 2. Geological map (after Baćani et al., 1999: 142, Fig. 1).

The end of Neolithic was marked by Vinča and Sopot cultures in the observed region. Vinča culture was present only in the easternmost part of the region of Croatia and it gave impulse that lead to the development of Sopot culture. The latter was first linked to the Vinča B phase but recently, after new archaeological research and new radiocarbon dates published, especially in Hungary, it is believed to have appeared at the end of Vinča A phase (Link, 2006; Kalitz et al., 2007) (Fig. 6). Sopot culture later appeared in several regional variants: Rašite type, Pepelana type, Brezovljani type, all in the west of northern Croatian territory, together with classical Sopot culture in the east. Again, the first division of Sopot culture was given by S. Dimitrijević (Phase IA, phase IB, phase II, phase III) (Dimitrijević, 1968, 1971) which was later filled in by Z. Marković (Marković, 1994). He added a short 4th phase already parallel with the first Eneolithic cultures in the region (Marković, 1985, 1994, 2012) which was later recognized on Sopot site itself (Krzrnarić Škrivanko, 2007; Balen et al., 2009). Thus, the end of Sopot culture was postponed from the beginning of Vinča D to the end of Vinča D-2/D-3 phase (Marković, 1994).


**ABSOLUTE DATING OF NEOLITHIC CULTURES IN NORTHERN CROATIA**

There are several problems linked to the attempt of absolute dating of these two cultures. Firstly, from around 150 known Starčevo culture sites, only 6 have been radiocarbon dated with total of 32 dates (Fig. 3, black) and from several hundred known Sopot sites, only 17 have been radiocarbon dated with total of 71 dates (Fig. 3, red). Furthermore, the dates published are only linked to the structures at best and not to the remains of material culture (i.e. context) thus not providing firm dating of specific phases of both Neolithic cultures. Nevertheless, these radiocarbon dates provide a rough time frame for the beginning and the end of each culture even giving limits to certain phases of these cultures.

The oldest radiocarbon dates for Starčevo culture come from Galovo and Sopot sites (Tab. 1). At Galovo site, two structures were dated to 6835±110 BP (5810–5620 BC), 6875±35 BP (5800–5715 BC) and 6850±60 BP (5790–5660 BC) (Minichreiter and Krajcar Bronić, 2006)3. Two more structures from the same site, considered the cult structures by the excavator, were dated even earlier: 7060±150 BP (6070–5770 BC) and 7000±140 BP (6000–5740 BC) (Minichreiter and Krajcar Bronić, 2006). The Sopot site yielded even older dates: layer before sterile ground was dated to 7120±50 BP (6060–5900 BC) while the oldest structure, a pit-dwelling, was dated to 7100±50 BP (6060–5890 BC) (Krzrnarić Škrivanko, 2011).

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3 The BP age is given here as 14C uncalibrated age and BC dates correspond to 1σ (68.2%).
The youngest radiocarbon dates for Starčevo culture come from Galovo and Zadubravlje sites (Tab. 1). From Galovo site there are two structures dated to 6300±80 BP (5380–5290 BC) and 6190±130 (5300–4960 BC) (Miničreiter and Krajcar Bronić, 2006). From Zadubravlje site one structure was dated to 6260±130 BP (5370–5040 BC) (Minichreiter and Krajcar Bronić, 2006). Here, the obvious problems are too low dates for clearly Starčevo culture structures from both sites that overlap with Sopot culture dates from other sites. It is difficult to say if here we can see the prolonged Starčevo culture life at certain sites or it is just a question of badly dated or corrupt samples.

The beginning of Sopot culture can’t be considered without Vinča culture in the wider region. Absolute dating of Vinča culture was recently given by D. Borić (2009): the beginning (Vinča A phase) is dated to 5400/5300–5200 BC while the end (Vinča D phase) is dated to 4850–4650/4600 BC. The only problem noted here is very high end date for Vinča D phase because it doesn’t correlate well with dates for the end of Vinča culture in wider region4.

The beginning of Sopot culture according to radiocarbon dates (Tab. 2) is quite problematic. Some dates are too high (old wood effect?) but the main problem is the lack of sites with earliest phase (IA) of this culture. So, the oldest dates correspond to the end of the first phase (IB) or later. One comes from Dubovo-Košno site (6320±100 BP; 5390–5140 BC), the other from Sopot site (6340±100 BP; 5470–5210 BC) but both were published without remains of material culture. The most probable dates come from Golinci – Selište and Kruševica – Njivice sites (Tab. 2), both corresponding to the IB phase: the first is 6160±45 BP (5210–5050 BC), the second 6115±60 BP (5210–4940 BC). The youngest radiocarbon dates for Sopot culture (Tab. 2) are much lower than Vinča D phase according to Borić (2009) or somewhat later in the wider region, and they partially overlap with dates for Eneolithic Lasinja culture (Balen, 2008). Several come from Sopot site: 5380±98 BP (4340–4040 BC), 5360±130 BP (4320–4040 BC), 5330±90 BP (4250–4040 BC), 5300±40 BP (4250–4030 BC) and 5220±100 BP (4230–3940 BC) (Obelić et al., 2002). One date is

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### Table 1

<table>
<thead>
<tr>
<th>Site</th>
<th>Lab and code</th>
<th>Material and context</th>
<th>¹⁴C age (BP)</th>
<th>δ¹³C/¹²C (%)</th>
<th>Calibration range (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sopot</td>
<td>Beta 251909</td>
<td>tooth from SU 80 (sq. J25); layer before sterile ground</td>
<td>7120±50</td>
<td>−20.0</td>
<td>6060–5900 BC (68.2%)</td>
<td>Krznarić Škrivankov, 2011, Table 3</td>
</tr>
<tr>
<td></td>
<td>Beta 251911</td>
<td>tooth from SU 143 (sq. J37); layer before sterile ground</td>
<td>7110±50</td>
<td>−19.7</td>
<td>6060–5900 BC (68.2%)</td>
<td>Minichreiter and Krajcar Bronić, 2006, Fig. 2; Minichreiter, 2007, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td></td>
<td>Beta 251910</td>
<td>tooth from SU 519 (sq. K35); pit-dwelling</td>
<td>7100±50</td>
<td>−20.5</td>
<td>6060–5890 BC (68.2%)</td>
<td>Obelić et al., 2002; Minichreiter and Krajcar Bronić, 2006, Fig. 2; Minichreiter, 2007, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td>Slavonski Brod–Galovo</td>
<td>I.R.B.Z., Z-3586</td>
<td>charcoal from the western cult structure 89 (sq. F/12-d), SF 312</td>
<td>7060±150</td>
<td>/</td>
<td>6070–5770 BC (68.2%)</td>
<td>Minichreiter and Krajcar Bronić, 2006, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td></td>
<td>I.R.B.Z., Z-3584</td>
<td>charcoal from the western cult structure 149 (sq. E/11-a), SF 150-151</td>
<td>7000±140</td>
<td>/</td>
<td>6000–5740 BC (68.2%)</td>
<td>Obelić et al., 2002; Minichreiter and Krajcar Bronić, 2006, Fig. 2; Minichreiter, 2007, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td></td>
<td>I.R.B.Z., Z-3587</td>
<td>charcoal from the western cult structure 389 (sq. G/12-a), SF 331</td>
<td>6865±65</td>
<td>/</td>
<td>5850–5710 BC (68.2%)</td>
<td>Minichreiter and Krajcar Bronić, 2006, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td>Slavonski Brod–Galovo</td>
<td>I.R.B.Z., Z-2936</td>
<td>charcoal from the klin 032, pit-dwelling 9 (sq. C/3) with 3 skeletal burials</td>
<td>6835±110</td>
<td>/</td>
<td>5810–5620 BC (68.2%)</td>
<td>Obelić et al., 2002; Minichreiter and Krajcar Bronić, 2006, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td></td>
<td>I.R.B.Z., Z-3574</td>
<td>charcoal from the pit-dwelling 205 (sq. I/13a,c), SF 484</td>
<td>6875±35</td>
<td>/</td>
<td>5800–5715 BC (68.2%)</td>
<td>Minichreiter and Krajcar Bronić, 2006, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td></td>
<td>I.R.B.Z., Z-3583</td>
<td>charcoal from the pit-dwelling 37 (sq. b/10-c), SL 044</td>
<td>6300±80</td>
<td>/</td>
<td>5380–5290 BC (68.2%)</td>
<td>Minichreiter and Krajcar Bronić, 2006, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td></td>
<td>I.R.B.Z., Z-2935</td>
<td>charcoal from a pit 15 (sq. D/2), with 1 skeletal burial</td>
<td>6185±130</td>
<td>/</td>
<td>5300–4960 BC (68.2%)</td>
<td>Obelić et al., 2002; Minichreiter, 2007, Fig. 1; Krajcar Bronić and Minichreiter, 2007; Krajcar Bronić, 2011, Fig. 4</td>
</tr>
<tr>
<td>Zadubravlje–Dužine</td>
<td>I.R.B.Z., Z-2925</td>
<td>charcoal from working pit 12 (sq. A/20-21)</td>
<td>6260±130</td>
<td>/</td>
<td>5370–5040 BC (68.2%)</td>
<td>Minichreiter and Krajcar Bronić, 2006, Fig. 5; Minichreiter, 2001; Krajcar Bronić, 2011, Fig. 5</td>
</tr>
</tbody>
</table>

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4 For example see absolute chronology for the late Vinča culture in Romania (Lazarovici, 2006; Lazarovici and Lazarovici, 2007).
from Nova Gradiška – Slavča site (5300±40 BP; 4250–3990 BC) (Mihaljević, 2013), one from Osijek – Hermanov vinograd site (5260±120 BP; 4230–3810 BC) and one from Otok – Mandekov vinograd site (5330±120 BP; 4330–4040 BC) (Obelić et al., 2002). Attempts to firmly date Sopot culture phases weren’t successful so far (Obelić et al., 2004, Krznarić Škrivanko, 2011; Slaka, 2012) because too high dates are considered or the 4th phase is ignored, in addition to the fact that the clear context of the finds is missing.

Observing the available radiocarbon dates, even if we ignore their obvious downsides, shows several problems concerning absolute dating of Starčevo and Sopot cultures. The beginning of Starčevo culture fits well the beginning of Neolithic in the wider region (see for example Hertelendi et al., 1995; Biagi and Spataro, 2005; Biagi et al., 2005; Lazarovici, 2006; Minichreiter and Krajar Bronić, 2006; Budja, 2013 etc.) but dating of its end in the north Croatia is not quite clear. Sopot culture shows problems concerning dating of all the phases, from the beginning until its end. It is worth noting that one date from Hungarian site Sormás-Mátai-dúlõ (VERA-3102, 6115±35 BP; 5210–4980 BC) (Barna and Pásztor, 2011), belonging to this site’s Sopot level, corresponds well with two dates from Croatian sites Golinci–Selište and Kruševica–Njivice (Tab. 2) although the context of these dates is not considered to represent the oldest phase of Sopot culture. As the Sopot culture first appeared in northern Croatia and then spread to the north, the question is when of these dates is not considered to represent the oldest phase of Sopot culture.

All radiocarbon dates available for Starčevo and Sopot cultures, when summed (Fig. 4), give us a time frame which will be used to compare it with climate proxies (Tab. 3). Although this method is not accurate and faces many problems5, it is at the moment the only possible way to observe how these cultures fit the Holocene rapid climate events. Unfortunately, no larger archaeological context or geoarchaeological data is available at the moment for the observed region.

5 Large number of dates available for few sites, very few dates available for other sites, majority of sites remains undated etc. (Weninger et al., 2014).
This time frame corresponds well with Hungarian Neolithic (Fig. 5) and generally corresponds well with absolute dating of Neolithic in wider region (Fig. 6), although there are some differences — the beginning of Starčevo culture is dated later and the beginning of Eneolithic earlier than in our observed region.

CLIMATE PROXIES

In recent times the interest for Holocene climate change increased considerably. One of the most remarkable discoveries is the existence of a distinctly repetitive pattern of global cooling anomalies, with major (among other cycles) 1450-year periodicity during the Glacial periods, extending through the Holocene (Weninger et al., 2009). These climate changes were manifested by cooling oscillations, tropical aridity and major atmospheric circulation changes (Budja, 2007) and are known as Rapid Climate Change (RCC) events (Mayewski et al., 2004; Weninger et al., 2010). The existence of rapid fluctuations in Northern Hemispheric Glacial and Holocene atmospheric circulation patterns was first recognised some years ago in a detailed analysis of the GISP2 (Greenland) ice core glaciochemical record (Mayewski et al., 1997; Clare and Weninger, 2010). Subsequent comparisons of the GISP2 record with terrestrial and marine records

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Absolute chronological time frame for the Neolithic cultures in northern Croatia</th>
</tr>
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<tbody>
<tr>
<td>around 6000 BC</td>
<td>the beginning of Starčevo culture</td>
</tr>
<tr>
<td>5500–5300 BC</td>
<td>the end of Starčevo culture</td>
</tr>
<tr>
<td>5300–5000 BC</td>
<td>the beginning of Sopot culture (?)</td>
</tr>
<tr>
<td>5200–5050 BC</td>
<td>duration of Sopot culture (most of the available dates)</td>
</tr>
<tr>
<td>5050–4300 BC</td>
<td>hiatus? (drastic decrease of available dates)</td>
</tr>
<tr>
<td>4300–4200 BC</td>
<td>the end of Sopot culture (the end of Neolithic/beginning of Eneolithic)</td>
</tr>
<tr>
<td>4200–4000/3990 BC</td>
<td>the end of Sopot culture (the end of Neolithic/beginning of Eneolithic)</td>
</tr>
</tbody>
</table>

Fig. 4 The sum of radiocarbon dates for Starčevo (black) and Sopot (red) cultures.

Fig. 5. Diagrammatic representation of the three phases of the Neolithic period (after Hertelendi et al., 1995: 242, Fig. 2).
on a global scale have demonstrated the existence of six distinct time-intervals, each of which showed major cooling anomalies during the Holocene (Mayewski et al., 2004; Clare and Weninger, 2010). The ages attributed to these (wider) Rapid Climate Change (RCC) intervals are: 9000–8000, 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600–150 calBP (Mayewski et al., 2004; Alley and Ágústsdóttir, 2005; Budja, 2007; Clare and Weninger, 2010; Weninger et al., 2009). The most recent manifestation is known as the Little Ice Age (LIA) (Budja 2007; Clare and Weninger, 2010; Weninger et al., 2009).

For the North Atlantic, these cooling phases are explained with changes in salinity caused by final deglaciation of the Laurentide ice sheet and related fresh-water outbursts into the ocean, as well as iceberg discharges which equally supplied fresh-water to the North Atlantic (Budja, 2007; Gronenborn, 2009), known as Holocene IRD events (Ice Rafted Debris) (Gronenborn, 2009) or Bond events (Bond et al., 1997). IRD events show a good correlation with insolation cycles and solar triggering is considered (Bond et al., 2001; Gronenborn, 2009). These North Atlantic temperature changes and changes in the ocean salinity could also have had hemispherical effect, with teleconnections to the monsoonal cycles (Alley and Ágústsdóttir, 2005; Gronenborn, 2009).

Two of the RCC intervals are important for this paper: 9000–8000 and 6000–5000 calBP (Clare and Weninger, 2010). The bibliography consulted is extensive (Alley et al., 1997; Bond et al., 1997; Bianchi and McCave, 1999; Hu et al., 1999; Perry and Hsu, 2000; Bond et al., 2001; Ougtsov et al., 2001; Sümege et al., 2002; Magny et al., 2003; Mayewski et al., 2004; Alley and Ágústsdóttir, 2005; Bailey, 2006; Kuper and Kröpelin, 2006; Weninger et al., 2006; Bouter-Roumazilles et al., 2007; Budja, 2007; Thomas et al., 2007; Weninger et al., 2007; Clare et al., 2008; Weninger et al., 2008; Berger and Guillaume, 2009; Bocquet-Appel et al., 2009; Gronenborn, 2009; Gronenborn and Sirocko, 2009; Kotova, 2009; Weninger et al., 2009; Clare and Weninger, 2010; Kotova and Makhortykh, 2010; Gulyás and Sümege, 2011; Lemmen et al., 2011; Carozza et al., 2012; Welc and Marks, 2014 – all with their corresponding bibliography) but we will only take specific RCC intervals into consideration and their correlation with archaeological indicators for the observed region of Slavonia.

8.2 ka calBP climate event

The ‘8.2 ka BP event’ is the most unfavourable of all events from the beginning of Holocene including the Little Ice Age (LIA). Anomalies have been observed in paleoclimate archives on a near global scale, except for the high southern latitudes (Budja, 2007). Greenland ice-core records show that temperatures in the North Atlantic region dropped abruptly around 8200 BP and took around 160 years to recover (Thomas et al., 2007; Weninger et al., 2009). This cooling was caused by flood outburst from the final deglaciation of the Laurentide ice sheet, strengthened atmospheric...
circulation over the North Atlantic and Siberia and more frequent polar north-westerly winter outbreaks over the Balkans and Aegean Sea (Budja 2007; Weninger et al., 2009). Extremely cold and dry air flowing rapidly over a warm sea surface caused water evaporation which could have resulted in very abrupt and heavy precipitation (Weninger et al., 2009). Analyzing the marine core LC21, situated near the east coast of Crete in Aegean sea, Weninger et al. (2009) noted three major temperature drops in the south east Aegean, dated to 8.6–8.0 ka calBP, 6.5–5.8 ka calBP and 3.5–2.8 ka calBP which corresponds to the RCC intervals on a global scale (Figs 7, 8).

Decline in winter temperatures of more than 4°C was noted in northern Greece (Tenaghi Philippon site) and north-west Romania (Steregou and Preluca Tiganului sites) in pollen records. The significant drop of Dead Sea water levels was noted for the period after the 8.6 ka calBP recovering slightly only around 7.5 ka calBP and continuing at relatively low levels until 5.6 ka calBP (Budja, 2007; Weninger et al., 2009). As the Dead Sea level responds primarily to precipitation changes in the northern Jordan Valley, it is possible to conclude that, during the low levels of the Dead Sea, precipitation decreased significantly in the wider eastern Mediterranean region (Weninger et al., 2009) (Figs 9, 10).

In south-central Europe, pollen analysis showed change in terrestrial vegetation in response to the climatic change between 8170 and 7950 calBP. This change is probably direct response to the annual temperatures decreasing by about 2–3°C and to increased moisture availability. Southern Balkans faced rainfall seasonality change, with drastic decrease in autumn to spring precipitation and considerable fall of temperatures (Budja, 2007). The reconstruction of climatic parameters from European lake-level fluctuation data suggest that regions at mid-latitudes between 43° and 50°N underwent wetter conditions in response to the cooling, while northern and southern Europe was marked by drier climate (Magny et al., 2003; Budja, 2007).

In the southern Levant, the 8200 calBP ‘climate event’ was associated with the transition from the Pre-Pottery (PPN) to Pottery Neolithic (PN); the Jericho settlement was abandoned as well as the settlements at Ain Ghazal (Levant), Catalhöyük East (Central Anatolia) and settlements of Cyprus (Budja, 2007; Weninger et al., 2009). It is suggested that this climate event correlated with spread of farming from West Asia and Near East into Europe but there is enough evidence that farming (i.e. pottery) in Europe appeared prior to the 8200 calBP although the domestication of animals arrived immediately after (Budja, 2007).

According to Gronenborn (2009), IRD events 5 and 4 were contemporaneous with two major shifts in the Neolithisation process in Temperate Europe (Figs 7, 9). The IRD event 5a can be linked to the beginning of the Neolithisation
around 6500 BC. The IRD event 5b started around 5700 BC and ended abruptly around 5100 BC with the 5.1 event, covering more or less the entire extension of the LBK in Central Europe (Gronenborn, 2009).

It can be concluded that the Neolithisation process of south-east and central Europe (regions at mid-latitudes between 43° and 50°N) was interrupted by 8200 calBP event because of the increase of precipitation, flooding and change in vegetation. The Morava River valley, a waterway connecting the southern Balkans to north-central Europe, was badly affected by river dynamics and floods. It can be speculated that in the Pannonian Plain there was an extension of wetlands and long-term flooding at the time of the climate event, because the records show that it was flooded at least twice a year before the regulation in the 19th century (Bánffy, 2004; Budja, 2007; Bánffy and Sümegi, 2012). This is also true for Sava, Drava and Danube interfluve (Slavonia region). The initial agriculture in Peloponnesus and most of Balkans predate the climate event (6200–6000 BC) but Neolithic populations crossed Danube and entered the southernmost region of the Pannonian Plain after the major climate fluctuations (i.e. around 6000 BC) (Budja, 2007).

6.0 ka calBP climate event

The time range of the next RCC period (6.0 ka calBP) is 6000–5200 calBP. In southern Europe, this period is associated with transition from the final Neolithic (or Late Copper Age/Late Eneolithic, according to region) to the Early Bronze Age. In this part of Europe (Greece, Bulgaria, Romania) archaeological research confirmed an abrupt collapse of long-standing cultural systems and long-lived settlements that can...
be dated to sometime around 6.0 ka calBP which corresponds to the onset of the RCC (Weninger et al., 2009). Measurements of non-sea salt (nss) [K⁺] from GISP2 ice-core let Weninger et al. (2009) to single out cold peaks at about 6162, 5971 and 5746 calBP followed by short warmer period between 5200 and 5150 calBP. The RCC finishes abruptly at 4992 calBP (Fig. 8). Evidence of poorer settlement pattern in this period for a long time was considered to be the result of

Fig. 9. Culture history informed interpretative chronozone model of the spread of farming across western Eurasia (telescoped time slice layers, non geo referenced). YD – Young Dryas; PBO – pre-Boreal oscillation; EHE – early Holocene event; 6.2-E – 6.2 event; 5.1-E – 5.1 event; LIA – Little Ice Age; CE – cold events; GDO – germination/dying-off events (after Gronenborn, 2009: 98, Fig. 1). Detail is shown in the lower section.
insufficient archaeological research but the new research in Thessaly showed that this lack of settlements during the end of Neolithic/Eneolithic can be linked to abrupt and major move away from tell settlements in favour of a distinct shift towards small upland sites. In recent times, it is also consid- ered that populations shifted from Neolithic agrarian to Cop- per Age pastoralist economy. At the beginning of the Early Bronze Age, there was a switch back to agriculture (Wenin- ger et al., 2009).

Further analysis of material culture and $^{14}$C dates showed that, for example, the tell Dipsis (Ezero) in Thrace was abandoned between 6200 and 5200 calBP, which corre- sponds to the transition from Karanovo VI to Karanovo VII in cultural terms; the $^{14}$C dates show the existence of a major cultural hiatus. This hiatus, between the end of Neolithic and the beginning of the Bronze Age in most of the Greece, lasted about 800 years or longer. The gap is also present in Bulgar- ian $^{14}$C sequence between 6100 and 5200 calBP. Here, as in Greece, the switch from an agrarian (tell-based) economy to pastoralism (with small settlements in upland locations) appears as well as the tell abandonment, for example Yagodna in Western Bulgaria. Yagodna was finally abandoned in the second half of the 6th millennium calBP because the climate became even too extreme to support less sensitive pastoralist economy. Hiatus is also visible in the succession of cultures in this region because the early Bronze Age Ezero culture ap-

![Climate proxies combined with Neolithic Starčevo and Sopot cultures and Eneolithic Lasinja culture in northern Croatia (modified after Weninger, 2014).](image)
and 4200 calBC (6250/6200–5200 calBP) in Greece, Bulgaria and Romania tell settlements were abandoned and new smaller upland settlements appeared. The economy also changed from agriculture to pastoralism. The gaps ( hiatus) of about 800 to 1000 years appear at that time between old Eneolithic and new early Bronze Age cultures which in general have no connection to their antecedents. Tell abandonment is noted in the eastern part of Pannonian plain after 4450 calBC as well (Hertelendi et al., 1998).

This is the period which corresponds to the end of Starčevo and the beginning of Sopot culture according to radiocarbon dates. Around 5200 calBC climate proxies show the lowest temperature in 7.1 ka calBP event. This can represent the lower date for the end of Starčevo culture but there is not enough radiocarbon data to confirm that. The beginning of Sopot culture should be placed around 5300 calBC (or just after); the greater change in global climate proxies can be observed at that time. After 5300 calBC in southern Balkan and Black Sea region tells were abruptly abandoned and the significant change in social and economic structure of the population appear. In these regions the next new change can be dated only after 4200 calBC.

The last observed 6.0 ka calBP event (4400–3200 calBC) shows very long unstable period in which the most unfavourable are 4600 and 4200 calBC. Sopot culture shows its most intensive existence between 5050 and 4300 calBC, period of dramatic change in eastern regions of Europe. Finally, the change in Sopot culture came late: between 4300 and 4200 calBC the decrease of radiocarbon dates can be observed and after 4200 calBC, while in the wider region Eneolithic is present for a few hundred years, Sopot culture slowly adapts to this new situation before it gives way to Lasinja and other Eneolithic cultures in Slavonia region (southern outskirts of Carpathian basin). Finally, the 4.2 ka calBP marks the full beginning of the Bronze Age in Slavonia region.

**CLIMATE PROXIES AS A FRAME FOR ABSOLUTE DATING**

The overview of global climate changes during the beginning of Holocene gave us an insight of how certain periods of significant oscillation in temperature, precipitation and circulation of cold air masses can be linked to partial social change in specific regions. It is clear that the beginning of the Neolithisation of northern Balkan and part of Carpathian basin can’t be expected before 6200–6000 calBC (Budja, 2007) because the antecedent period was extreme on global scale and the climate conditions in Europe were very unfavourable (dry and cold in the north and south zones, extremely moist in the central zone). Large quantities of precipitation made certain parts of Europe impossible to cross (Budja, 2007; Bánffy and Szőmeci, 2012), while in the eastern Mediterranean the severe draft is observed (Budja, 2007; Weninger et al., 2009). Northern Africa was changed by the abrupt arrival of monsoons at that time and desert was replaced by savannah-like environments and quickly inhabited (Kuper and Kröpelin, 2006).

Radiocarbon dates for the beginning of Starčevo culture fit well here: the earliest dates from the sites Sopot and Galovo appear slightly after the end of 8.2 ka calBP event (around 6000 calBC). As the 8.2 calBP event lasted about 160 years (Thomas et al., 2007; Weninger et al., 2009), the beginning of the earliest phase of this culture can be placed at this time. Somewhat earlier date can be expected for the beginning of this culture, but certainly not earlier than 6200 calBC.

Climate proxies show somewhat stronger change during the 7.1 ka calBP event, i.e. between 5700 and 5100 calBC. This change is manifested by decrease of temperature and precipitation in Europe, while less dry conditions in the Middle East prevail. Retracting monsoons caused new desiccation of Sahara at 5300 calBC. During the period between 5300 and 4200 calBC (6250/6200–5200 calBP) in Greece, Bulgaria and Romania tell settlements were abandoned and new smaller upland settlements appeared. The economy also changed from agriculture to pastoralism. The gaps ( hiatus) of about 800 to 1000 years appear at that time between old Eneolithic and new early Bronze Age cultures which in general have no connection to their antecedents. Tell abandonment is noted in the eastern part of Pannonian plain after 4450 calBC as well (Hertelendi et al., 1998).

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**CONCLUSION**

Climate change, although not the principal and only cause, had an impact on the social change during the Neolithic and beginning of Eneolithic in southeast and central Europe. Three cold intervals had an impact on the formation, development and final transformation of Neolithic populations in these regions. Comparison of radiocarbon dates with these cold intervals (8.2 ka, 7.1 ka and 6.0 ka cal BP) facilitates, to a certain point, better understanding of specific phases of Neolithic Starčevo and Sopot cultures in northern Croatian territory (southern outskirts of Carpathian basin). The beginning of Starčevo culture can be linked to the end of 8.2 ka cal BP interval while its final phase can be linked to the end of 7.1 ka cal BP interval. The beginning of Sopot culture can be placed somewhat earlier but still during the 7.1 ka cal BP interval. Duration of Sopot culture coincided with the period of tell abandonment in southeast Europe and the Black Sea region and towards its end the decrease of available radiocarbon dates is noted, possibly signifying decrease of life in the region but it is not clear to what extent the life of the known settlements was abandoned. The eponym Sopot site was abandoned around 4200 BC or somewhat later and life there was never renewed.
It is clear that the beginning of the late Neolithic Sopot culture in southern outskirts of Carpathian basin, i.e. north Croatian territory or Slavonia region, coincides with the major changes in Greece, Romania and Bulgaria where the abrupt abandonment of settlements and great cultural changes happened. It is also clear that the end of Neolithic life in Slavonia region coincides with renewal of life on Balkans and in the Black Sea region. That also marks the beginning of Eneolithic way of life which ends in the second half of the 3rd millennium BC, giving way to the beginning of the Bronze Age just around the time of 4.2 ka calBP event.

There is a possibility that southern outskirts of Carpathian basin, having specific geographic and geological conditions, was able to sustain Neolithic way of life somewhat longer than the surrounding region without any hiatus detected but more interdisciplinary data is needed to confirm this theory.

Lastly, no serious analysis of archaeological remains in the light of climate changes can be done without extensive interdisciplinary research. We consider this paper to be the first step towards this new research.

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