

Beginnings of the Neolithic in Southeast Europe: the Early Neolithic sequence and absolute dates from Džuljunica-Smārdeš (Bulgaria)

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ABSTRACT – *Investigations of a balk in the centre of the prehistoric settlement of Džuljunica-Smārdeš comprised a sequence of archaeological deposits from the very onset of Neolithisation in South-eastern Europe throughout the end of the Early Neolithic. The arrival of Neolithic lifeways in the region coincides with the end of a period for which palaeoclimate proxies attest to considerable climate fluctuation. In connection with these investigations, the zoological finds were examined, which provide insight into the economy of this key settlement for the entire Balkan region.*

IZVLEČEK – *Raziskave ozkega pasu sedimenta med dvema izkopnima jarkoma v središču prazgodovinske naselbine Džuljunica-Smārdeš predstavljajo zaporedje arheoloških depozitov od samega začetka neolitizacije v Jugovzhodni Evropi do konca zgodnjega neolitika. Prihod neolitskega načina življenja v regiji sovпада s koncem obdobja, za katerega paleoklimatski kazalci pričajo o znatnih klimatskih nihanjih. V povezavi s temi raziskavami smo preučili zoološke najdbe, ki omogočajo vpogled v gospodarstvo te za celoten Balkan ključne naselbine.*

KEY WORDS – *Neolithisation; Bulgaria; painted pottery; ‘Rapid Climate Change’*

Introduction

The dispersal of the Neolithic from the Near East to Europe is a long-standing focus of scientific research. In this context, Southeast Europe is of particular relevance to these investigations due to its status as a transit connecting Anatolia with Central Europe. Accordingly, this land mass is situated between the source area of Neolithisation and the European heartlands. The vast river valleys that transect this mountainous terrain provided natural thoroughfares along which agriculture, animal husbandry and ceramic-producing technologies disseminated. Significantly, new discoveries made since the 1980s have demonstrated that the onset of Neolithisation actu-

ally predates the better known tell occupations otherwise considered characteristic of the Neolithic in this region. In this context, the earliest settlements in Greece are now dated to the second half of the 7th millennium calBC, and although the Neolithic reached areas north of the Aegean only slightly later, it soon became evident that these occupations predated the formation of tell settlements in this region as well. Meanwhile, several sites recorded in North Bulgaria and Thrace are also known to predate the lowest occupation level at the prominent Neolithic site of Karanovo, most notably at Koprivec, Poljanica-Platoto (Todorova 2003), Pomoštica (Elen-

ski 2008b), Orlovec (Stanev 2008) and Tabaška Cave (Survey Elenski, unpublished) (Fig. 1). However, intensive studies have shown that these assemblages should not be considered ‘monochrome’, in the Anatolian sense of the term (Stefanova 1996; Krauß 2006.161–162; 2008.119–121). For example, several of the earliest (Pre-Karanovo I) Neolithic sites known in the Balkans produced both monochrome and painted pottery. This fact alone refutes the hypothesis that there existed a ‘Monochrome Neolithic’ as an earliest phase of the Balkan Early Neolithic sequence (Lichardus-Itten et al. 2002).

Discussions of the character of the earliest Neolithic pottery in Southeast Europe have so far lacked any reliable absolute-chronological basis. In fact, the absence of a ‘Monochrome Neolithic’ is still indicated only by typological comparisons of material from the few relevant sites from which a small number or uncertain ^{14}C -ages have been published (cf. Görsdorf, Bojadžiev 1996). Similarly to the Southwest Anatolian Lakes District, e.g., at Hacilar (Mellaart 1970), ‘Monochrome’ pottery is the predominant ceramic ware in the developed Southeast European Early Neolithic, while painted pottery occurs in only small amounts (Krauß 2011). The Early Neolithic settlement of Džuljunica-Smārdeš is currently proving a key site for determining the characteristics of the earliest Neolithic on the Balkans. Meanwhile, numerous survey trenches excavated in the substantial settlement area have produced an extensive array of finds, and there are now good reasons to assume that the occupation of this site commenced at the very onset of Neolithisation in the East Balkans. In

addition, this site remained occupied throughout the entire Early Neolithic sequence, thus providing us with a unique insight into cultural-historical developments at the dawn of agriculture and animal husbandry in this region.

Geographical location and settlement topography

The catchment of the Yantra, one of the largest tributaries of the lower Danube, drains the central Balkan massif to the north. Geographically, the point where the Yantra enters the Danube corresponds almost exactly with the southernmost extremity in the course of the Danube between its sources in the southern Black Forest to its mouth at the Black Sea. The excellent geographical location of the Yantra is self-evident and has proved particularly important for the region throughout its history. The country between the main ridge of the Balkan Mountains and the Danube can be divided into three larger regions that include a still densely wooded mountainous area in the south, the northerly adjacent mountain foothills, and the Danube lowlands, with their characteristic undulating loess deposits. This is reflected in the highly contoured shoreline on the Bulgarian side of the Danube compared to the very level banks on the northern (Romanian) side.

The Early Neolithic settlement of Džuljunica is situated 3km north of the eponymous village, approx. 500m west of the local railway station, in a field known as Smārdeš (Fig. 2). The location was probably chosen due to the occurrence of natural springs

which flow from the base of a natural prominence upon which the site is located. Even today, four springs at the foot of the site are active. The prominence itself is a slightly elevated river terrace above the Džuljunica River, which, together with other tributaries, flows into the Yantra some 6.5km north of the settlement. The geographical situation of the site in the prehistoric period has not yet been determined, including its relation to the Yantra and its tributaries, which today flow just 2km from the settlement. The previously meandering water courses of these rivers have

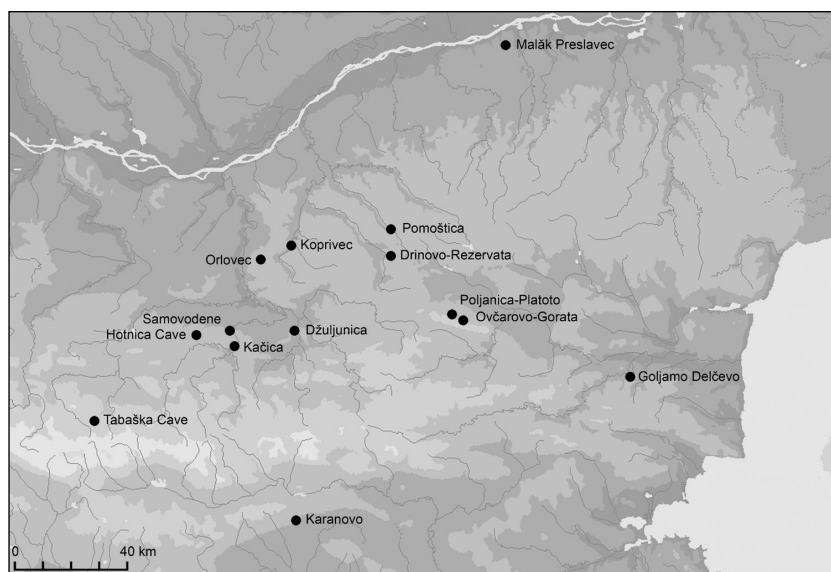


Fig. 1. Location of the Early Neolithic sites in NE-Bulgaria mentioned in the text.

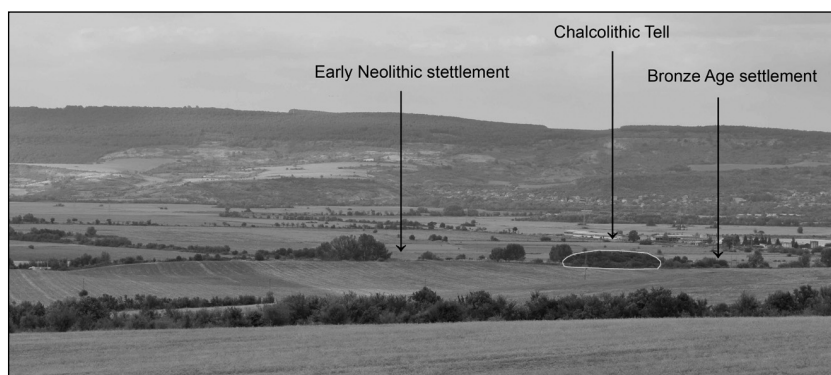


Fig. 2. Džuljunica-Smārdeš from the hilltop south of the site with approximate location of Neolithic (red), Chalcolithic (blue) and Bronze Age (green) sites.

since been artificially regulated and corrected. However, old water courses, some of which reach up to one kilometre from the site, have been identified in satellite images and antique maps. The water discharged from the modern springs flows in a westerly direction, directly towards the Yantra. Pronounced erosion channels in the northeast and southwest have significantly altered the shape of the prominence, with slope gradients of 16° in the northeast and 22° in the southwest. The site lies at between 70 and 77m above sea level. The highest elevations are at the west of the terrace, decreasing slightly to the southeast. To the north, the site gives way to the old floodplain, conferring a plateau-like appearance upon the settlement area.

On the basis of results from surface surveys, it is estimated that Neolithic occupations extended over

is a small spur on which a Copper Age settlement mound developed. Sporadic finds found on the tell and attributed to the Early and Middle Bronze Age suggest that the accumulation of deposits did not come to a complete end at the close of the Copper Age, but continued into these later phases. A substantial concentration of Bronze Age finds has been detected in an area southeast of the mound, where the centre of the Bronze Age settlement is expected.

History of research

The first mention of a settlement mound at Džuljunica dates to the late 19th century. In a report by the Škorpil brothers (*Škorpil, Škorpil 1898.99*), Czech antiquarians, reference was made to the clearly visible Copper Age tell, which was later included in the register of archaeological sites compiled by Vasil Mikov (*1933.58*). The first archaeological investigations were undertaken in 1983–84, when salvage excavations became necessary in the course of road construction. The focus of this small-scale examination was a section through the Copper Age tell in the northeast caused by these intrusions and now braced by a concrete wall. The succession of deposits revealed in this section span the entire duration of the Bulgarian Copper Age (5th millennium cal-BC) with sporadic finds from the Early Bronze Age on the surface of the mound (*Stanev 1984.28–29; 1985.35*). A later analysis of the excavated ma-

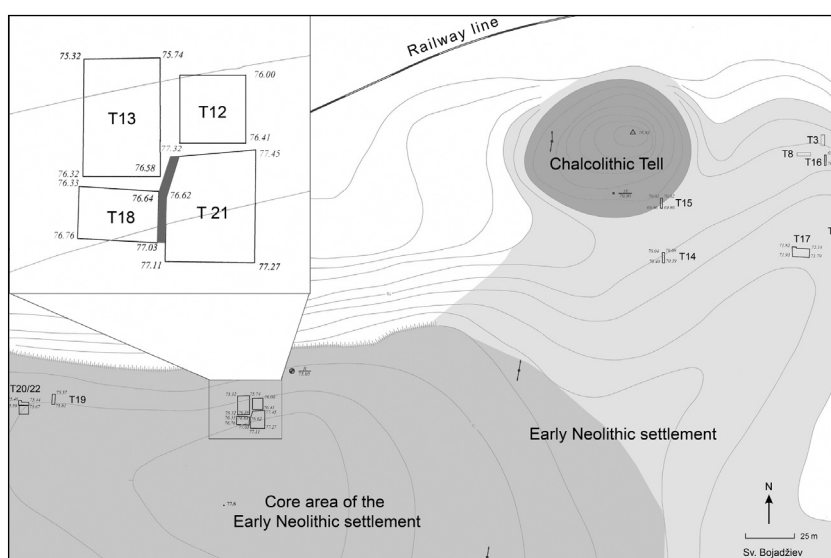


Fig. 3. Džuljunica-Smārdeš. Extension of the Early Neolithic site and Chalcolithic tell (grey shading) with location of trenches excavated since 2001 by N. Elenski (T). Trenches 12, 13, 18 and 21, and the location of the balk investigated in 2010 (red) are shown in detail.

terials showed that among finds from the Copper Age recovered from a depth of 4.10 to 6.10m below the modern surface there was also material attributed to the Early Neolithic which was interpreted by the excavator as indicating an Early Neolithic settlement lying beneath the tell (*Stanev 1995.93*).

Several test trenches to the southwest, south, and east of the Copper Age tell that were excavated between 2001 and 2005 by Nedko Elenski, and renewed work commencing in 2008 (*Elenski 2006; 2008a*), have been dedicated primarily to the investigation of the Early Neolithic settlement (Fig. 3). The general development of this earliest occupation can now be presented. The oldest two phases at Džuljunica (Dž-I and Dž-II) extend from the northern edge of the terrace, covering its entire width from the southwest to the northeast; in fact, the various test trenches confirm the presence of these oldest two levels over the entire terrace. The third occupation level (Dž-III) was detected only in the centre and on the eastern side of the terrace, where it takes the form of a thin sediment accumulation almost entirely lacking in architectural features and with only few fragmented finds. By the end of the Early Neolithic, the settled area had decreased in size and was restricted to a small area in the centre of the terrace (Dž-IV), leading to what might be described as initial tell-development.

The earliest investigations in 2005 revealed a high concentration of earliest Neolithic pottery along the eastern edge of the terrace, while finds from the end of this period were found concentrated on its western side. So far, a total of 22 test trenches have been excavated. Initially, the positioning of trenches was

oriented to finds of Early Neolithic pottery discovered below the Copper Age tell. For this reason, the first test trenches (1–8 and 16–17) were excavated in the east of the settlement. Only in the course of excavations was a further series of connected trenches (10–13) opened up in the west. Remarkably, these excavations revealed accumulations from the entire Early Neolithic sequence of the Eastern Balkans. As no continuous cultural deposits from later occupation phases were encountered in this area, the focus of attention could be placed firmly on the Early Neolithic. Post-Neolithic disturbances in this area were seldom, and barely affected the structure of the earlier settlement levels. Two additional trenches (14 and 15) opened to the south of the Copper Age tell revealed no further Early Neolithic accumulations.

The end of Early Neolithic settlement was also documented in excavations on the eastern side of the terrace. This evidence took the form of disturbed and redeposited material that was later cut by an Early Bronze Age ditch; no coherent features and structures were discovered (*Elenski 2002.27–28; 2003.17–18*). Test trenches 4 and 17 represent approx. the southern limit of the Early Neolithic settlement layer in the east. Significant settlement accumulations in this area are assigned to the Copper Age and Early Bronze Age. In contrast, the underlying 20cm thick Early Neolithic layer produced only sporadic fragments of pottery (*Elenski 2002.27–28; Elenski, Leštakov 2006.36–39*).

The only trench on the east of the terrace to reveal any significant deposits from the Early Neolithic was test trench 8, which was excavated 60m east of the

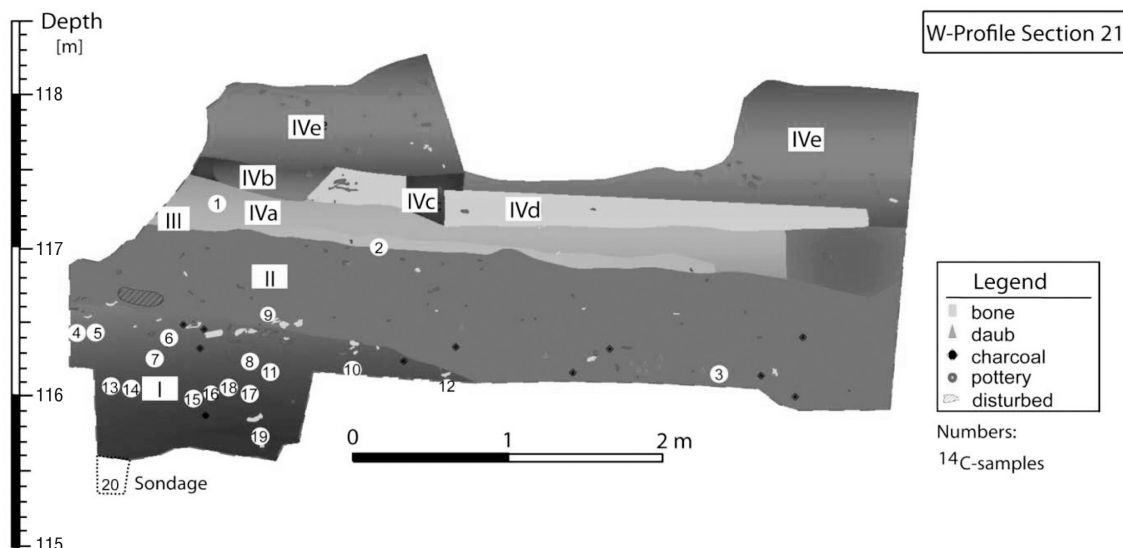


Fig. 4. Džuljunica-Smārdeš, Section 21, West-Profile, with stratigraphic position of ^{14}C -samples (cf. Tab. 1).

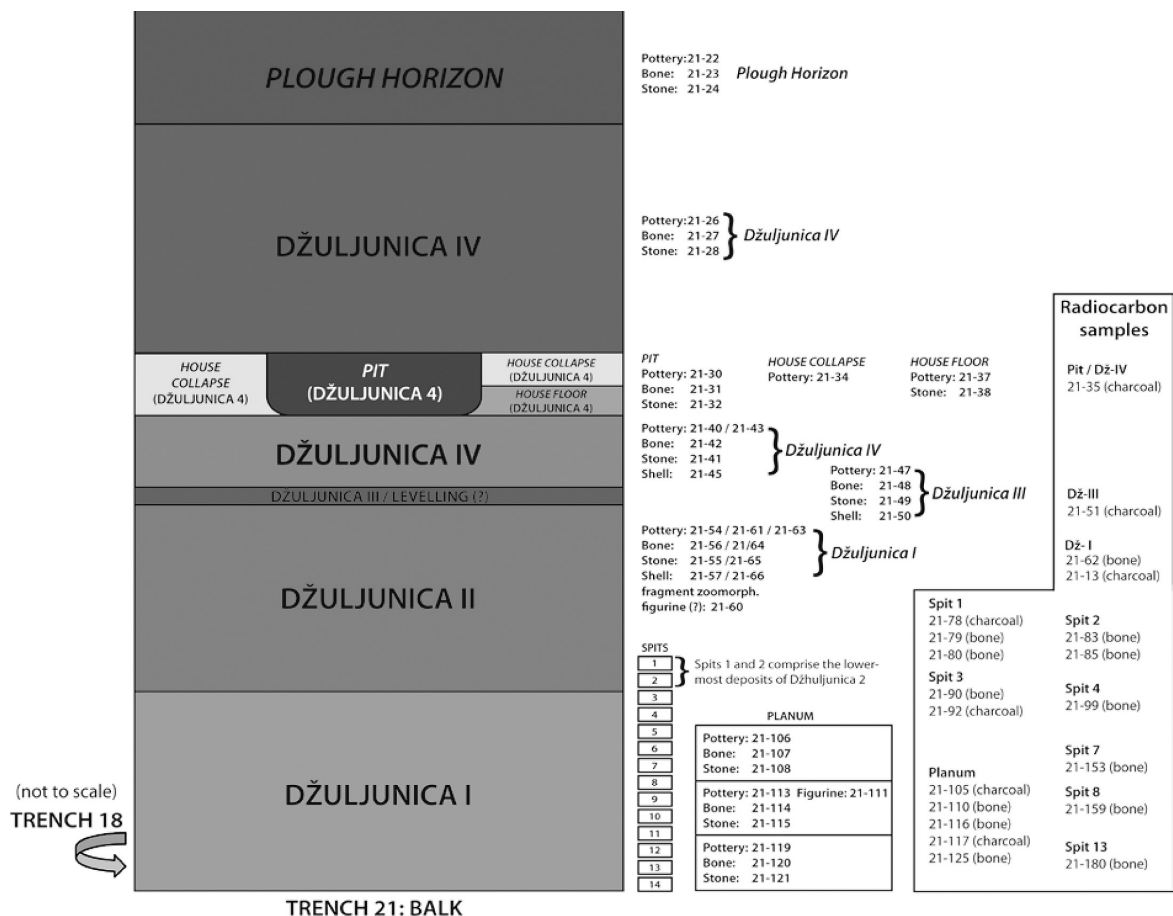


Fig. 5. Schematic representation of stratigraphic units and associated finds and radiocarbon samples excavated at Džuljunica-Smārdeš, 20th–28th September 2010.

tell. These remains were covered by a 1.3 to 2.0m thick layer of Early and Late Copper Age strata. Early Neolithic accumulations were shown to comprise three superimposed layers with a total thickness of 1.0 to 2.2m. Insights into changes in the size of the settlement are therefore based primarily on observations made in trenches 12, 13, 18 and 21, which were opened in close proximity to one another on the central part of the terrace

Description of settlement layers

The oldest layer (Dž-I) lies directly on loess and is on average 0.2 to 0.3m thick, although in some pits it reaches depths of up to 1.0m. In the central part of the terrace (in test trenches 12, 13, 18 and 21), a house sunk into the native loess was excavated. In all probability, structures from this early period were without exception pit houses, between which further features were discovered that were probably not directly associated with the houses. Signs of further structures which might belong to the houses from this layer were located in trenches 8 and 22. It is possible that we are dealing here with a line of

houses which follows the course of the northern edge of the terrace. The extension of the excavation should clarify the layout of the settlement in its earliest phase, providing far better insights than are presently possible based on observations from the very central part of the settlement, which allows for only very general conclusions.

The second settlement layer (Dž-II) is 0.45 to 0.90m thick in the central trenches 12, 13, 18 and 21. Clearly defined buildings or prehistoric surfaces have so far not been discovered for this phase, although three extensive concentrations comprising the remnants of clay ovens and three large ashy deposits with numerous finds, primarily painted pottery fragments, were recorded. In the course of extensive horizontal excavation, it was observed that some pits from this second layer cut into deposits of the underlying first settlement layer. In trench 22, in the far west of the settlement, a pit from the second settlement layer was recorded which contained human and faunal skeletal remains. In comparison to the earliest settlement level (Dž-I) this second layer is characterised by considerably thicker deposits and

especially by the occurrence of a greater number of finds. Once again, in spite of the limited extent of observations that can be made in this layer due to the use of test trenches, clear characteristics of this settlement phase can be discerned. However, any interpretation is rendered especially difficult owing to the nature of the excavated structures, *i.e.* houses which were not destroyed by fire and therefore are poorly preserved. Therefore, a more extensive horizontal excavation is essential if we are to better understand the delimitations of these structures.

The third level (Dž-III) has been documented only sporadically over the entire area, being at most just 0.10m thick. In comparison to all the other layers, this particular layer is not only significantly thinner but also of a much firmer texture, and not ubiquitously present even in the centre of the settlement. While this third layer can be observed throughout trenches 13 and 18, in trenches 12 and 21 it is only visible in two thirds of the excavated area. This layer contains a large number of stone artefacts and highly fragmented pottery and bone finds. It is extremely likely that we are dealing here with a levelling layer. There are absolutely no signs of house floors in this level and no remains of loam daub. This suggests that it may have been a structure-free area within the settlement and with any associated structures so far poorly known due to the small extent of excavation work. Nevertheless, the platform of an oven has been attributed to this settlement phase.

The fourth settlement level (Dž-IV), which has so far only been detected in the central part of the settlement, is 0.90m thick and is divided into three different sub-phases:

- The lowermost sub-phase of the uppermost Early Neolithic settlement (Dž-IVa) is a 0.40m thick deposit of loose, dark grey sediment. In the southern central part of the settlement (trench 13) a row of six postholes was observed. Additionally, three subterranean structures were recorded in trench 21; these were originally accessed via platforms, beams or

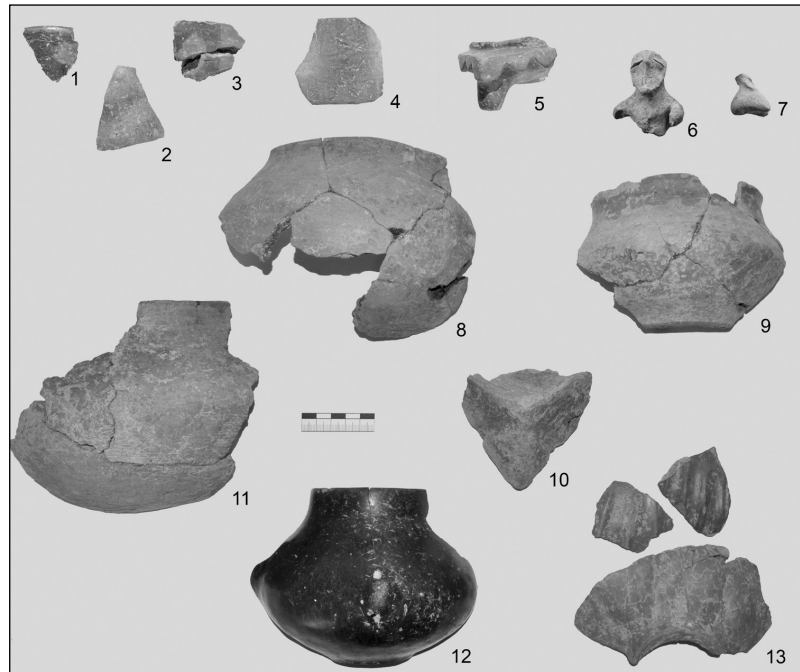


Fig. 6. Džuljunica I. 1-3 dark painted pottery; 8-9, 11-13 pottery from excavations by N. Elenski; 10 corner of a four-legged vessel; 6-7 Early Neolithic figurines from the planum adjacent to the section documented in 2010 (cf. Figs. 23-24).

steps. It is probable that these structures served as workshops, for flint knapping, for example.

- In the second sub-phase (Dž-IVb) a ground-level house structure, and two thirds of a second such structure (both untouched by fire) were investigated. These buildings were built directly adjacent to one another, *i.e.* sharing a common wall. The first structure displays a rectangular plan; floors comprised a 0.10m thick layer of trodden earth. The wall foundations rested on a single or double row of stones; there were no signs of postholes; the house walls were constructed using loam. An oval-plan oven was excavated in the north-western corner of the room. The second building also featured a rectangular plan, with a 0.05m thick trodden earth floor. Stone foundations in this structure were lacking, except beneath the common wall separating it from the adjacent building. In the north-eastern corner of the house, a massive rectangular-plan oven was discovered. The remains of this structure suggest that it measured approx. 2.20 x 2.00m, with a 0.30m thick wall.

- In the third (uppermost) sub-phase of the fourth settlement level (Dž-IVc) a small part of an unburned structure was investigated. This house partially superimposed one of the buildings from the underlying sub-phase. The higher-lying northern part of

this house had already been damaged by modern ploughing, as had a part of a hearth construction, fragments of which were collected from the surface of the field in the immediate vicinity. The plan of the house appears to have been rectangular, and its trodden earth floor was some 0.10–0.05m thick. An oval oven-platform was located in the western part of the house.

In the eastern part of the settlement, younger occupation levels assigned to the Early and Late Chalcolithic are observed overlying the Early Neolithic deposits. Two Late Copper Age burials were discovered in this area (Elenski 2002.27–28; 2003.17–18; 2006). Additionally, in the east the remains of a Bronze Age ring ditch were excavated. This ditch enclosed an area with concentrations of pits and circular loam platforms (Elenski 2002.27–28; 2003.17–18; 2006). In the slightly raised central part of the settlement, where all four Early Neolithic levels were documented, several pits from the Early and Late Iron Age and Late Antiquity were uncovered (Elenski 2006; 2009; 2010; 2011). Finally, this part of the site also yielded remains of a domestic structure from the Early Middle Ages (9th–10th century AD) with accompanying pits (Elenski 2005; 2006; 2010; 2011).

Location of the balk and methodology of the 2010 investigations

In summer 2010, supplementary investigations were undertaken in the course of continuing work at Džuljunica-Smārdeš by a joint team from the University of Cologne (Collaborative Research Centre 806 – Our way to Europe, Project F1), financed by the German Research Foundation (DFG), and the University of Tübingen. The focus of these activities was the excavation and documentation of a stratigraphically significant section in an unexcavated balk separating test trenches 18 and 21 (Fig. 4). The stratigraphic excavation of this balk promised to provide important information relating to the occupation sequence for the Early Neolithic; all documented Early Neolithic phases at the site were attested in this section, and no significant disturbances from younger occupation phases were expected. The Early Neolithic occupation deposits in this area had been disturbed only by the aforementioned shallow pits from the Iron Age and by a house feature from the Early Middle Ages in trench 21.

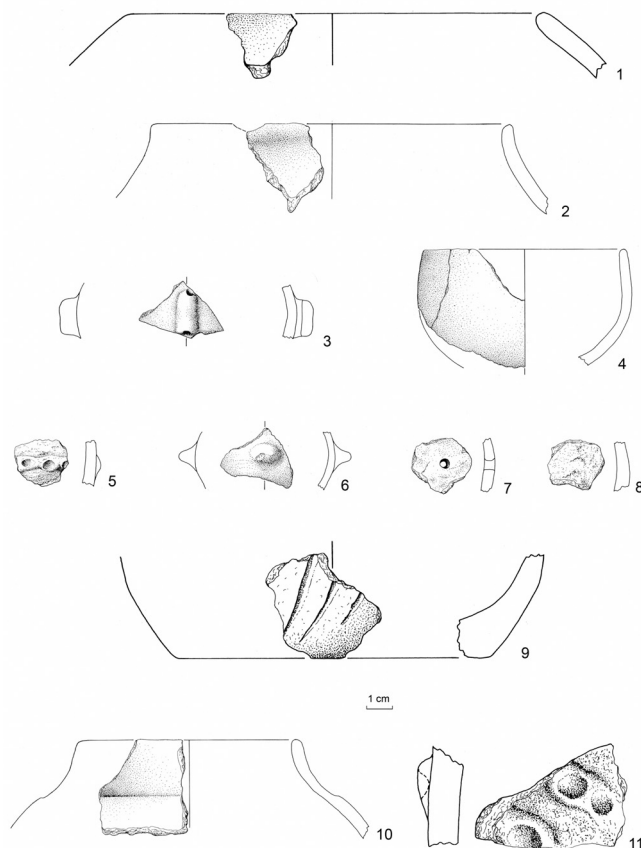


Fig. 7. Džuljunica I. Ceramic finds from the balk: 1–9 spit 3 (n. 21–88); 10–11 spit 4 (n. 21–94).

The balk was excavated according to stratigraphic layers and all sediment was sieved. On the reverse side of the balk, *i.e.* in trench 18, a narrow trench was excavated to assess the maximum depth of earliest Neolithic (Dž-I) deposits. These revealed that they extended some 30–40cm below the current planum of trench 21. Subsequently, these deposits were the focus of particularly meticulous documentation. Accumulations assigned to this initial phase were excavated in artificial spits of 10–15cm. In trench 21, the planum directly adjacent to the section was also extended downwards, *i.e.* parallel to the excavation of the balk. All finds were documented and samples for radiocarbon dating (bone and charcoal) extracted from all stratigraphic relevant units.

All steps of our excavation were documented numerically, and each is referred to by a two-part number separated by a hyphen. While the first (*prefix*) number refers to the location of the balk in *trench 21*, the second number identifies the particular step (or *position*). For example, 21–10 is the tenth recorded step of our excavation of the balk. In this way, finds and samples were assigned a unique *position-number* at the exact moment of their recovery. In this paper, we again refer to these numbers in illustra-

tion captions and in the radiocarbon table. Figure 5 provides an overview of the allocated *position-numbers* of finds and radiocarbon samples, and their stratigraphic provenance.

Finds from individual settlement layers and their cultural-historical position in the Balkan Neolithic

Finds from the oldest settlement layer at Džuljunica (Dž-I) (Figs. 6–9) show clear similarities with material of the West Anatolian Late Neolithic. As such, pottery from this level is coeval with the very beginning of its usage in the Southeast European cultural sequence. Bulbous vessel forms with flattened bases or slightly pronounced foot are particularly characteristic. The vessel form repertoire also includes spherical pots with a narrowing or slightly conical inclining neck, bowls with an S-shaped profile, and open bowls with straight walls.

The elaborate surface treatment of vessels while in their unfired and leather-hard state is quite remarkable and has resulted in a consolidated and shiny, in some cases enamel-like, appearance. This is all the more exceptional considering the coarse matrix of the pottery, with its numerous coarse organic inclusions. The only exceptions are the smaller, thin-walled vessels; no organic inclusions are visible with the naked eye in the fractures of these pots. These vessels appear in no way inferior to modern porcelain in their strength, hardness and gloss. Handles are limited to vertical cord lugs at the widest part of the vessel. Even among the oldest pottery, impressed decoration and plastic applications are attested, *e.g.*, *warts* or wide, well-smoothed incisions. In their fractures, coarse wares are mostly deep black, and the fine ceramics varying from grey to brown. Surface colours range from dark hues of ochre to brown, orange and red. Some fragments feature smoke marks and are discoloured dark brown to black. A few sherds also carry a simple painted decoration in a dark colour (Figs. 6.1–4; 8.1). This painted decoration takes the form of plain wavy and wide comb motifs which extend over large areas of the vessel surface. However, painted pottery constitutes less than 1% of the excavated material.

The pottery from Dž-I is comparable with assemblages from the near vicinity, includ-

ing the oldest material from Koprivec (Krauß 2006. *Taf.* 1.3.5) and Pomoštica (Elenski 2008b. *Abb.* 1–9), as well as with vessels from Orlovec (Stanev 2008. *Abb.* 98–101) and Poljanica-Platoto (Todorova 2003. *Abb.* 1). Similar vessel forms were recovered from Hotnica-Pešterata (Ilčeva 2002. *Taf.* 1–4), but this material most probably already represents a transition from Dž-I to Dž-II. Convincing parallels are attested in assemblages from West Anatolia, especially from the Izmir region, specifically Ulucak Va and early IV (Çilingiroğlu et al. 2004; Çilingiroğlu 2009. *Abb.* 4.1, 4.2; 2011. *Abb.* 3, 5), Çukuriçi Höyük (Galik, Horejs 2011. *Abb.* 5) and Yeşilova (Derin 2011. *Abb.* 5–7). In the geographically nearer Marmara region, Dž-1 material can be parallelised with Classical Fikirtepe, although vessel forms from Ilıpınar IX–VIII (Thissen 2001. *Abb.* 21–29) or the eponymous site at Fikirtepe (Özdoğan 1999. *Abb.* 33) only allow the identification of more general consistencies with our typological spectrum.

Generally speaking, vessel forms from the second settlement phase Dž-II (Figs. 10–15) do not differ substantially from those of the first phase. However,

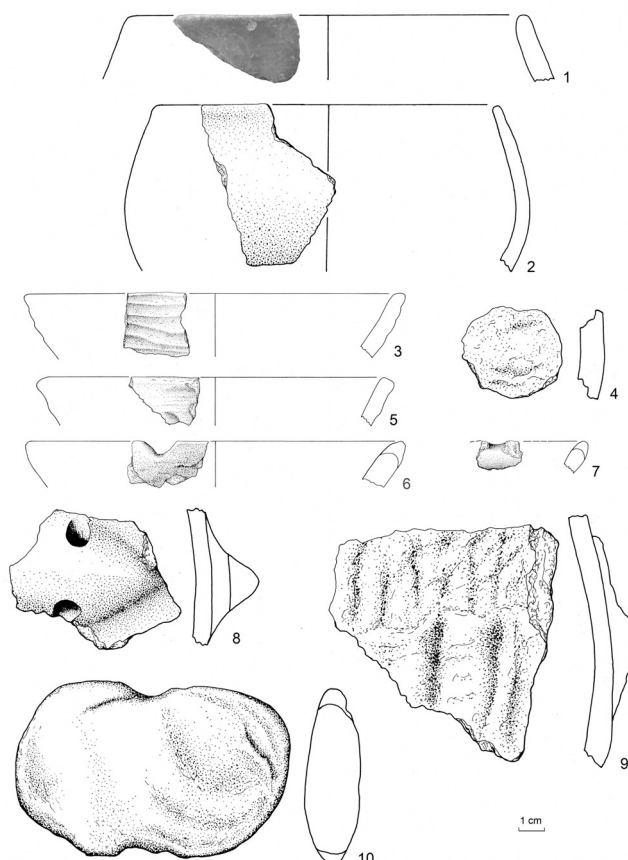


Fig. 8. Džuljunica I. Ceramic and stone finds from the platum (trench 21) adjacent to the balk: 1–4, 8–9 n. 21–88; 5, 7 n. 21–113; 6 n. 21–120; 10 grooved mallet? – n. 21–109; 1 fragment of a dark-on-light painted vessel.

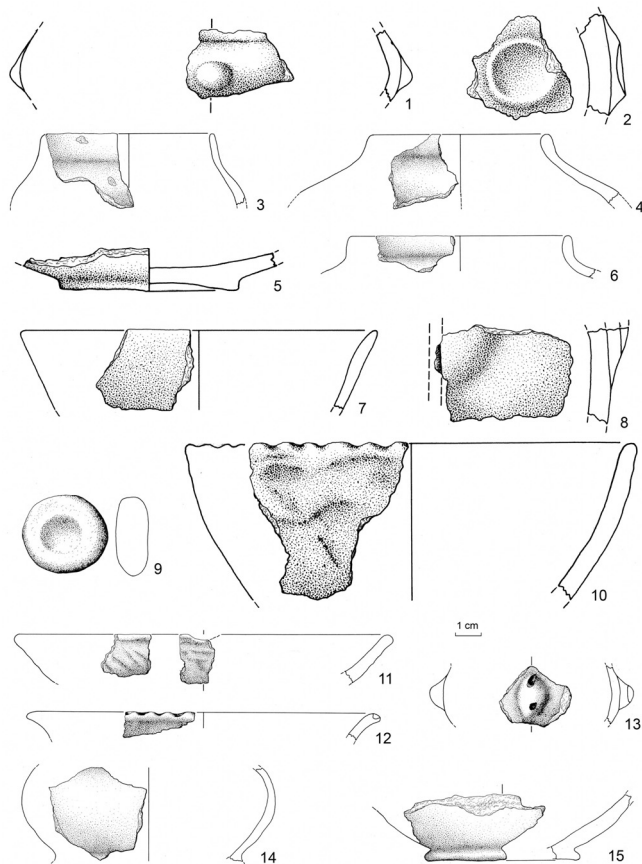


Fig. 9. Džuljunica I. Ceramic and stone finds from the balk: 1-5 spit 5 (n. 21-141); 6 spit 6 (n. 21-145); 7-8, 10 spit 8 (n. 21-155); 11-12 spit 10 (n. 21-167); 9, 13-15 spit 11 (n. 21-171); 9 stone support for a mortar.

as finds from this phase are more numerous, a few of the forms appear in slightly greater variation; nevertheless, there are no new vessel forms associated with this settlement phase. Most vessels feature a surface treatment which is of an equally high standard as noted for the previous settlement layer. A new development is the occurrence of white painted decorations on a red slip (Figs. 12.1-10; 14.3,7; 15.8); the dark painted decoration from Dž-I continues to be documented (Figs. 10.4; 11; 14.1). In addition, two fragments feature a creamy or ivory painted decoration (Fig. 12.14-15) and three sherds were painted entirely white (Fig. 12.11-13). White-painted motifs include dabbed spots arranged into triangle shapes, latticed and stepped bands, parallel W-motifs arranged one above the other, and patterns reminiscent of textiles. The ratio of painted pottery in this layer reaches just 1-2% of the entire assemblage. One tenth of painted sherds are of the dark-painted variety. Significantly, in the upper part of Dž-II deposits, dark-painted wares vanish and only white-painted decoration occurs. The white-on-red decoration connects Dž-II with the Karanovo I horizon in Thrace. Finds of pottery with white-painted

decoration in combination with dark-painted vessels have recently been reported from Turkish Thrace, from the site Aşağı Pınar 7 (M. Özdoğan 2011. *Abb.* 10-11). On the other hand, extensive decorations using beige paint are documented from the Izmir region; these may indicate parallels between Dž-II material and Ulucak IV h-1 (Çilingiroğlu 2009. *Abb.* 4.19, 4.21).

For the central part of the site, the third settlement layer Dž-III has already been described as a very thin deposit with relatively few finds. Due to the high state of fragmentation, pottery from this layer does not allow for a reliable reconstruction of vessel forms (Figs. 16-17). Especially notable, however, is the lack of highly burnished sherds with a dense surface. Only a few fragments carry a white-painted decoration on a red slip (Fig. 16), while dark-painted pottery is now absent for the first time. The stratigraphic position of this layer suggests that it may run parallel to developed Karanovo I, which would certainly not be contradicted by the material recovered from this deposit. Particularly crucial for this conclusion is the presence of white-painted, and the absence of dark-painted, decoration. A more precise chronological delimitation is not possible due to the small number of finds.

tion is not possible due to the small number of finds.

Pottery recovered from the fourth settlement layer Dž-IV includes vessel shapes characteristic for the developed Early Neolithic in the region (Figs. 18-20), especially as known from the settlement of Ovčarovo-Gorata (Krauß 2011. *Abb.* 6-7; 2014. *Taf.* 1-59). Vessels are characterised by bases with a solid foot or a pronounced foot rim. Common vessel shapes are tall beakers, also with lateral strap handles, and diverse bowl and pot forms. There also occur occasional cylindrical lids which belong to bulbous vessels with elongated cylindrical necks. Generally, pottery from this phase is coarser than in the earlier phases, albeit that the occurrence of fragments of fine ware still attests to efforts to produce highly burnished and lustrous surfaces. Vessel decoration is now dominated by plastic types of surface treatment. In contrast, painted decoration is no longer discerned. Particularly characteristic is an extensive canellated/fluted relief decoration found especially on beakers (Figs. 18.1-3; 19.3; 20.2, 6-7, 12-13), and various plastic applications, such as spirals, small

blossom patterns, as well as knobs or warts. The entire surface of coarse vessels is frequently covered, with the exception of the rim and foot zones, either with prick marks or with parallel or diamond-shaped incised motifs.

From a larger scale perspective, we are dealing here with a horizon that correlates with Karanovo II in Thrace, which on the European side of Turkey is attested at Aşağı Pınar, layer 6 (Parzinger 2005.Taf. 116–117; E. Özdoğan 2011.Abb. 10). Coeval with this phase, but typologically different, is material from known sites in Anatolia. On the basis of radiocarbon ages, it is assumed that Dž-IV is roughly contemporaneous with Ilipinar V and the uppermost Chalcolithic layer of Ulucak IV.

Turning now to the ceramic small finds, for the lowermost levels Dž-I and Dž-II so-called labrets, small idols in the shape of highly stylised cattle heads, are particularly characteristic (Fig. 21). Two fundamental types are differentiated: more compact specimens with a wide body rounded at the bottom (Fig. 21.1–7), and elongated rod-shaped pieces (Fig. 21.8–9). A broken idol carries a decoration comprising deeply incised lines (Fig. 21. 4).

A massive baton made of grey stone with a wide and perforated end might also be attributed to this group

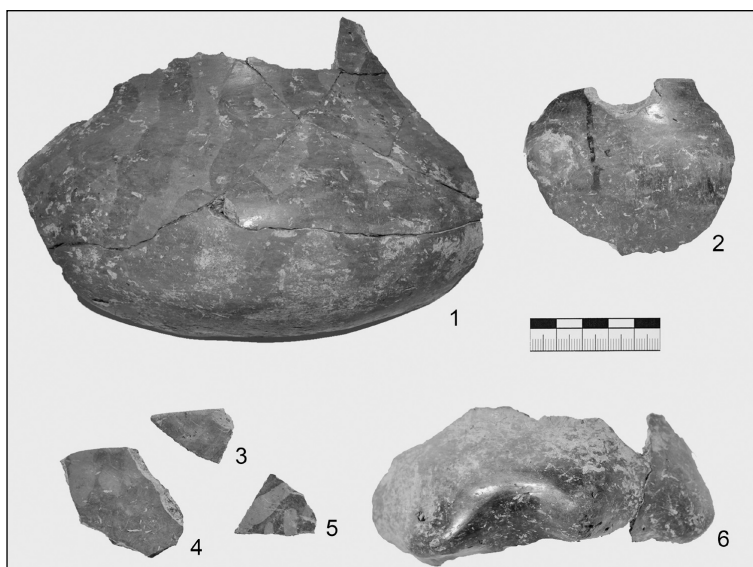


Fig. 11. Džuljunica II. Ceramic vessels with traces of dark painting from excavations by N. Elenski.



Fig. 10. Džuljunica II. Ceramic vessels and a four legged vessel (4) with zoomorphic head and traces of dark colour from excavations by N. Elenski.

of objects (Fig. 22.1). The pointed end of this piece in particular is strongly reminiscent of ceramic rod-shaped labret types. This sceptre-like artefact was discovered in test trench 12 in 2004 and is attributed to level Dž-II.

Fragments of a similar stone with a fine crystalline structure and a highly smoothed inner surface may be the remains of flat bowls or palettes. Only one specimen was recovered from trench 21 and can be attributed to level Dž-I (Fig. 22.3). Two further pieces, including one with a cantilevered edge, were discovered in trench 22 (Fig. 22.2, 4). While large numbers of these palettes are already known from Anatolia, the fragments from D–D are, as far as we are aware, the first ever discovered in Southeast Europe.

A special ceramic form identified at the site is the four-footed vessel (Figs. 6.5, 10; 10.4) which is attested only in the oldest settlement layers Dž-I and Dž-II. These vessels are either void of all decoration or they are trays with a relief-type adornment of their sides; normally this decoration takes the form of hanging triangles or protuberances pinched out of the vessel surface.

Among the most remarkable finds from Džuljunica are two anthropomorphic figurines discovered in 2010 during our excavation of the balk se-

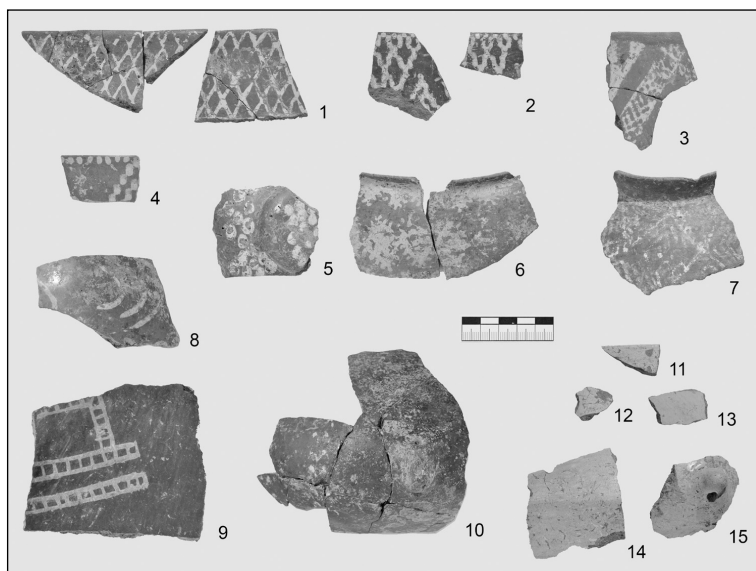


Fig. 12. Džuljunica II. Ceramic vessels with white and cream painting from excavations by N. Elenski: 1–10 white-on-red painted sherds; 11–13 sherds with white slipped surface; 14–15 sherds with crème slipped surface.

parating trenches 18 and 21. The first figurine, the gender of which cannot be determined, comprises a human torso and head, with what appears to be a masked face and coffee-bean eyes (Fig. 23; see also Fig. 6.6). The edge of the head is scuffed. The fore-arms and the lower part of the body are missing. A small breakage point on the front of the figurine suggests that the arms of the figure were originally folded across the belly. Exceptional from a typological perspective is the masked appearance of the face, a considerably younger feature that is more commonly associated with figurines of the Vinča culture. Typologically, the piece can be lined up alongside previously discovered Early Neolithic figurines from Southeast Europe, first and foremost due to the characteristic coffee-bean eyes. The assignment of this figurine from Džuljunica to the Early Neolithic is further substantiated by its securely documented embedding in lowermost Dž-1 settlement layer deposits, just 0.50m in front of the investigated section. Radiocarbon ages were determined on a charcoal (OxA-25044: 7095±40 ¹⁴C-BP) and on a bone sample (OxA-24979: 7145±38 ¹⁴C-BP) in the direct proximity of the find. Accordingly, the figurine was deposited at this location around 6000 calBC. The surface and breakage points are heavily rubbed, indicating that this piece was in circulation for an extended period.

A second smaller figurine was found at the same level, approximately 1.5m south of the first figurine (Fig. 24; see also Fig. 5.7). This second figurine is

of an extremely compact type. It is seated and features a greatly enlarged rump, and shortened legs. The arms, which are only suggested, also appear to be crossed across the breasts. Large parts of the head have been chipped away. In spite of its small size, this piece can be attributed to a known format: the representation of a seated, presumably female individual that is comparable, for example, with a figure vessel from Ulucak IV b2 (Cilingiroğlu et al. 2004, Fig. 25.32, 58). Parallels from Ulucak also show quite clearly how the position of the arms of the Džuljunica figure should be reconstructed. The figure is holding her hands below the breasts, presenting them in this way to the viewer. This gesture is a commonly encountered characteristic of Neolithic figurines in the Near East and

Anatolia, but only observed in very few examples from Southeast Europe (cf. Hansen 2007.350, Tab. 9). It is of further note that this gesture is typical, and observed primarily among the earliest Neolithic figurines which are already disappearing in the developed Early Neolithic period (cf. Hansen 2007.363, Abb. 202).

Džuljunica radiocarbon dates

The radiocarbon dates from Džuljunica are listed in Table 1. A total of 21 samples were processed by the ¹⁴C-AMS (Accelerator Mass Spectrometry) technique at Oxford Radiocarbon Laboratory (Lab Code: OxA). As indicated by the Sample Code (column 3), all ages relate to material recovered from Trench 21, either directly from the balk itself or from its immediate proximity (adjacent planum). Figure 4 shows the provenance of ¹⁴C-dated samples from the balk, projected onto the section (A–B) and adhering to the applied documentation system and site-phasing (Dž-I to IV; cf. Tab. 1). Although short-lived animal bones (N = 14) constituted the emphasis of our sampling strategy, seven (potentially) long-lived wood-charcoals were also dated in order to verify the ¹⁴C-radiometric chemical integrity of bone samples. The series of radiocarbon measurements from Džuljunica comprises a total of 12 ages for Dž-I, and 7 ages for Dž-II. The two youngest Phases Dž-III and Dž-IV are represented by one date each. In all cases, the stable isotope δ¹³C-values fall within the range of expected values (column 6).

Figure 25 provides an overview of the ^{14}C -data dispersal on the calendric time-scale for Džuljunica compared with ^{14}C -data from Ovčarovo-Gorata (Tab. 2). From the age distribution of samples from Dž-I and Dž-II we conclude that these phases are probably relatively short in duration, each in the range of a maximum of 100 calendric years. A charcoal sample (OxA-25047) from Dž-III has a ^{14}C -age that appears too old (cf. Fig. 25). Since this age resembles data from directly underlying phases Dž-I and Dž-II, we conclude that this sample was reworked from earlier deposits. The *youngest* sample OxA-25045 from phase Dž-IV has a ^{14}C -age (6686 ± 39 ^{14}C -BP) that is in good typological agreement with an extended series ($N = 13$) of highly consistent ^{14}C -ages of bone-samples from Ovčarovo-Gorata (Tab. 2). Notably, the majority of previously measured charcoal samples from Horizon III of Ovčarovo-Gorata have yielded ^{14}C -ages that are clearly too young, for which an explanation may be sought in the high ash content of these samples (Bln-2030; Bln-2031; Bln-2032; cf. Görtsdorf, Bojadžiev 1996). Although the duplicate measurements (Bln-1544: 6688 ± 60 ^{14}C -BP; Bln-1620: 6463 ± 50 ^{14}C -BP) on the charcoal sample from Ovčarovo-Gorata (Horizon I) are not statistically perfect ($p = 0.1\%$), their weighted average 6576 ± 35 ^{14}C -BP (calculated for explorative purposes) still lies well within the overall range of ^{14}C -ages obtained for bone samples (Tab. 1).

The *oldest* sample (OxA-24937) in the Džuljunica series has a ^{14}C -age of 7588 ± 37 ^{14}C -BP. Since this specific bone (assigned to Dž-I) was sampled at an intermediate depth of the section (depth 116.05m), we interpret this measurement as a *radiometric* outlier. In particular, since this measurement is significantly older than all the other ^{14}C -ages attested for Dž-I and II, we can rule out that this sample was *reworked* from older deposits. Such deposits are not identified at the site. For this reason, we exclude OxA-24937 from our stratigraphic age-model (see below).

In addition to the first (*radiometric*) outlier (OxA-24937), the series contains a second (*stratigraphic*) outlier (OxA-24936), albeit with an otherwise acceptable ^{14}C -age (7083 ± 36 ^{14}C -BP). This sample has unique properties: it was taken at a stratigraphic depth of 115.40m, and – as such – was the lowest

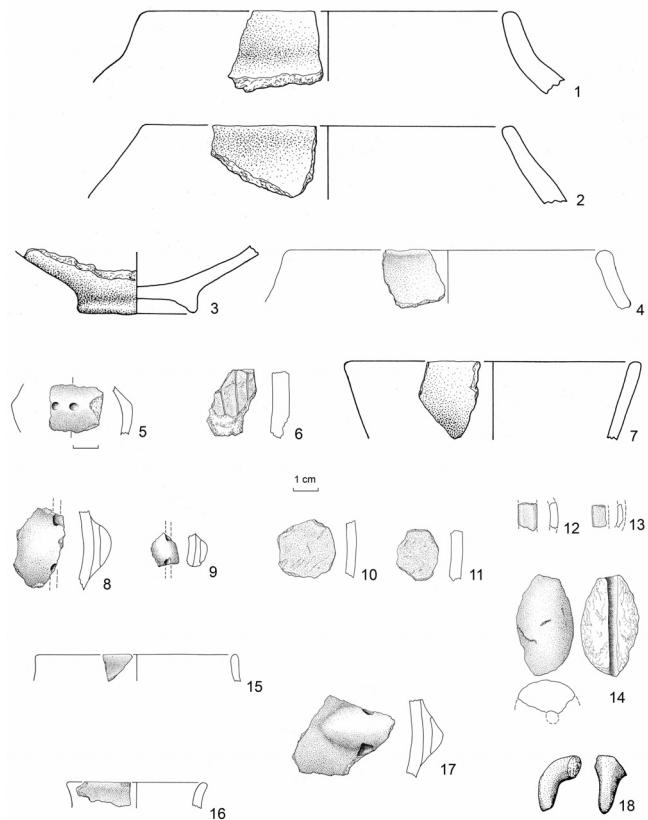


Fig. 13. Džuljunica II. Ceramic and clay finds from the balk: 1–9 n. 21–54; 18 n. 21–60; 10–14 n. 21–61; 15–17 n. 21–63; 10–11 ceramic tokens from pottery sherds; 12–13 fragments of ceramic rings; 14 fragment of a loam weight; 18 horn from a zoomorphic figurine?

sample recovered from Trench 21. The status of this age as a (*stratigraphic*) outlier only became clear in the course of stratigraphic age modelling.

Gaussian Monte Carlo Wiggle Matching

Using the metric depth-values of the ^{14}C -data from Džuljunica, as provided in Table 1 (column 8), we constructed a linear stratigraphic age-depth model for phases Dž I–II. Subsequently, this model was implemented in order to achieve a high-resolution chronology for these specific phases using Gaussian Monte Carlo Wiggle Matching (GMCWM). The age-model is founded on three assumptions:

- ① (average) sediment growth from the onset of Dž-I to the end of Dž-II is constant;
- ② sediment accumulation was uninterrupted; and consequently
- ③ there exists a linear age-depth relation between the recorded stratigraphic depth of the ^{14}C -dated bone samples and their calendric ages.

These assumptions are – to all intents and purposes – confirmed by our study results (Fig. 28). In the fol-

lowing, we provide details of the statistical analysis that are also illustrated in Figures 26 and 27.

Weighted averages

The method of GMCWM is an extension of the earlier developed wiggle matching method (e.g., Neustupny 1973; Pearson 1986; Weninger 1986; 1992). Wiggle matching underlies the basic idea to make use of additional independent information in order to refine the often limited precision and accuracy of dating achievable for single ^{14}C -ages. When single dates are age-calibrated in an unrelated (*individual*) manner, all we achieve is a list of (again unrelated) statistical intervals on the calendric time-scale. Further, the method of calculating weighted averages fails to provide access to the requested higher dating resolution. For example, Table 1 contains three ^{14}C -measurements (OxA-24931, OxA-24932, OxA-25040) that were obtained on different bone samples, all of which are from the same stratigraphic depth (16.16m). Assuming these samples have the same calendar age, which we judge is reasonable, it is possible to combine the values, and in particular, calculate a weighted average with a smaller standard deviation.

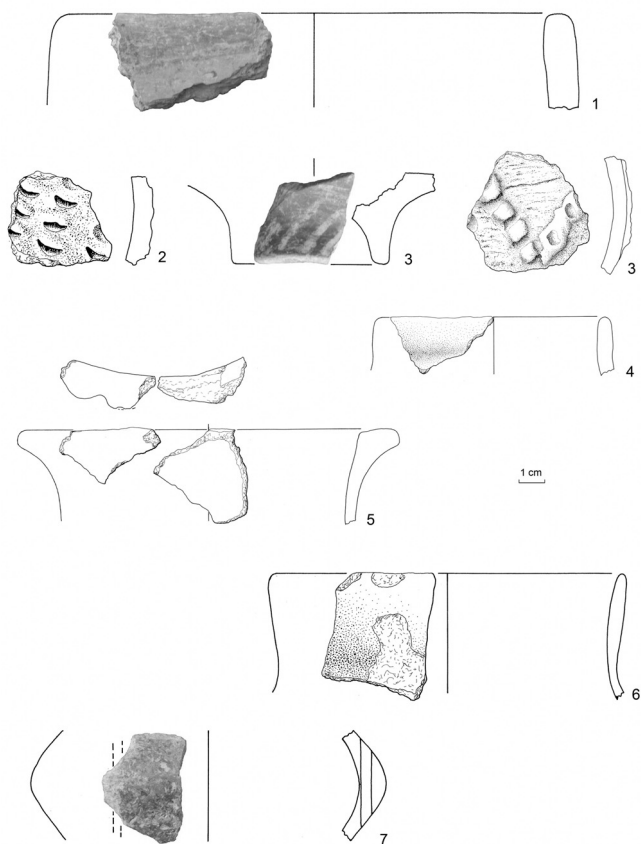


Fig. 14. Džuljunica II. Ceramic finds from the balk and the adjacent planum (trench 21): 1–6 spit 1 (n. 21–73); 7 from the planum; 1 fragment of a dark painted vessel; 3, 7 white-on-red painted fragments.

Nr.	Lab-Code	Sample-Code	Material (species)	^{14}C -Age [BP]	$\delta^{13}\text{C}$ [‰PDB]	Phase	Depth [m]
1	OxA-25045	DZH 21-35	charcoal	6686±39	-25.35	Dž IV	117.31
2	OxA-25047	DZH 21-51	charcoal	7140±40	-24.38	Dž III	117.01
3	OxA-25046	DZH 21-13	charcoal	6950±40	-25.59	Dž II	116.20
4	OxA-24981	DZH 21-80	bone (large adult bovide)	7185±40	-20.76	Dž II	116.41
5	OxA-25043	DZH 21-78	charcoal	7055±40	-25.76	Dž II	116.41
6	OxA-24977	DZH 21-79	bone (large adult bovide)	7136±40	-20.11	Dž II	116.41
7	OxA-24978	DZH 21-85	bone (adult sheep)	7054±39	-20.44	Dž II	116.26
8	OxA-24939	DZH 21-83	bone (sheep)	7171±36	-19.59	Dž II	116.26
9	OxA-24935	DZH 21-62	bone (large adult bovide)	7026±35	-20.46	Dž II	116.56
10	OxA-24931	DZH 21-90	bone (subadult sheep)	7066±38	-20.00	Dž I	116.16
11	OxA-24932	DZH 21-90	bone (subadult sheep)	7053±35	-19.93	Dž I	116.16
12	OxA-25040	DZH 21-92	charcoal	7049±39	-24.83	Dž I	116.16
13	OxA-24938	DZH 21-99	bone (large adult bovide)	7134±35	-19.20	Dž I	116.06
14	OxA-25044	DZH 21-105	charcoal	7095±40	-25.87	Dž I	116.05
15	OxA-24979	DZH 21-110	bone (large adult bovide)	7145±38	-20.26	Dž I	115.96
16	OxA-25033	DZH 21-116	animal bone	7084±36	-20.28	Dž I	115.92
17	OxA-24980	DZH 21-159	bone (large adult bovide)	7011±38	-19.97	Dž I	116.05
18	OxA-24937	DZH 21-153	bone (wild adult pig)	7588±37	-20.24	Dž I	116.11
19	OxA-25042	DZH 21-117	charcoal	7095±40	-24.29	Dž I	115.76
20	OxA-24934	DZH 21-125	bone (large juvenile bovide)	7195±37	-19.73	Dž I	115.70
21	OxA-24936	DZH 21-180	animal bone	7083±36	-19.09	Dž I	115.40

Tab. 1. Radiocarbon dates from Džuljunica (Trench 21).

tion. As shown by χ^2 -test, there is a high probability (94.7%) that the numeric spread of the three ^{14}C -ages (7066 ± 38 ; 7049 ± 39 ; 7049 ± 39 ^{14}C -BP) is an expression of chance fluctuations in the strength of the respective $^{14}\text{C}/^{12}\text{C}$ AMS ion-beams. As such, we can replace the three ages by their combined value (7056 ± 21 ^{14}C -BP, $p = 94,7\%$). However, although the combined value is characterised by a significantly lower standard deviation (STD = ± 21 ^{14}C -BP) than the separate data (± 38 , ± 39 , ± 39 ^{14}C -BP), both the position and length of the calendric-scale interval (6020 – 5860 calBC, 95% confidence) is almost identical to the intervals previously obtained for the individual components. The component intervals are: 6050 – 5850 calBC (OxA-24931), 6040 – 5840 calBC (OxA-24932), and 6050 – 5810 calBC (OxA-25040). This result can be summarised as follows: no methods, including stacking or weighting single ^{14}C -ages, both on the ^{14}C -scale or alternatively on the calendric time-scale, provide access to the enhanced dating precision required. Perhaps unexpectedly, although well-illustrated by this example, the limitations of single ^{14}C -age/sample analysis increase with increasing dating precision.

General considerations on ^{14}C -age calibration

As explained in Weninger *et al.* (2011), the theoretical reasons for these limitations are to be sought in the underlying algebra of probabilistic ^{14}C -age calibration. Briefly, in mathematical language, the calibration operation is not only non-linear (due to the wiggles of the ^{14}C -age calibration curve), but in particular, also non-commutative (ordered). In consequence, there is a (one-sided) uncertainty relation between the ^{14}C -scale and the calendar time-scale, which means that all ^{14}C -based chronological results depend strongly on which of the two scales the analysis is initially (or secondarily) performed (*e.g.*, first on the ^{14}C -scale and second on the calendric time-scale, or vice-versa). Better known from quantum mechanics, but where the uncertainty relation between the different *paired* variables (*e.g.*, between energy and time) is two-sided, all such non-commutative systems have a strong tendency towards an irreversible *lock-in* of variables (when measured), onto certain pre-defined states of the study system (*e.g.*, energy levels in atoms). Interestingly, this quantisation effect can also be observed in the results of archaeological radiocarbon analysis, by whatever

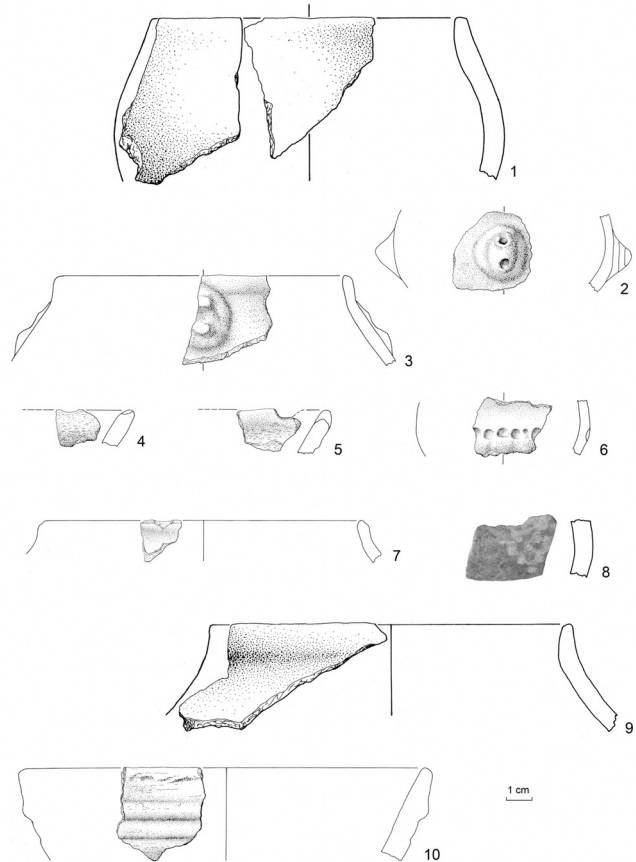


Fig. 15. Džuljunica II. Ceramic finds from the balk; 1–3 spit 1 (n. 21–73); 4–10 spit 2 (n. 21–82); 8 fragment with white-on-red painting.

method, but most clearly in single ^{14}C -age analysis. In view of the high dating precision achieved at the Oxford ^{14}C -AMS-laboratory for Džuljunica samples, and knowing that the observable effects of age-quantisation become stronger with increased dating precision, we therefore confidently forecast that such *lock-in* effects will also appear as a result of Džuljunica ^{14}C -analysis.



Fig. 16. Džuljunica III. Foot from a white-on-red painted beaker. Excavated by N. Elenski.

Nr.	Lab-Code	Material	Species/ Function	Locus	Square/ Quadr.	Feature/ Sample Nr.	¹⁴ C-Age [BP]	Depth [m]	Comments/ Sample Quality
1	Bln-1544	charcoal		Hor. I			6688±60		same sample Bln-1620
2	Bln-1620	charcoal		Hor. I			6463±50		same sample Bln-1544
3	Bln-2030	charcoal		Hor. III	61	Pit	6125±45	0.60	too young high ash content
4	Bln-2031	charcoal		Hor. III	61	Pit	5440±50	0.30	too young high ash content
5	Bln-2032	charcoal		Hor. III	33		6555±70	0.26	high ash content
6	Poz-16984	bone	<i>Bos</i> bone point	Hor. I	Ž7		6890±40	0.10	4.1% collagen
7	Poz-16985	bone	<i>Ovis/Capra</i> bone point	Hor. I	M6		6890±40	0.20	2.5% collagen
8	Poz-16986	bone	<i>Ovis/Capra</i> bone point	Hor. III	115/125		6500±40	1.30	2.2% collagen
9	Poz-18480	bone	<i>Bos</i> bone point	Hor. IV	–	MTg 2510A Feldnr. 222	6900±40	–	0.8% collagen
10	Poz-18483	bone	bone point	Hor. II	M1	MTg 2480A Feldnr. 142	6750±40	0.10	0.4% collagen
11	Poz-18484	bone	<i>Bos</i> bone disc	Hor. III	104	MTg 2554A Feldnr. 149	6640±40	0.10	0.5% collagen
12	Poz-18486	bone	bone point	Hor. I	63	MTg 1955A Feldinv. 10	6800±40	2.40	0.5% collagen
13	Poz-18487	bone	<i>Ovis/Capra</i> worked bone	Hor. IV	24	MTg 1962A Feldnr. A18	6660±40	0.20	0.6% collagen
14	Poz-18489	bone	<i>Bos</i> worked bone	nd	62/2	MTg 2609A Feldnr. 169	6750±40	1.90	6.2% collagen
15	Poz-18490	bone	bone spoon	Hor. III	115	MTg 2609A Feldnr. 169	6780±40	1.30	9.5% collagen
16	Poz-18491	bone	bone spoon	Hor. II	–	MTg 2603A Feldnr. 139	6810±40	0.15	11.2% collagen
17	Poz-18493	bone	<i>Bos</i> worked bone	Hor. I	61/3	MTg 1632A Feldnr. 8	6670±40	0.30	5.3% collagen
18	Poz-18494	bone	<i>Bos/Cervus</i> bone disc	Hor. IV	30	MTg 2555A Feldnr. 80	6690±40	0.20	6.6% collagen

Tab. 2. Radiocarbon dates from Ovčarovo-Gorata (43°11' N, 26°39' E). Source: Nr. 1–4 (Görsdorf, Bojadžiev 1996.128–129); Nr. 5–18 (Krauß 2014.282–283).

As mentioned above, in the present paper we based the stratigraphic analysis of Džuljunica ¹⁴C-data on GMCWM. While the alternative method of Bayesian Sequencing (most recently in *Bronk Ramsey 2011*) makes use of the available stratigraphic information in terms of age-relations that are given on an ordinal scale (*younger-older*), the application of GMWCM requires this information to be interval-scaled (*e.g.*, tree-ring counts, pottery seriation, metric depth). Both methods share the disadvantage that it is practically impossible to simultaneously optimise both the precision and accuracy of the archaeological age model under study. In theoretical terms, this is yet another consequence of the above-mentioned non-commutative relation between the ¹⁴C and the calendric time-scale. Accepting this fundamental limitation, the major advantage of GMWCM is that we at-

tempt not only to optimise the dating precision, which is a relatively straightforward matter, but in addition use an algorithm whereby the dating probability is implemented as a *proxy* for the otherwise unknown dating accuracy. In the following, we use GMCWM based on the measured metric depth of the short-lived bone samples (Tab. 1). For taphonomic reasons, we exclude the two outliers (identified above) and all charcoal samples from these studies.

The GMWCM algorithm

As described in Marion Benz *et al.* (2012), the GMCWM algorithm fits the depth-scaled archaeological data repeatedly to the calibration curve for an optional number of runs (read: age-models) between 1 and 100, each of which is assigned a max. 10 000 statistical iterations (read: input of age-model vari-

ables). Prior to each run, the metric depth values [cm] are linearly scaled to calendric ages [yrs] according to the specific age model [yrs/cm] under study. In the course of the analysis, by run-wise lengthening of the calendric-scale distance between samples, the algorithm uniformly expands the age model in annual steps between 0 and 4 [yrs/cm]. These are specific values that are relevant in the present study. The overall aim of this approach is to identify all age-depth models for which there is acceptable statistical agreement between the archaeological ^{14}C -data and corresponding points of the ^{14}C -age calibration curve. The final analytical step is to identify which of the different models is 'best'. As numeric measure for this qualification, in the course of each of the 100 runs, the GMCWM algorithm calculates the summed probability for the archaeological ^{14}C -data set in comparison to the corresponding points of the ^{14}C -age calibration curve.

This calculation covers both the standard deviation (STD) of the archaeological ^{14}C -ages and the STD assigned to the calibration curve. Steered by three independently running random number generators, each of the 100 runs provides 10 000 different results, whereby the algorithm simulates the following age-model errors: (1) Monte Carlo (Gaussian) re-measurement of the archaeological data steered by given standard deviations (STD); (2) Monte Carlo (Gaussian) re-measurement of the calibration curve data steered by STD typically set to values of ± 10 ^{14}C -BP, with corresponding Monte Carlo recalculation of the calibration curve; as well as (3) Monte Carlo (Gaussian) calendric-scale variation of the initial age model steered by the input age-depth values.

In the present study, for this third error component, we applied constant errors of ± 5 years on the calendric-scale, to allow for corresponding errors in age-depth simulation in the order of ± 5 – 10 [cm]. For each of the 100 runs the obtained distribution of best-fit values contains 10 000 individual calendric age values, each of which represents the best-fitting calendric age (maximum probability) for the specific run. Following each run the results are shown on-screen, first as a histogram for which the calendric-scale

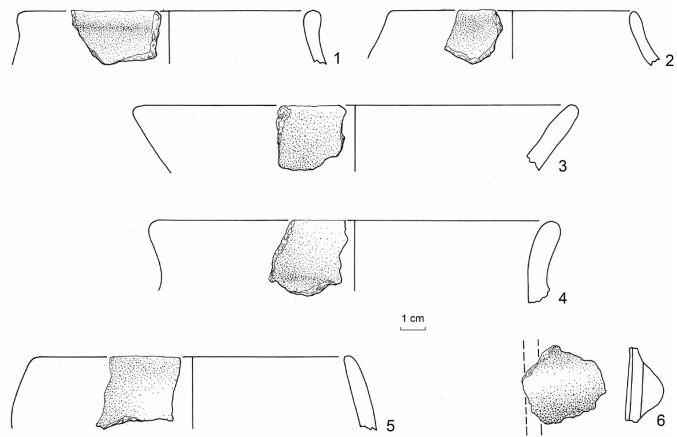


Fig. 17. Džuljunica III. Ceramic finds from the balk (n. 21–47).

width is calculated (Fig. 27 left) and second as a graph that shows the actual position of the archaeological data in comparison to the calibration curve (Fig. 27 right). Following graphic output the algorithm then begins calculations for the next run (age-model). Consequently, in the course of the analysis, the observer is presented with a graphically animated (incrementally expanding) sequence of age models on-screen. Typical run-times are 2 minutes to 6 hours, depending on the numeric precision requested.

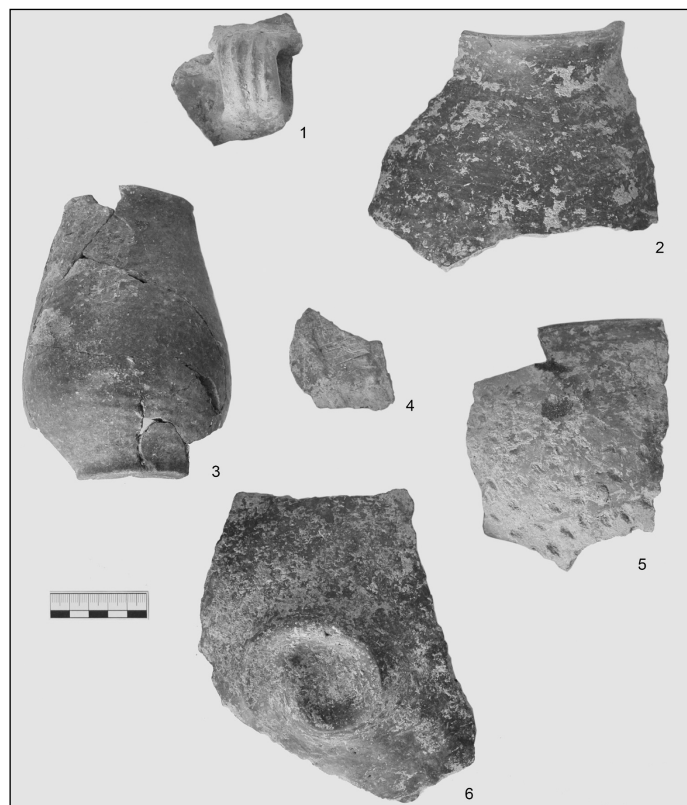


Fig. 18. Džuljunica IV. Pottery finds from excavations by N. Elenski: 1–3 canellated/fluted relief; 4, 6 plastic applications.

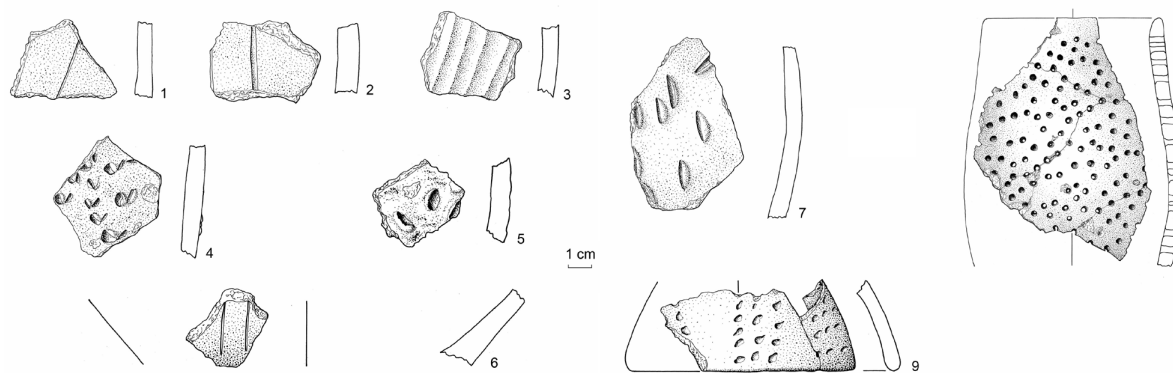


Fig. 19. Džuljunica IV. Ceramic finds from the balk: 1-4 n. 21-26; 5-6 n. 21-30; 7-9 n. 21-34; 1-2, 6 with incised lines; 3 cannellated/fluted surface; 4-5, 7 fingernail impressions; 8 sieve vessel; 9 lid with in-presso decoration.

When the GMWC-analysis is completed the software finally produces what we call a *statistics graph* (Fig. 26).

Results

As shown in the statistics graph (Fig. 26) the dating probability function (red line) has a maximum value of $p \sim 80\%$ for tell growth of 0.35 yrs/cm . Smaller, but still highly significant probabilities ($p \sim 35\%$), are achieved for an extended plateau in the range $1.2-2.2 \text{ yrs/cm}$. The probability then deteriorates to values lower than $p = 5\%$ at the end of the scale. In comparison, the dating precision (blue line) is highest (*i.e.* the smallest best-fit histogram width ± 5 to $\pm 7 \text{ calyrs}$) for tell growth in the range of $0-1 \text{ yrs/cm}$. A local peak shows less precision for models $\sim 1.3 \text{ yrs/cm}$, followed by higher precision again ($\pm 10 \text{ yrs}$ histogram width) for growth values larger than $\sim 1.5 \text{ yrs/cm}$. Finally, the dating precision function also deteriorates towards the end of the scale.

As mentioned above, in developing GMCWM we made efforts to optimise both precision and accuracy simultaneously. This was achieved by introduction of an optimising factor, *F*. Initially we defined *F* as the linear product of probability and precision. However, as shown by experimental studies with data of known age, sensitivity can be increased by defining *F* by using the squared probability function. An explanation can be sought in the fact that radiocarbon dates have algebraic properties similar to those in quantum physics, where defining probabilities for measured observables based on the squared values of wave-particle functions is standard practise (*e.g.*, *Omnès 1994*.

83). Interestingly, the analogy works correctly. As can be taken from Figure 26, the *F* function (green) has its strongest peak for tell growth at $\sim 0.35 \text{ yrs/cm}$ (similar to the probability function), but a peak in the *F*-function is now also attained for tell growth of $\sim 1.70 \text{ yrs/cm}$. Put together, the statistics graph informs us of the existence of two distinctly different (alternative) age models (we call Model 1 and Model 2), between which we must choose. These two models represent the quantum states into which the chronological system jumps when we try to mea-

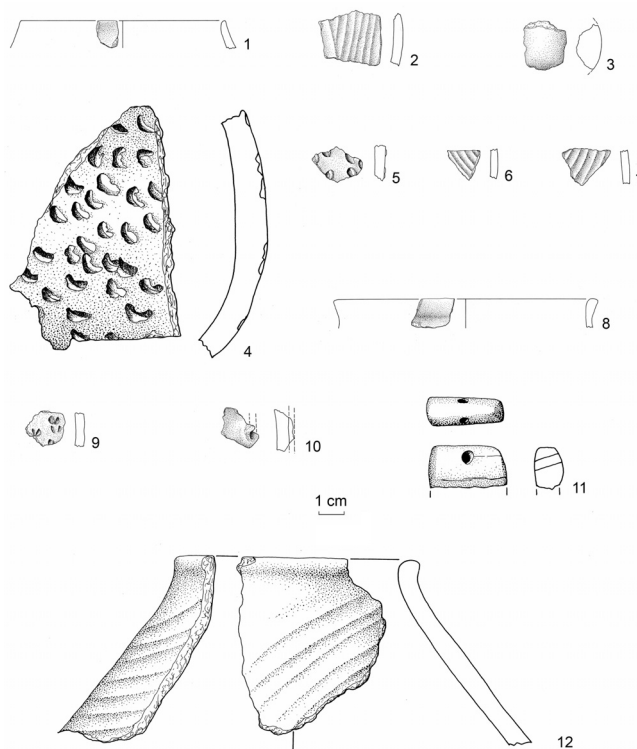


Fig. 20. Džuljunica IV. Ceramic, clay and bone finds from the balk and the adjacent planum: 1-4 n. 21-37; 5-10 n. 21-40; 11 n. 21-43; 12 from the planum; 2, 6-7, 12 with cannellated/fluted surface; 4-5, 9 fingernail impresso; 11 bone pendant.

sure (enforce) a continuous sequence of stratigraphic age models.

Accepting Model 1 would imply that the two Džuljunica Phases Dž-I and Dž-II would together cover a time-span of only ~30 calendar years ($\sim 0.35 \text{ yrs/cm} \times 86 \text{ cm}$). Although it has the highest probability, by archaeological reasoning, Model 1 appears too short. In comparison, with an implied time-span of $1.75 \text{ yrs/cm} \times 86 \text{ cm} = 150 \text{ yrs}$, Model 2 agrees much better with archaeological expectations based on considerations for realistic tell growth and on pottery style comparisons between Džuljunica and other ^{14}C -dated sites (Ulucak, Çukuriçi, Ovčarovo-Gorata). Finally, when shown in context with the INTCAL09 high-precision calibration of raw data at the laboratories at Seattle and Heidelberg (Fig. 28) it becomes clear that the existence of two alternative best-fitting models is due to a reversed calibration curve wiggle between 5960 and 5900 calBC. In Model 1, all Džuljunica ^{14}C -data (phases Dž-I and Dž-II) lock into the steep slope of the calibration curve between 5950 and 6050 calBC. In Model 2, the Dž I-data still lock into this steep region but the Dž II-data are now attracted to the next following strong wiggle, which has a maximum of around 5930 calBC. Since this wiggle can be identified in the laboratory raw data, but is over-smoothed in the construction of the INTCAL09 calibration curve, we are confident that Model 2 is acceptable, despite its slightly lower overall probability. It appears that some of the Džuljunica Dž-II ^{14}C -data are picking up the corresponding slightly higher atmospheric ^{14}C -ages. This is only possible due to their relatively high dating precision (STD ~ 35 ^{14}C -BP). Finally, Figure 28 shows the GISP2 $\delta^{18}\text{O}$ -measurements of Minze Stuiver *et al.* (1998) as a proxy for North Atlantic ocean/atmosphere temperature, and GISP2 non-sea salt K^+ as a proxy for the strength of Siberian High pressure (Mayewski *et al.* 1997; Rohling *et al.* 2002). It can be deduced from this comparison that the earliest Neolithic was established at Džuljunica some 100 years (perhaps 4 generations) after the end of RCC-conditions (Rapid Climate Change) (We-



Fig. 21. Zoomorphic idols, so called labrets, from Džuljunica II. Excavations: N. Elenski.

ninger *et al.* 2009). Figure 29 shows the chronological results achieved for Džuljunica in comparison to other Neolithic settlements in Northeast Bulgaria.

Early Neolithic animal remains from Džuljunica

The dispersal of animal husbandry technologies from western Anatolia into Southeastern Europe is a poorly understood process. Recent studies in western and central Anatolia indicate that animal husbandry evolved in diverse forms in this intervening area between the Fertile Crescent and Southeast Europe (Çakırlar 2012). In other words, no single animal husbandry package was introduced to Southeast Europe from Southwest Asia. Instead various kinds of

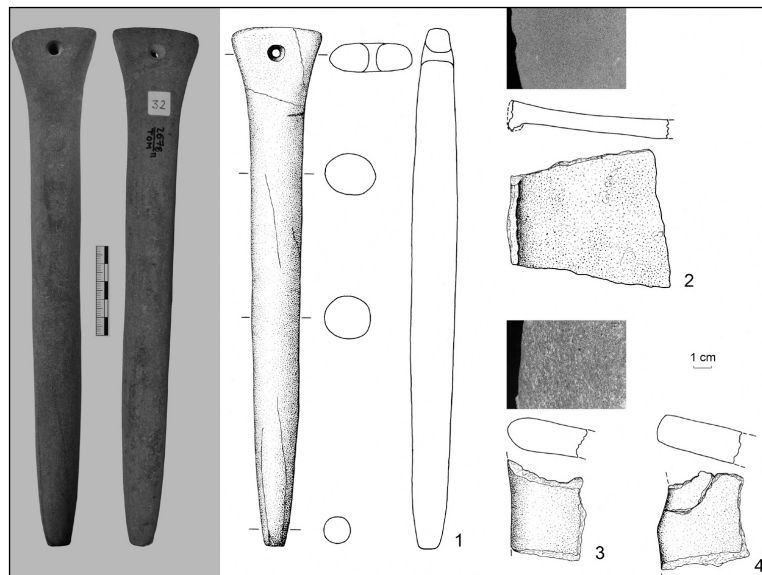


Fig. 22. Items of fine sandstone from Džuljunica I and II. Excavations N. Elenski: 1 sceptre-like object from Džuljunica II, reminiscent of the smaller labrets with perforated head; 2–4 fragments of stone palettes, 3 from Džuljunica I, 2 and 4 from Džuljunica II.

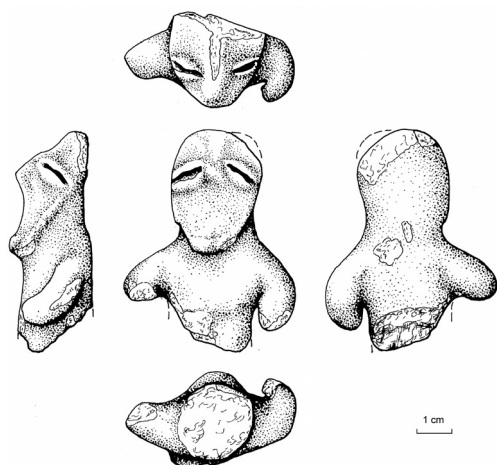


Fig. 23. Torso of an Early Neolithic clay figurine from Džuljunica I. Planum adjacent to the balk (n. 21–111).

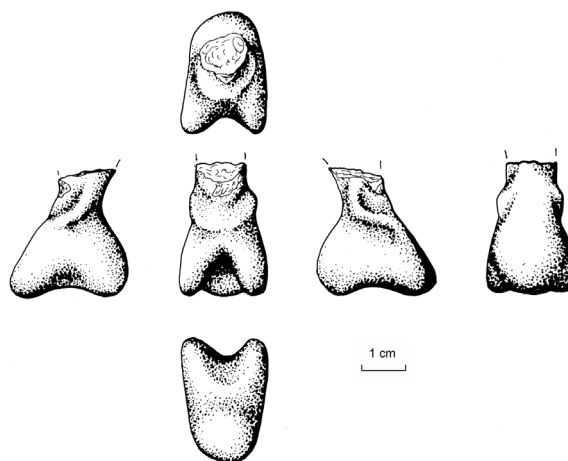


Fig. 24. Headless female Early Neolithic clay figurine from Džuljunica I. Planum adjacent to the balk. Excavations: N. Elenski.

evolving animal husbandries would have been moving across a wide frontier until they eventually reached this region. How were animal husbandry technologies transmitted further west, across the Aegean and into the temperate regions of the Balkan Peninsula? And how were they further transformed there? Zooarchaeological assemblages from well-stratified, radiocarbon-dated deposits representing early Neolithic settlements like Džuljunica are crucial to understanding the integration of herding during the transition to sedentary life in Europe.

Material and methods

We studied 900 specimens from the stratigraphic balk excavated in 2010, which covers the entire Neolithic sequence, and 1264 specimens from the horizontal exposures representing the earliest (Dž –I) Neolithic phases. The assemblages from the balk were recovered through 2mm mesh and for the most part (approx. 89%) include unidentifiable mammal remains. The Dž–I assemblage from horizontal excavations yielded a larger proportion of identifiable specimens (c. 45%). The sample size is thus small,

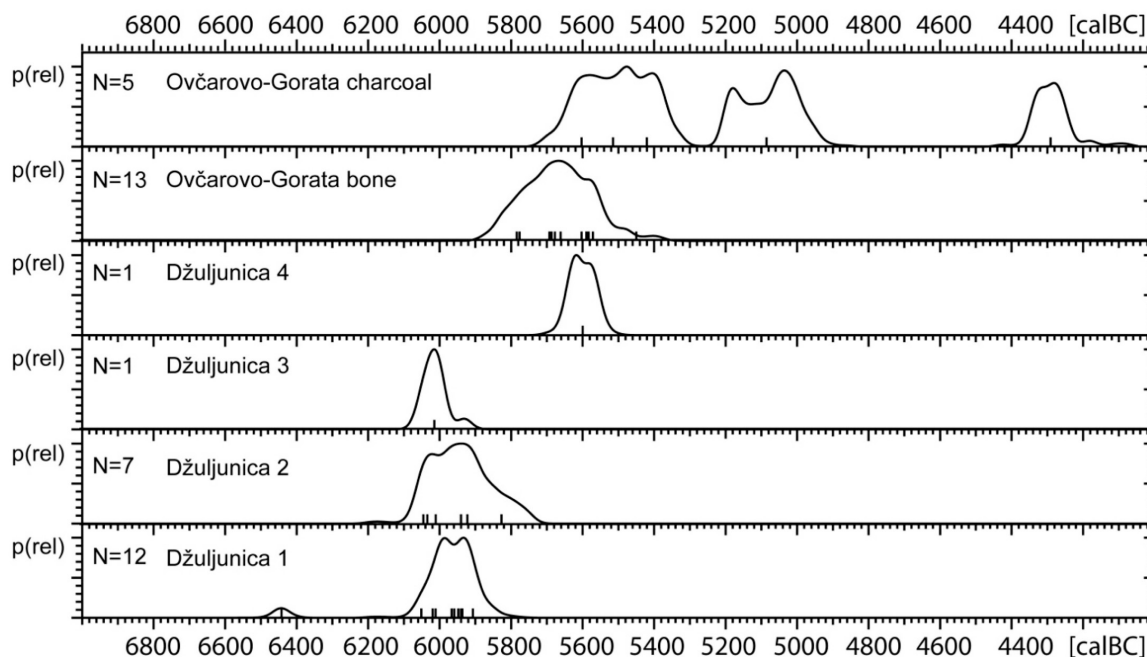


Fig. 25. Probabilistic calibration of ^{14}C -data from Džuljunica (Tab. 1) and Ovčarovo-Gorata (Tab. 2). The data from Džuljunica are grouped according to phase Dž I–IV, with phase-groups arranged in stratigraphic order from Dž 1 (oldest) to Dž 4 (youngest). The data from Ovčarovo-Gorata are grouped according to sample material (bone and charcoal). Radiocarbon calibration based on INTCAL09-data (Reimer et al. 2009). Calibration method: (Weninger 1986). Graph produced by CalPal-software (Weninger, Jöris 2008).

and the study of archaeofaunal assemblages from the younger Neolithic layers of Džuljunica continues. For these reasons, here we refrain from speculating about how animal exploitation developed during the course of Early Neolithic occupation in Džuljunica and focus on the character of animal husbandry as it emerged in Dž-I.

The assemblage was studied in the archaeological laboratory of the New Bulgarian University in Sofia and at the Regional Historical Museum of Veliko Tŕrnovo. Domesticated pig and cattle (*i.e.* domesticated animals whose wild ancestors are known to have occurred in Bulgaria in prehistory) were identified based on their morphology, specifically by comparing them with standard wild specimens of known sex and provenance (Degerbøl, Fredskild 1970; Hongo, Meadow 2000; Payne, Bull 1988). Osteometric measurements followed Angela von den Driesch (1976). NISP (= Number of Identified Specimens) is the basic quantification unit used to calculate the proportions of the represented taxa. A more detailed presentation of the material will follow in future publications.

Results and discussion

Sheep, goat, and domestic cattle are present in Dž-I. The domestic status of the sheep and goats in Dž-I is clear, because Džuljunica falls well out of the natural distribution area of their wild progenitors (Uerpmann 1987). Sheep and goat comprise approx. 50% of the vertebrate material from the horizontal exposures and approx. 65% of the material from the balk (Tab. 3). The most likely cause of this dissimilarity is the difference in the recovery techniques used in the two excavations. It is well known that sieving mitigates bias causing a low turnout of smaller animals (Payne 1972; Clason, Prummel 1977). Regardless of artificial differences in proportions, both assemblages demonstrate the important place of imported ovicaprid herds in domestic herd composition in Dž-I.

Cattle comprise approx. 30–35% of the identified mam-

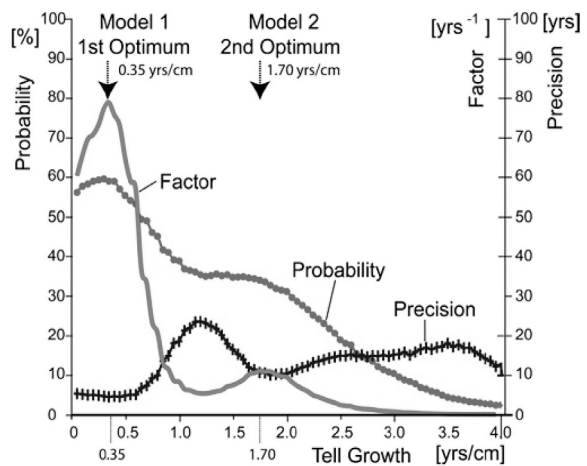


Fig. 26. GMCWM statistics graph for Džuljunica ^{14}C -data (Phases Dž I–II) with simulated tell growth in the overall range 0–4.0yrs/cm, based on 100 runs with increments 0.04yrs/cm. Red – dating probability left scale: Probability [%]; Blue – dating precision (right scale: histogram width, Precision [yrs]); Green – Optimising Best-Fit Factor F (Probability-squared/ Precision [yrs $^{-1}$]). Optimal results, based on maximal values for F , are achieved for age-models 0.35yrs/cm and 1.70yrs/cm.

malian specimens in Dž-I. The presence of domestic cattle in Dž-I is attested by the relatively small sizes of the *Bos* specimens (Fig. 30). Measurements indicate that aurochs (*Bos primigenius*) are also present in small amounts. This indication fits expectations based on earlier studies from Koprivec near

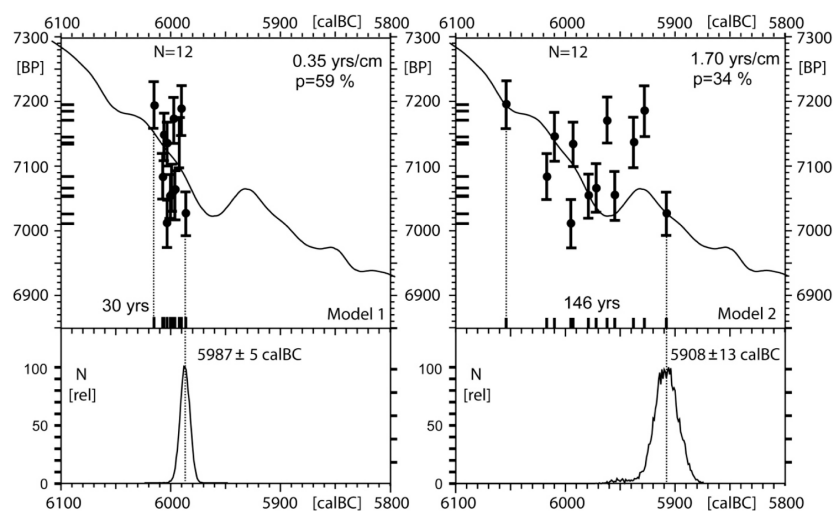


Fig. 27. Comparison of Age-Model 1 and Age-Model 2. Left – ^{14}C -sequence for Džuljunica (Phases Dž I–II) according to Model 1 (0.35yrs/cm); Right – ^{14}C -sequence for Džuljunica (Phases Dž I–II) according to Model 2 (1.75yrs/cm); in comparison to INTCAL09 curve (Reimer et al. 2009). Both models provide high-precision fits of Džuljunica ^{14}C -ages to INTCAL09. By archaeological reasoning, Model 1 is too short (cf. text). Model 2 agrees well with archaeological expectations based on considerations for realistic tell growth and on pottery style comparisons between Džuljunica and other ^{14}C -dated sites (Ulucak, Çukuriçi, Ovčarovo-Gorata).

Taxa represented	Frequency
<i>Bos taurus</i> (cattle)	VA
<i>Ovis aries</i> / <i>Capra hircus</i> (sheep or goat)	VA
<i>Canis domesticus</i> (dog)	R
<i>Bos primigenius</i> (aurochs)	C
<i>Cervidae</i> (deer)	C
<i>Sus scrofa</i> (wild boar)	R
<i>Castor fiber</i> (Eurasian beaver)	R
<i>Lepus capensis</i> (European hare)	R
<i>Unionidae</i> (Freshwater clams)	C

Tab. 3. List of faunal taxa represented in Džuljunica and their relative abundance (R = rare; C = common; A = abundant; VA = very abundant).

Džuljunica (Manhart 1998) and Fikirtepe further to the southeast (Boessneck, Von den Driesch 1979).

Morphologically domestic pigs are absent from the assemblages studied thus far. Morphologically wild boar (*Sus scrofa*) is represented by very few specimens in both sieved and hand-collected assemblages. The measurements of both cranial and post-cranial elements fall well within published ranges from modern populations (Tab. 4). For the time being, it is difficult to argue for the presence of domestic pig in early Džuljunica. The special role played by pigs and boars in the dissemination of early animal husbandry technologies is only beginning to be understood. While osteometric analysis indicates that morphologically domestic pigs were absent in the 7th millennium BC cultures of Central Anatolia (Arbuckle et al. 2014; Russel, Martin 2005), the same type of analysis shows that domestic pigs were rapidly adopted after the initial phase of Neolithic settlement in northwestern Anatolia around 6100 calBC (Çakırlar 2013). They were also present in southern, southwestern, and central-western parts of Anatolia from the earliest Neolithic (Çakırlar 2012). Furthermore, ancient DNA analysis demonstrates that wild boar and domestic pig interbred in western Anatolia (Ottoni et al. 2013). In view of these recent studies and observations on the *Sus* sp. specimens from Džuljunica, it is possible to surmise that domestic pigs were added to the herds of Džuljunica at a later period, either through local domestication, the introduction of domestic breeds, or both.

In contrast to the paucity of boar remains, specimens of deer (*Cervus elaphus*, and *Capreolus*

capreolus) are common, at percentages similar to what has been observed for Fikirtepe (Boessneck, Von den Driesch 1979). These remains show that hunting was practiced fairly regularly by these early Neolithic communities, whose mode of animal exploitation was geared primarily towards herding.

Our results substantiate previous faunal studies that attest to the important role of cattle herding at numerous Neolithic sites in Southeastern Europe and for the dispersal of early farming into temperate Europe (Benecke 2006; Conolly et al. 2012). At Dž-I, cattle, sheep and goat herding played a significant role from the very earliest phase of occupation. Although Džuljunica is located in northern Bulgaria, this situation is in agreement with trends observed at Early Neolithic sites in southern Bulgaria (Benecke, Ninov 2002). The proposed link between dairy production and an emphasis on cattle breeding (Evershed et al. 2008) is yet to be explored by appropriate zooarchaeological tools applied to sufficiently large samples. While the abundance and size of cattle, sheep and goat for Dž-I supports the demic diffusion model of Neolithisation for Bulgaria, the paucity and large size of *Sus* sp., together with the possibility of late adoption of domestic pigs, demonstrate one of the ways in which local innovation shaped the Neolithisation of Southeast Europe.

Conclusions

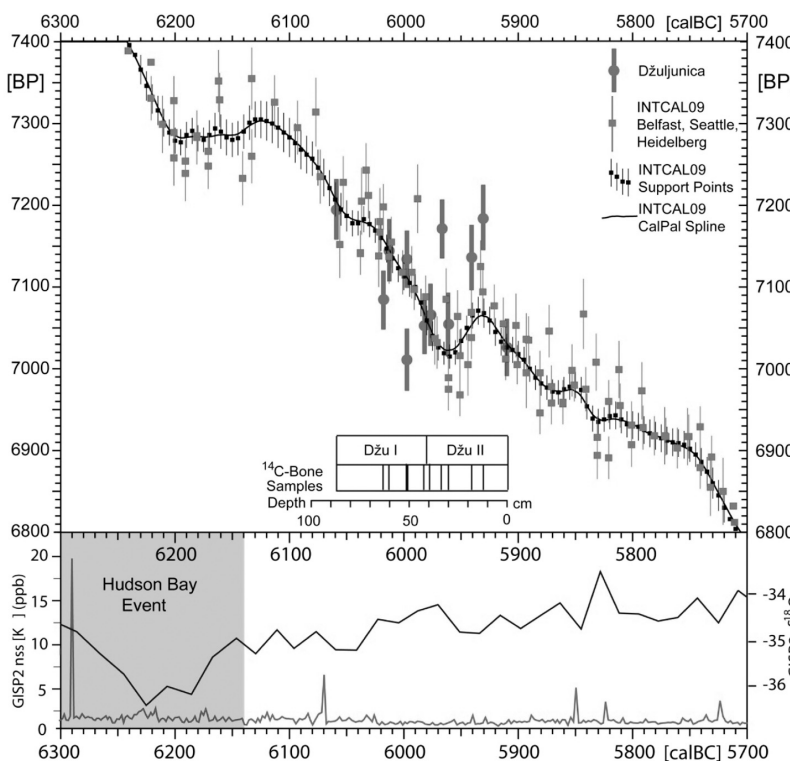
The investigations undertaken at Džuljunica-Smārdeš in 2010 focused on the excavation of the balk separating trenches 18 and 21. The systematic excavation and documentation of this balk, which comprised a sequence of archaeological deposits beginning in the Early Neolithic, provided us with the unique opportunity to study developments for the eastern Balkan region from the Pre-Karanovo I phase through Karanovo II.

The lowermost settlement deposits (Dž-I) can be assigned to a phase which coincided with the Neolithi-

Specimen no.	Element	Measurement	Remarks
162	Ulna	BPC = 26.4mm	Difference from Hongo, Meadow 2000 standard individual: 1.1mm
617	Radius	BFp = 36.5mm	Difference from Hongo, Meadow 2000 standard individual: 2.3mm
343	Maxilla with teeth	Breadth of M1 = 15.7mm; Breadth of P4 = 15.8mm	Compare with Payne, Bull 1988.appen.

Tab. 4. Measurements of three *Sus* sp. specimens from Džuljunica I and their relationship to modern wild individuals of known sex and provenance.

Fig. 28. Linear stratigraphic age model for Džuljunica ¹⁴C-data (Phases Dž I-II) according to Model 2 (1.70yrs/cm), in comparison to INTCAL09 curve (Reimer et al. 2009), INTCAL09 high-precision calibration raw data (Seattle/Heidelberg), and climate records (GISP2 $\delta^{18}O$ [Stuiver et al. 1998] as proxy for North Atlantic ocean/atmosphere temperature, and GISP2 non-sea salt K^+ as proxy for the strength of Siberian High pressure [Mayewski et al. 1997; Rohling et al. 2002]; GISP2-age model shifted 40yrs younger according to refined GICC05-ages [Vinther et al. 2006]).



sation of the region, for which there are currently no older Neolithic finds. From a typological perspective, material from this level corresponds to finds made at Koprivec and from Poljanica-Platoto.

Additionally, finds from Dž-I attest to clear affinities with material from West Anatolia. This context is also confirmed by radiocarbon data. While the larger figurine discovered at Džuljunica (Fig. 23) already indicates independent Balkan traditions from the outset of Neolithisation, the smaller figurine (Fig. 24) still displays typical Anatolian features. This trend is also reflected in the results of our investigations into the faunal assemblage from the site. While the ear-

liest Neolithic communities arrived in the region with herds of sheep and goat, and domesticated cattle, pig was either domesticated locally or imported into the region later.

Certainly, it cannot be ruled out that the Neolithisation of the Central Balkans did not occur a few generations prior to the earliest occupation deposits from Džuljunica. Data from Thessaly indicate that Neolithisation occurred slightly earlier in Greece, and the river valleys of the Vardar/Axios, Struma/Strymon and Morava would have provided natural routes for

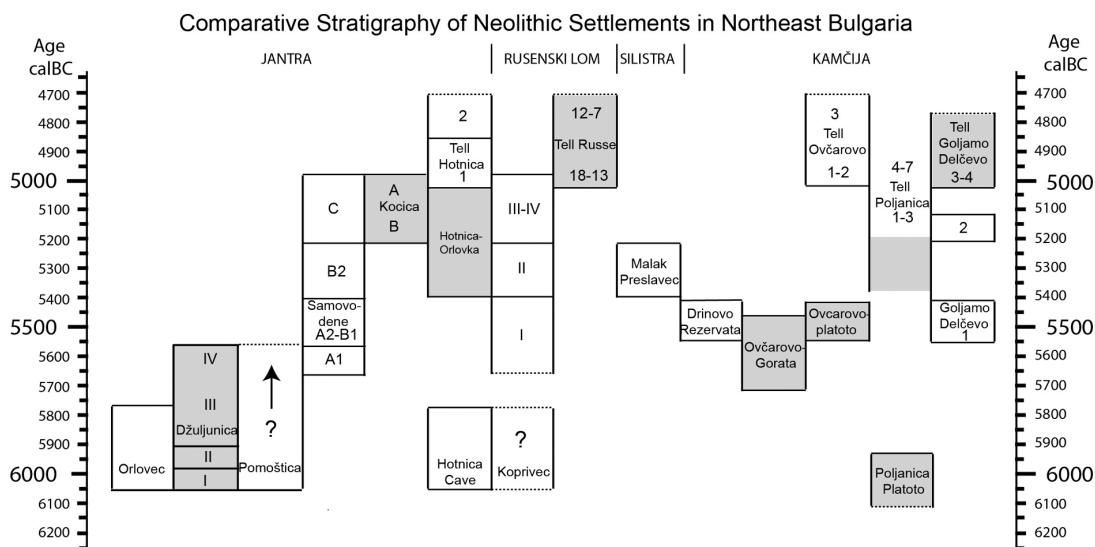


Fig. 29. Schematic comparative stratigraphy of Neolithic settlements in northeast Bulgaria. Grey-shaded boxes indicate radiocarbon-dated sequences.

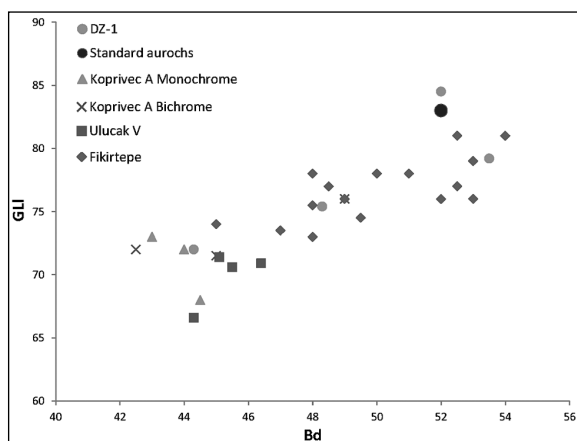


Fig. 30. As a proxy for domestic vs. wild cattle populations at the Neolithisation frontier between Anatolia and the Balkans, comparison of length (GL) and breadth (Bd) measurements of *Bos sp. astragali* (knuckle bone) from Dž-I, roughly contemporary settlements in the greater Early Neolithic European frontier (Koprivec data from Manhart 1998; Ulucak V data from Çakırlar 2012; Fikirtepe data from Boessneck and von den Driesch 1979), and a standard prehistoric aurochs from northern Europe (Degerbøl, Fredskild 1970).

the dispersal of the new form of subsistence. Furthermore, it is not insignificant that the arrival of Neolithic lifeways in the region coincided with the end of a period for which palaeoclimate proxies attest to considerable climate fluctuation. From the middle of the 7th millennium calBC until its final century, a Rapid Climate Change (RCC) interval – with the same mechanism as the recent *Little Ice Age* – prevailed. RCC conditions are synonymous, for example, with harsh winters, but also with severe droughts. Additionally, in the century directly preceding the Neolithisation of the Central Balkans, these climate perturbations would have been intensified by the effects of the 8.2ka calBP Hudson Bay event. Causal relation-

ships between climate change and the Neolithisation of Southeast Europe in the late 7th millennium calBC are an area of considerable interest which should be pursued in the future.

By the Dž-II and Dž-III phases, Neolithic communities had dispersed over the entire region, from the Aegean coast to the Carpathian Basin. The widely occurring white-on-red painted pottery (especially with white dots) testifies to a large communication sphere stretching from central West Anatolia (Ulucak and Çukuriçi) to Gura Baciului, at the centre of the Carpathian Basin.

From Dž-IV/Ovčarovo-Gorata (Karanovo II) there is a distinctive trend to regionalisation. In the Eastern Balkans, this trend is expressed in the near disappearance of painted decoration and the introduction of vessels with canellated/fluted surfaces. The smooth transition from this period to the subsequent Middle Neolithic, not identified at Džuljunica, heralds the period of tell development in Southeast Europe.

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