Variability in lithic technology during the Neolithic in the western Balkans

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ABSTRACT – *The period between 6200–4500 cal BC is a time of significant socio-economic and technological changes in the western Balkans. The spread of farming practices also triggered a series of changes in stone tool production. This paper explores intra- and inter-site variability in Neolithic lithic technology across the region, using both qualitative and quantitative methods. The results show that technology and typology remained relatively consistent, while the management of raw materials reveals distinct regional differences in both the Early and Late Neolithic. Geographical patterns of lithic distribution and access to resources further highlight regional and inter-regional connections, offering insights into community interactions and mobility.*

KEY WORDS – *lithic technology; raw materials; variability; Neolithic; Starčevo culture; Vinča culture; Sopot culture; western Balkans*

Variabilnost litične tehnologije v neolitiku na zahodnem Balkanu

IZVLEČEK – *Obdobje med 6200–4500 pr. n. št. je čas pomembnih družbeno-ekonomskih in tehnoloških sprememb na zahodnem Balkanu. Širjenje poljedelskih praks je sprožilo tudi vrsto sprememb v proizvodnji kamnitega orodja. V članku s pomočjo kvalitativnih in kvantitativnih metod predstavljamo raziskave variabilnosti litične tehnologije znotraj najdišča in med najdišči v regiji. Rezultati kažejo, da sta tehnologija in tipologija ostali relativno konsistentni, medtem ko upravljanje surovin razkriva izrazite regionalne razlike v zgodnjem in poznem neolitiku. Geografski vzorci distribucij kamnitih orodij in dostopov do virov dodatno osvetljujejo regionalne in medregionalne povezave ter ponujajo vpogled v interakcije in mobilnost skupnosti.*

KLJUČNE BESEDE – *litična tehnologija; surovine; variabilnost; neolitik; kultura Starčevo; kultura Vinča; kultura Sopot; zahodni Balkan*

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Introduction

The neolithisation was a complex process which had an impact on all aspects of social and economic life, including the material culture of the involved communities. Changes in subsistence strategies not only accelerated the growth and development of Neolithic societies but also had an influence on stone tool production and use. Janusz K. Kozłowski (*1982; 1988; 2004; Kaczanowska, Kozłowski 2009*) identified for instance several aspects of lithic technology most indicative of this complex phenomenon: changes in the lithic raw materials supply; systematic extraction of raw materials by mining; specialisation in production, including workshops for blade manufacture resulting in blade standardisation; use of pressure technique; refinement in production of tools used for harvesting crops, *i.e.* sickles.

This paper explores the role and main trends in lithic technology during the spread and development of early farming within the inland part of the western Balkans (modern-day Serbia, Montenegro, Bosnia and Herzegovina, and Croatia). Farming practices emerged in the southern and eastern parts of the western Balkans around 6250–6200 cal BC, and spread generally northwards along the major alluvial corridors, reaching the Pannonian Plain by 6000 cal BC (*Biagi* et al. *2005; Davison* et al. *2006; Borić, Dimitrijević 2007; Porčić* et al. *2020; Vander Linden, Silva 2021*). The initial phase of the neolithisation in the western Balkans is associated with the Starčevo culture (*c.* 6200/6000–5500/5400 cal BC), and the later phase (*c.* 5500/5400–4500 cal BC) was marked by the co-existence of the Vinča culture in the central Balkans (Serbia and Montenegro), the Sopot culture in northern Croatia (*i.e.* Slavonia) and northern Bosnia, and the Butmir culture in central Bosnia and Herzegovina (Tab. 1).

In the central Balkans, the process of neolithisation from the lithic point of view has usually been studied through the perspective of (dis-)continuity from the Late Mesolithic to the Early Neolithic (*e.g., Kozłowski, Kozłowski 1984; Kozłowski* et al. *1994; Mihailović 2001b; 2007a; 2007b; Bogosavljević Petrović, Starović 2013; 2016; Mitrović 2018*). The analysis of lithic assemblages from sites in the Iron Gates shows that during the Early Mesolithic, a variety of raw materials were used, while in the Late Mesolithic, in addition to the local raw materials – primarily quartz, quartzite, and heterogeneous groups of cherts – a completely new raw material type occurs, *i.e.* Balkan flint. This raw material has already been recognised as an integral part of the neolithisation of southeast Europe (*Gurova 2008; 2011; 2012a; 2012b; Gurova, Bonsall 2014; Gurova* et al. *2016; 2021; 2022; 2025*). The entire concept behind its use, from procurement, production methods and techniques, standardised products – blades and a formal toolkit – and distribution, represents a key marker to identify Early Neolithic communities in the Balkans and their position in the time of extensive social and economic changes. The introduction of this new concept in the central Balkans indicates new demands and standards of the society, which consequently required adaption of knowledge and skills. The presence of Balkan flint artefacts in Mesolithic contexts has been documented at several open-air sites in the Iron Gates, such as Lepenski Vir, Padina, and Vlasac (*Kozłowski, Kozłowski 1982; 1984; Borić, Dimitrijević 2007; Mitrović 2018*), and recently at a cave site in southeastern Serbia – Pešterija cave (*Mihailović* et al. *2024*). The latter also yielded a single medial blade fragment with a silica gloss, suggesting its function as a sickle blade and thus early agricultural practices. The occurrence of Balkan flint and sickle inserts in a Mesolithic context has been interpreted as possible evidence of the earliest contacts between Mesolithic and Neolithic communities (*Mihailović 2007b; Mihailović* et al. *2024*), which further influenced the production process and its organisation (*Bogosavljević Petrović, Starović 2013*).

The role of lithic industries in the process of neolithisation in eastern Croatia was recently elaborated by Rajna Šošić Klindžić *et al.* (*2018*). They concluded that the neolithisation did not follow a linear development from the lithic technology point of view. Old traditions

Phase	Early Neolithic	Late Neolithic	
Years range cal BC	*c.* 62/6000–55/5400 cal BC	*c.* 55/5400–5000 cal BC	*c.* 5000–4500 cal BC
Adriatic coast	Impresso	Danilo	Hvar
Continental Inland	Starčevo-Körös-Criş	Vinča A–B	Vinča C–D
Pannonian Inland	Starčevo-Körös-Criş	Vinča A–B, Sopot	Vinča C–D, Sopot
Sub-Alpine Inland	Starčevo-Körös-Criş	Kakanj	Butmir

Tab. 1. Chronological ranges of phases used in this study, and the cultural groups present in the studied regions (figure by I. Jovanović, after* Gaastra *et al.* 2019.2, Tab. 1; Porčić *et al.* 2020*).

and innovative practices existed simultaneously, pointing to interaction between these communities. According to Šošić Klindžić *et al.* (*2018*), the initial Balkan model of neolithisation had changed during the spread towards the west, primarily as a result of the adaptation to a new environment, and to a small extent through contacts with local foraging communities. One of the most important environmental factors was the availability of new raw materials, which caused modifications and changes in lithic technology and organisation of production. In terms of taxonomy, these changes express the replacement of the Starčevo culture by the Sopot culture. Interestingly, Balkan flint does not occur much across eastern Croatian Neolithic sites.

The relative lack of Late Mesolithic sites and lithic assemblages in the inland part of the western Balkans, in contrast to the rich and well-documented Mesolithic lithic records of the Eastern Adriatic zone (*Kaczanowska, Kozłowski 2018*), limits an approach solely aiming at identifying (dis-)continuity across the Mesolithic-Neolithic. By contrast, our work aims at characterising spatial and temporal variation across the entire Neolithic sequence, and to assess how such variation informs us about the wider process of neolithisation (Tab. 1). Working at multiple scales (site-based, regional and pan-regional), this paper thus considers what was spread and how, rather than who. The processes which affected the transmission of technological traits and shaped the local development of lithic technology across the western Balkans were initially assessed based on the technological variability in the Early Neolithic. The same methodological procedure was then applied to the Late Neolithic assemblages to see if the patterns observed for the Early Neolithic extended during the following period.

Research aims and hypotheses

The main objective of this research is to investigate the dynamics and mechanisms of neolithisation of the western Balkans from the lithic technology perspective, by testing the following hypotheses:

- during the Early Neolithic, lithic technology formed a relatively homogenous package across the continental stream of Neolithisation;
- during the Late Neolithic, greater diversity and the emergence of regional technological traditions occurred, as raw material procurement strategies and manufacturing practices became increasingly linked to local environments and changing cultural preferences.

These hypotheses are informed by previously published studies from the broader area of central and southeast Europe (*Kaczanowska, Kozłowski 1997; Šošić Klindžić 2011; Gurova 2014*). Early Neolithic lithic industries in these regions are typically characterised by relatively low variability and a preferential reliance on a limited range of high-quality materials, often acquired from distant sources. In contrast, the Late Neolithic is frequently associated with a broader exploitation of locally available resources. A comparable increase in regional diversity during the Late Neolithic has also been observed in farming regimes in the western Balkans (*Gaastra* et al. *2019; de Vareilles* et al. *2022*).

Additional research objectives include:

- identifying potential regional and/or period-specific technological traditions through the analysis of variability in lithic technology, particularly in raw material use, knapping methods and techniques, blade production, and tool assemblages;
- examining the transmission and potential exchange of technological traits amongst Neolithic communities across the western Balkans, and assessing patterns of mobility and interactions through time and space;
- evaluating the degree of continuity or discontinuity between Early and Late Neolithic lithic technologies in the region.

Data

The study is based on two interconnected datasets. First, 19 assemblages (seven Early Neolithic and twelve Late Neolithic) were analysed directly by one of the authors (*Jovanović 2022*). These were subsequently combined with published material to form broader comparative datasets for the Early and Late Neolithic, respectively. To ensure comparability, the combined dataset was analysed using the same statistical procedures, based on variables consistently reported across both newly analysed and published assemblages. The Early Neolithic dataset comprises forty assemblages attributed to the Starčevo culture, while the Late Neolithic dataset includes twenty-eight assemblages associated with the Vinča and Sopot cultures.

Data collection prioritised artefacts recovered from recent excavations conducted under controlled conditions, from secure archaeological contexts with accompanying archives and robust chronological attribution. As only a limited number of assemblages met all these

criteria, older museum collections were also included. Selection criteria comprised availability of the collections, contextual coherence (assemblages from mixed Early and Late Neolithic contexts were not included), and geographical representativeness. Unpublished lithic collections were examined in museums across Serbia, Montenegro, and Bosnia and Herzegovina in order to ensure broad spatial coverage of the Starčevo and Vinča cultural distributions. Some of these assemblages were excavated several decades ago and are accompanied by incomplete documentation. In many cases, contextual information is limited to inventory records or object labels indicating trenches, spits, or relative depths. These factors constrained the uniform application of analytical procedures across the entire sample, and some tests were therefore omitted for certain assemblages. For Croatia, given the availability of published data on Early Neolithic lithic technology, only published material was used.

The directly analysed assemblages are distributed across five areas of the western Balkans: south-eastern Serbia, central Serbia, northern Montenegro, north-eastern Serbia, and northern Bosnia (Fig. 1). Together they comprise 7885 chipped stone artefacts. These regions represent archaeologically significant settlement zones, predominantly located in major river valleys. South-eastern Serbia includes three Early and one Late Neolithic assemblages from sites in the Nišava Valley, investigated during the construction of the E-80 motorway (*Blagojević, Đorđević 2017; Lazić 2017*). Central Serbia includes one Early and one Late Neolithic assemblage from the Great Morava basin. Northern Montenegro (Lim Valley) comprises one Early and four Late Neolithic assemblages. North-eastern Serbia (Vršac area) includes one Early and one Late Neolithic assemblage. Northern Bosnia includes one Early and three Late Neolithic museum collections from the Doboj region, as well as two Late Neolithic assemblages from recent excavations in the Lower Vrbas Valley (*Jovanović 2014; Pandžić, Vander Linden 2014*). Most assemblages were analysed in full, except for Kosjerovo (northern Bosnia) and Potporanj (Vršac), where approximately 10% samples were studied.

Previous work on inter-site comparison of the data collected by the author (*Jovanović 2022*) indicates a coherent lithic technology amongst the analysed sites, with a certain level of regional variability (*Jovanović, Vander Linden 2019*). To evaluate whether this pattern

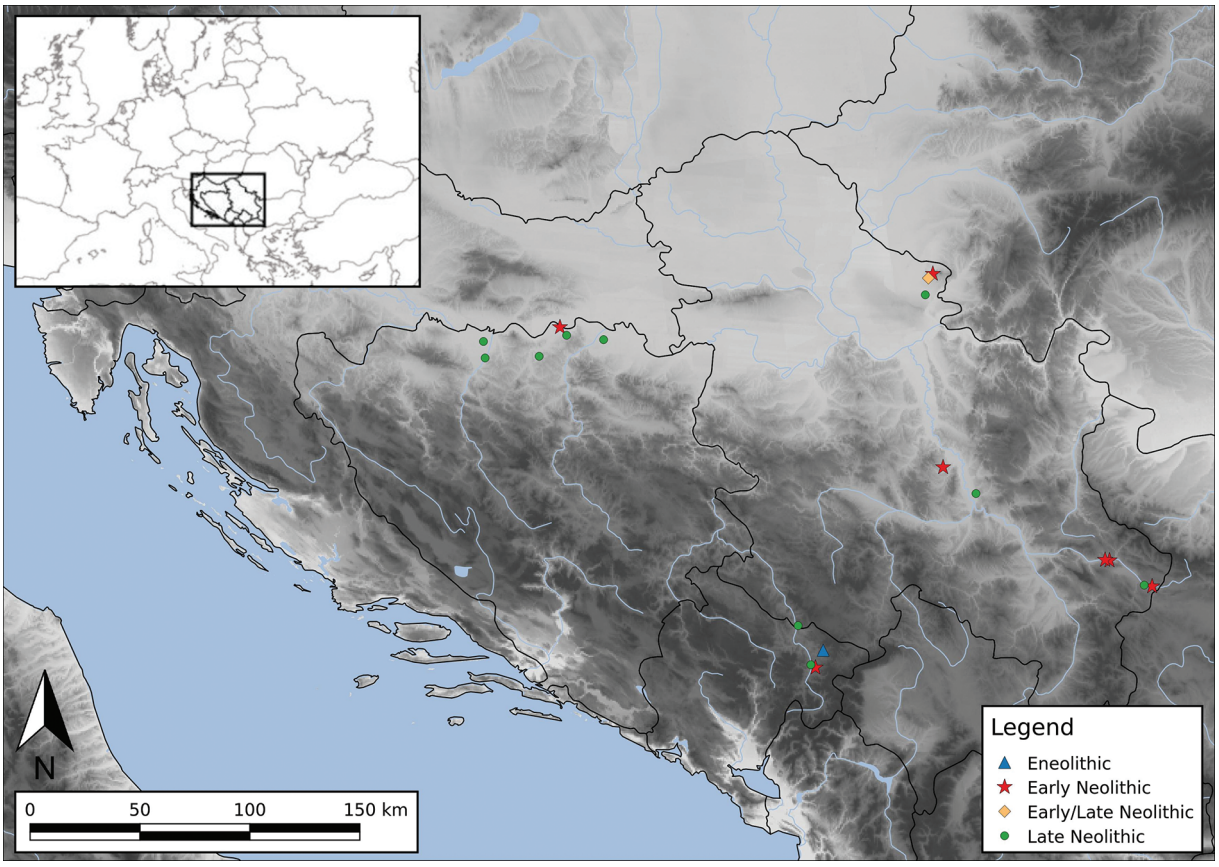


Fig. 1. Location of assemblages analysed by the author (figure by I. Jovanović).

persists at a broader scale, published assemblages were incorporated into the analysis. However, differences in recording systems and terminology, particularly regarding raw material identification, limit direct comparability. Consequently, inter-site comparison was restricted to variables consistently reported in the literature, including presence/absence and frequencies of major raw material types, technological categories of lithic artefacts, and tool types.

The Early Neolithic dataset (forty assemblages), attributed to the Starčevo culture, was grouped into seven geographical micro-regions based on spatial distribution and environmental setting (Fig. 2; Tab. 2 see below). With the exception of Šalitrena pećina, the only cave site in the dataset, all assemblages derive from open-air settlements, typically located in river valleys.

The Late Neolithic dataset (twenty-eight assemblages) includes both published material and directly analysed assemblages attributed to the Vinča and Sopot cultures (Fig. 3; Tab. 3 see below). Assemblages associated with the Butmir culture were not available for study. The Vinča material was further subdivided into Early (Vinča A–B/Tordoš I–II; seven assemblages) and Late (Vinča C–D/Pločnik I–II; fourteen assemblages) phases (*Whittle* et al. *2016*) (Tab. 1), enabling diachronic analysis across the Vinča sequence. These assemblages were grouped into five geographical micro-regions (Tab. 3 see below).

Methods

Raw material identification

Raw material classification was carried out through macroscopic examination of major rock types, following established practices in Neolithic lithic studies in the Balkans. This approach ensures analytical consistency across assemblages originating from different regions and research traditions, which is essential for assessing variability at inter-site and inter-regional scales. Given the uneven availability of petrographic and geochemical provenance data across both newly analysed and published assemblages, macroscopic identification was therefore retained as the primary classificatory level, enabling compatibility with existing datasets and robust comparison of raw material variability across the western Balkans.

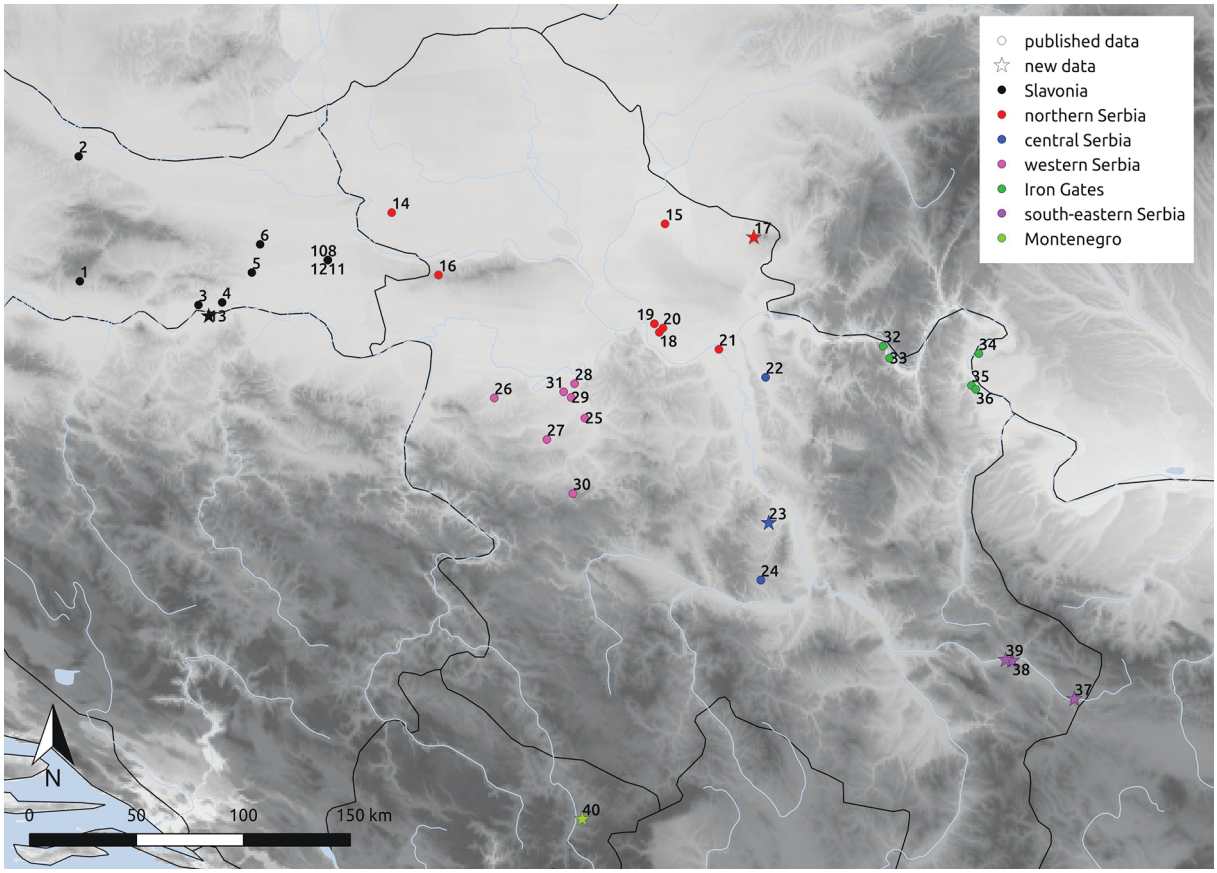


Fig. 2. Location of the Early Neolithic sites included in the analysis. Colours indicate analytical micro-regions used in the comparative analysis (figure by I. Jovanović).

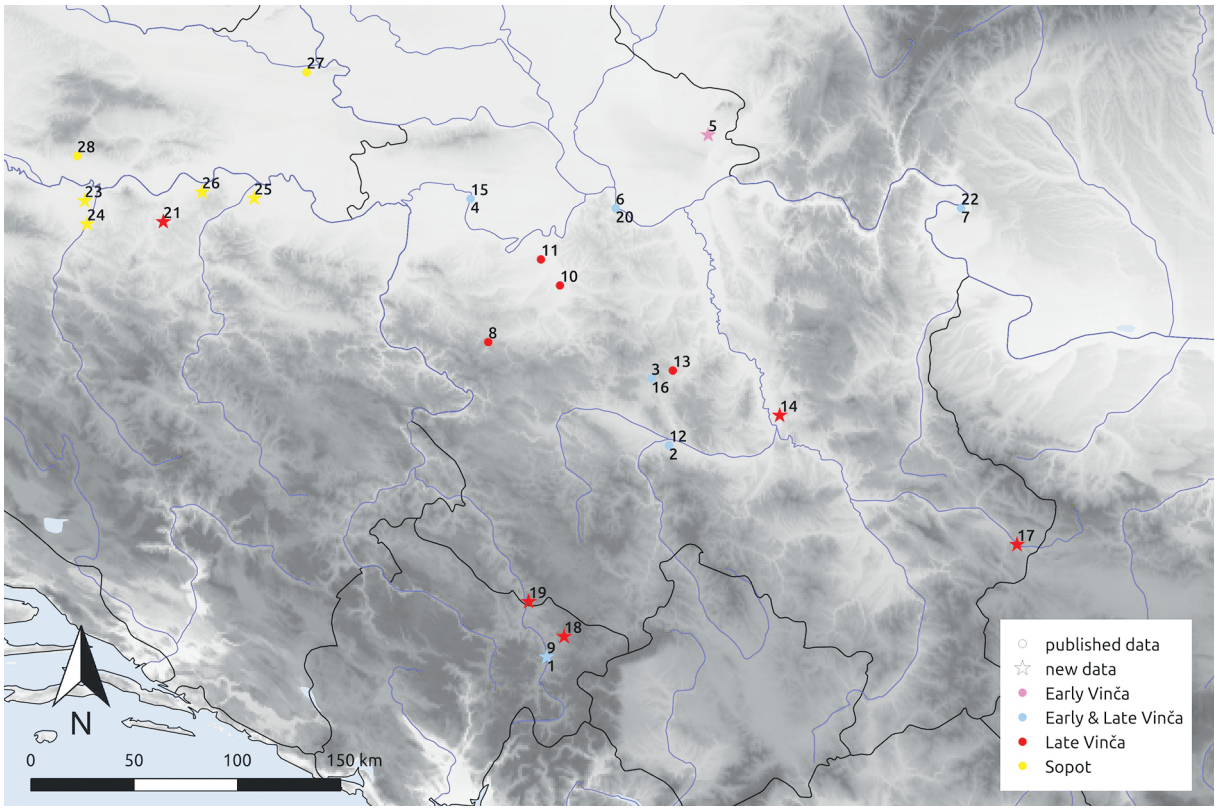


Fig. 3. Location of the Late Neolithic sites included in the analysis. Colours indicate analytical micro-regions used in the comparative analysis (figure by I. Jovanović).

To contextualise raw material procurement, lithic resources were broadly distinguished according to their distance from potential geological sources. Following commonly used approaches in Neolithic lithic studies (*e.g., Kaczanowska 2003; Gastov 2006; Crandell 2008*), materials may be classified as local, regional, and extra-regional depending on the distance between archaeological sites and geological outcrops. Such distinctions provide a general framework for discussing procurement strategies and the circulation of raw materials within Neolithic exchange networks.

The following section briefly describes the main raw materials identified in the analysed assemblages, focusing on their macroscopic characteristics, geological occurrence, and relevance for Neolithic lithic production.

Balkan flint is a siliceous raw material composed of a chalcedony–quartz matrix, occurring in beige, ochre, light brown and dark brown varieties. A distinctive feature is the presence of fossil relics, often visible as white spots (*Gurova, Nachev 2008*) (Fig.14.1). Nodules are generally irregular and covered by a white chalky cortex. The main geological sources of Balkan flint are associated with the Upper Cretaceous Mezdra Siliceous-Carbonate Formation of the Moesian Platform in northern Bulgaria *(Gurova 2008; 2012a; Bonsall* et al. *2010; Gurova* et al. *2016; 2021; 2022; 2025).* Trace-element analyses of a limited number of Early Neolithic artefacts from Serbia show geochemical correspondence with Balkan flint sources in northern Bulgaria, particularly near Nikopol, Somovit, Gortalovo, Bohot Lake, and Zhernov (*Gurova* et al. *2016*). On this basis, the Balkan flint identified in the assemblages discussed here is assumed to derive primarily from these Bulgarian outcrops. Balkan flint is one of the most widely distributed non-local raw materials in Early Neolithic assemblages across the central Balkans. It therefore represents an important indicator of long-distance procurement and exchange networks.

Chert is a fine-grained siliceous sedimentary rock composed of microcrystalline or cryptocrystalline quartz. It commonly forms as nodules or irregular concretions within limestone or chalk deposits, although larger concentrations may create continuous siliceous layers within the sediment mass (*Selley 2005*). Depending on the depositional environment, chert may contain skeletons of siliceous organisms such as radiolarians, diatoms, or sponges (*Halamić, Šošić Klindžić 2009*). It occurs in a wide range of colour varieties, re-

flecting impurities and inclusions derived from the surrounding sediments. In the archaeological literature of the western Balkans, the term *chert* (Serbian *rožnac*) is often used as a general designation for siliceous rocks. The same applies to the terms *flint* (Serbian *kremen*) and *silex*, which are sometimes used interchangeably (*Šošić Klindžić 2010a.192; Šarić 2014.22*). Due to the lack of petrographic analyses for both newly analysed and most of the published assemblages, the term *chert* is used here in a broad sense to refer to a range of siliceous raw materials that cannot be more precisely distinguished macroscopically (Fig. 16.4).

Chert with inclusions belongs to the broader group of cherts but is treated here as a separate raw material type due to its distinctive visual properties. It is characterised by a matrix occurring in red, reddish-grey, light grey, and dark grey colours, with contrasting white or grey inclusions (Fig. 16.5). This raw material has so far been identified only in collections from Potporanj near Vršac (north-eastern Serbia) and likely derives from outcrops in the Vršac Hill (Bogosavljević Petrović, pers. comm.).

Obsidian is a volcanic glass formed by the rapid cooling of molten rock, resulting in an amorphous texture, smooth surface, and conchoidal fracture, making it highly suitable for knapping. It is typically black (Figs. 14. 3;16.2), although other colour varieties also occur. As no confirmed obsidian sources are known in the western Balkans, obsidian artefacts found in this region are generally considered exotic, precious, and imported raw materials (*Tripković 2001*). Provenance studies indicate that obsidian artefacts from Neolithic sites in the western Balkans originate from Carpathian sources, particularly the Carpathian 1 (C1) sources in the Zemplín Hills of eastern Slovakia, which appear to have been most intensively exploited during the Late Neolithic, probably due to their favourable knapping properties (*Thorpe* et al. *1984; Greif 1995.89; Tripković, Milić 2009; Milić 2016*).

Opal is a hydrated form of silica ($SiO_2 \cdot nH_2O$), with an amorphous texture, relatively low hardness (5–6 on the Mohs scale), high brittleness and conchoidal fracture. Depending on formation conditions, opal may be transparent, translucent, or opaque, and may occur in various colours (Fig. 14.2).

Quartz is a crystalline form of silicon dioxide (SiO_2) and one of the most abundant and widely distributed minerals. It occurs in igneous, metamorphic, and sedimentary rocks. Quartz is a very hard material (7 on the Mohs scale) and typically breaks with a conchoidal fracture. In the assemblages analysed here, the most relevant variety is translucent hexagonal rock crystal, also referred to as *gorski kristal* in the geological and archaeological literature of the western Balkans (*e.g., Šarić 2014.27*). Quartz crystals and mineral deposits are widespread across the region, with particularly rich occurrences in central Serbia (Šumadija), especially in the area between the Great Morava and Western Morava rivers (*Kurešević 2005.22; Bogosavljević Petrović* et al. *2015.2–3;*).

Quartzite is a hard, non-foliated metamorphic rock composed almost entirely of quartz. Its granular texture makes it less suitable for tool production, especially blades and retouched tools, although its hardness (7 on the Mohs scale) makes quartzite pebbles well-suited for use as hammerstones. It is most commonly white but may occur in various colours depending on mineral impurities (Fig. 14.4). In the western Balkans, quartzite used in stone tool production usually originates from secondary sources, especially river deposits. An exception is the Early Neolithic site of Blagotin, where a substantial quartzite industry appears to derive from nearby primary sources (*Šarić 2014.27*). Since the attributes indicating intentional knapping are often difficult to identify on quartzite artefacts, such material may be overlooked during excavation and therefore underrepresented in archaeological collections. Consequently, differences in quartzite frequencies between sites in the western Balkans should be interpreted with caution.

Radiolarite is a siliceous sedimentary rock formed by the accumulation of radiolarian skeletons on the ocean floor (*Anderson 2008*). In geological terms, radiolarites *sensu stricto* are cherts containing more than 50% radiolarian tests embedded in a siliceous matrix, whereas radiolarian cherts contain less than 50% radiolarian tests (*Ruiz-Ortiz* et al. *1989,* cited in *Halamić, Šošić Klindžić 2009*). Distinguishing between these varieties generally requires microscopic or geochemical analysis. Within the study area, deposits of radiolarite and radiolarian cherts of Triassic and Jurassic age occur within the Dinaride Ophiolite Zone, extending from north-western Croatia through Bosnia and Herzegovina into south-western Serbia (*Hrvatović 2006.72–74*). Several outcrops have been identified in northern Bosnia and Croatia (*Halamić* et al. *2001; 2005; Halamić, Šošić Klindžić 2009*). Radiolarite artefacts identified in the analysed assemblages were

usually produced from river pebbles, suggesting procurement from secondary deposits. The material occurs in several colour varieties, most commonly dark reddish-brown and grey (Fig. 16.3).

Silicified limestone belongs to the broader category of cherts, more precisely to radiolarian cherts (*Halamić* et al*. 2001; 2005; Halamić, Šošić Klindžić 2009*). Due to its distinctive appearance and geographic distribution, it is treated here as a separate raw material type and designated as *silicified limestone*, following the terminology proposed by Šošić Klindžić (*2010b*). This high-quality knappable material contains a very high proportion of SiO_2 (>90%), with most of the silica being of biogenic origin. It most commonly occurs in reddish-brown colour, although beige varieties and mixtures of red and beige are also present (Fig. 14.5). Several sources of silicified limestone have been identified in northwestern Croatia and northern Bosnia and Herzegovina (*Halamić* et al. *1999; 2001; 2005; Halamić, Šošić Klindžić 2009*). This raw material is particularly common in Early Neolithic assemblages from northern Bosnia and Herzegovina.

White soft stone is a generic term used in the archaeological literature of the central Balkans to describe a group of light-coloured siliceous raw materials with similar macroscopic characteristics (Fig. 16.1). Neolithic communities of the region, particularly during the Vinča period, show a marked preference for such materials in both chipped and ground stone industries. Various terms have been used to describe this category, including *white light stone* (*Antonović 1997; 2003*), *white rocks of various origins* (*Šarić 2014.28*), and *white soft stone* (*Bogosavljević 1990; Bogosavljević Petrović 1991; 1999; 2015.280*). Previous studies show that this category includes several lithologies. Based on the analysis of ground stone assemblages, Dragana Antonović (*1997; 2003*) suggested that most tools classified as white light stone were made of silicified magnesite, although silicified limestone, porcelanite, and tuff were also identified. Macroscopic observations of chipped stone artefacts led Josip Šarić (*2014*) to propose that many specimens were made of silicified tuff, with occasional occurrences of silicified limestone and petrified wood. Petrographic analyses of chipped stone artefacts from the Vinča site of Belovode have shown that this raw material group also includes various types of white cherts, ranging from microcrystalline to organogenic varieties (*Cvetković, Šarić 2010*, cited in *Bogosavljević Petrović, Marković 2011*). Artefacts made of these white cherts share similar macroscopic characteristics with materials described as white opals in central Serbia and white cherts at sites such as Selevac, and were predominantly used for blade production. In the present study, the definition proposed by Vera Bogosavljević Petrović is adopted, as it is based on petrographic analysis of chipped stone assemblages. The term *white soft stone* is therefore used here as a broad designation for this group of visually similar siliceous materials.

Artefact analysis

Artefacts were studied using the *chaîne opératoire* approach (*Leroi-Gourhan 1964; Lemonnier 1986; Pelegrin 1990; 1993; Lemonnier, Speth 1992; Inizan* et al. *1999; Audouze* et al. *2017; Audouze, Karlin 2017; Delage 2017; Porqueddu* et al. *2023*) and the attribute analysis (*Clay 1976; Tafelmaier* et al. *2022*). The assemblages were first sorted based on raw material type. Within each raw material group, artefacts were classified into different technological categories based on their position in the operational sequence. Each artefact was subsequently studied using the attribute analysis, which involved recording the presence or absence of various morpho-technological traits and taking a series of measurements.

A comprehensive amount and wide range of data obtained in this way were analysed using a combination of statistical tests, including both exploratory and inferential analyses, to assess key trends in raw material use, operational sequence, and tool repertoire. Significant patterns and relationships in data were explored using Correspondence Analysis (CA). This test is particularly suitable for comparing assemblages of different sizes and datasets consisting of counts or presence/absence of nominal categories. The analysis was carried out directly on the original data matrix of values of objects on variables, without the intervening information-losing step of creating similarities or distances (*Shennan 1997.308*).

Correspondence Analysis was employed primarily as an exploratory tool to visualise patterns of variability among assemblages. The analysis treats the frequencies of variables as equivalent inputs and does not incorporate external parameters such as the distance between archaeological sites and geological sources of raw materials. Consequently, differences between locally available and non-local raw materials are not weighted in the CA calculations themselves. In this study, the CA results are therefore interpreted cautious-

ly and used mainly to identify patterns of similarity and differences among assemblages. These statistical patterns are subsequently evaluated in light of archaeological and geological knowledge, including the distinction between local and non-local raw materials. This approach allows the statistical structure of the dataset to be visualised while contextualising the results within broader discussions of raw material procurement and exchange networks.

To examine the variability of categorical data within and between assemblages, as well as across regional and cultural groups, permutation analysis of variance (PERMANOVA) was used. This technique evaluates differences in both the location and spread of variables in a multivariate space, based on any distance measure, in this case using the Bray-Curtis dissimilarity index. PERMANOVA enabled the definition of conventions at both small (site) and large (region) scales, and the identification of potential regionally and/or chronologically specific technological traditions. All statistical tests were performed in Paleontological Statistics Software Package (PAST), version 4.03 (*Hammer* et al. *2001*).

Analysis and results

The following sections present the results of the statistical and comparative analyses of lithic assemblages, focusing on variability in raw material procurement, technological organisation and tool composition across the Early and Late Neolithic datasets.

The analytical procedure described above was applied systematically to both the Early and Late Neolithic datasets. Results are presented separately for each period in order to facilitate chronological comparison; however, the same classificatory framework and statistical tests were used throughout to ensure analytical consistency.

A combination of qualitative and quantitative data gave an insight in the general structure of the assemblages, the main intention and trend in the lithic production, as well as knapping methods and techniques. Given the fact that stone tool production involves various technological processes and activities, which result in different knapping products, based on the frequency of technological classes of artefacts it was possible to determine what stages of the operational sequence are present at each site, and thus estimate their role in the organisation of lithic technology.

Early Neolithic

Raw materials

Macroscopic examination of Early Neolithic assemblages revealed a relatively wide range of raw materials, which mainly coincides with the materials found at all known Starčevo sites in the central Balkans (see *Šarić 2014.Tabs. 1–2*). It includes Balkan flint, various kinds of chert and opals, obsidian, quartz, quartzite, radiolarite, silicified limestone, and white soft stones (varieties of raw materials with similar macroscopic characteristics and of white colour) (see *e.g., Bogosavljević Petrović 2015.280*).

Figure 4 presents the results of the CA analysis in the form of a biplot. The first CA axis accounts for 37.69% of the total variation, and the second one for 18.62% (Eigenvalues 0.84 and 0.42 respectively; raw data in Tab. 13). Axis 1 separates silicified limestone and radiolarite from the rest of the raw materials, while axis 2 introduces differences between the main types and quartzite. A cluster on the right side of the x-axis, positioned around silicified limestone and radiolarite, consists solely of Slavonian sites. The sites from all other regions are clustered on the left side of the first component, around a wider range of raw materials. Within this big cluster, it is possible to identify some structure revealing regional differences in preference of raw materials. These are a cluster of sites from western Serbia grouped around chert; a cluster of sites from southeastern Serbia grouped around Balkan flint, and sites from central Serbia grouped around quartzite. Contrastingly, sites from northern Serbia and the Iron Gates reflect higher variability of raw materials amongst them, with both regions placing a greater importance on Balkan flint.

Results of the PERMANOVA indicate that at least one group of sites significantly differs from the others (TSS =15.12, SSw=10.49, F=2.427, p=0.0001). In order to evaluate which groups are significantly separated, a posteriori pairwise comparison was performed (Tab. 4; F-values are given in the Appendix, Tab. 14). The analysis indicates coherency in raw material use in most of the Starčevo area distribution, apart from two geographically separated regions, Slavonia and the Iron Gates, which also differ from one another. Slavonia presents a unique raw material structure, and local Early Neolithic communities had a strong preference for silicified limestone, which came from the neighbouring area around Doboj in northern Bosnia (*Šošić Klindžić 2010a*). They also regularly used radiolarite

and various kinds of cherts. However, as seen in Table 4 there is no significant difference between this region and central Serbia, as well as Montenegro. While the latter situation cannot be explained due to the sole presence of a single Early Neolithic site, it is noteworthy that central Serbia presents local varieties of cherts and quartzite, which played an important role in stone tool production. Like Slavonia, the Iron Gates is also statistically significantly different from the majority of the regions, apart from central Serbia and Montenegro (Tab. 4). Besides locally available cherts and quartzite, which were broadly exploited by the Early Neolithic communities of the Iron Gates, Balkan flint also had a key role in stone tool production in this region. A similar range and importance of raw materials was observed in central Serbia, but the biggest similarity between these two regions is reflected in the intensive use of quartzite, which did not occur in other regions (see Appendix, Tab. 13).

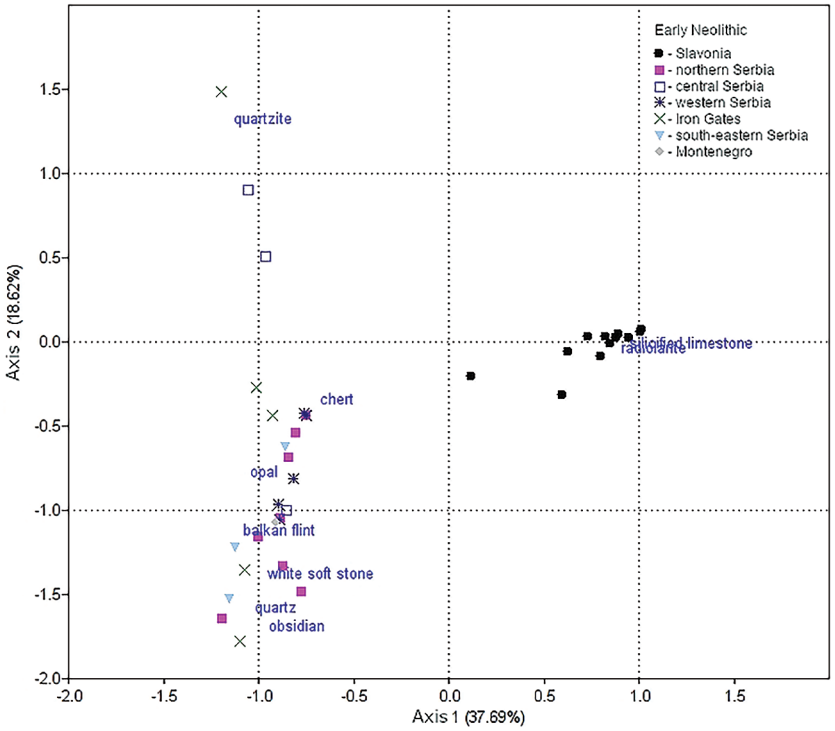


Fig. 4. Correspondence analysis of raw materials from Early Neolithic sites. The analysis is based on frequency; data are classified into seven different regions (figure by I. Jovanović).

Technological categories

A comparison of the reduction sequences with regard to the raw materials was not possible to perform due to the different levels of information in the literature between the regions. The frequencies of technological classes of artefacts were often given for the entire assemblage, without taking into account raw material types. Using this limited information for an inter-site comparison can result in misleading inferences about technological processes and choices involved in stone tool production, especially when keeping in mind the co-occurrence of different *chaînes opératoires* observed at some sites, and the use of different raw materials for different purposes. For instance, the flake- and blade-oriented operational chains dominate the assemblage of Međureč, whereby flakes were mostly made of quartzite, while blades were made of various raw materials, mostly opal (*Jovanović, Vander Linden 2019.241*).

In view of the lack of consistency of recording systems, inter-regional comparison was done based on the frequency of the technological classes of artefacts, com-

	Slavonia	northern Serbia	central Serbia	western Serbia	Iron Gates	south-eastern Serbia	Montenegro
Slavonia		**0.0008**	0.0511	**0.0021**	**0.0001**	**0.0053**	0.2080
northern Serbia	**0.0008**		0.8703	0.4621	**0.0271**	0.4013	0.7837
central Serbia	0.0511	0.8703		0.3928	0.0708	0.1031	1.0000
western Serbia	**0.0021**	0.4621	0.3928		**0.0056**	0.1186	0.7420
Iron Gates	**0.0001**	**0.0271**	0.0708	**0.0056**		**0.0168**	0.1691
south-eastern Serbia	**0.0053**	0.4013	0.1031	0.1186	**0.0168**		0.2546
Montenegro	0.2080	0.7837	1.0000	0.7420	0.1691	0.2546	

Tab. 4. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of raw materials from Early Neolithic sites. Significant p-values are shown in bold (figure by I. Jovanović).

bined for all raw materials, which include flakes, chips, rejuvenation flakes, crests, blades, debris, and cores; evidence of the initial phase of the reduction sequence, *i.e.* cortical artefacts are missing. Figure 5 presents the results of the correspondence analysis. The first two axes, pictures on the biplot, account for over 72% of the variation, with 40.44% for the first axis, and the second 32.16% (Eigenvalues 0.09 and 0.07 respectively; raw data in Tab. 15).

Axis 1 separates flakes and debris from all other categories, whereby waste products are also separated from the rest along axis 2. The majority of the sites form a coherent cluster around the following technological categories of artefacts: blades, flakes, rejuvenation flakes, and cores. This suggests that similar technological processes – comprising core preparation, blank production, and maintenance and rejuvenation of cores – were practised across most of the area. The main intention was to produce blades, which were then modified into a desirable tool or used without previous modification. The prevalence of blade cores over flake cores (Fig. 6.1–6; raw data in Appendix, Tab. 17) in almost all regions confirms that a blade-oriented industry was the focal point for the lithic technology during the Early Neolithic in the western Balkans. However, an exception is the Iron Gates with the flake-oriented industry (Fig. 6.5), which is confirmed by a large number of flakes and flake cores made of quartzite at Knjepište, Ušće Kameničkog potoka, and Velesnica. A quartzite flake industry has also been confirmed at at least one site in almost each region. These are Galovo in Slavonia, Donja Branjevina and Kozluk in northern Serbia, Međureč and Blagotin in central Serbia, and Popovica brdo in western Serbia.

The observed coherence in lithic technology during the Early Neolithic was then tested using PERMANOVA (TSS=11.68, SSw=9.066, F=1.586, p=0.0403). This test confirmed that, apart from the Iron Gates, most of the regions are similar (Tab. 5; F-values are given in the Appendix, Tab. 16).

Tools

In most regions, both flakes and blades were used in similar proportions as blanks for making tools, except in southeastern Serbia and Montenegro where tools made on blades are more common (Fig. 7.1–6 and 8. 1–6; for the raw data of ratios between tools made on flakes and tools made on blades see Appendix, Tab. 18). Interestingly, the Iron Gates shows an inner variability in preference of tool blanks; two sites, Velesnica and Ušće Kameničkog potoka, have more tools made on flakes than on blades, while the rest of the sample has either similar or a much higher proportion of tools made on blades.

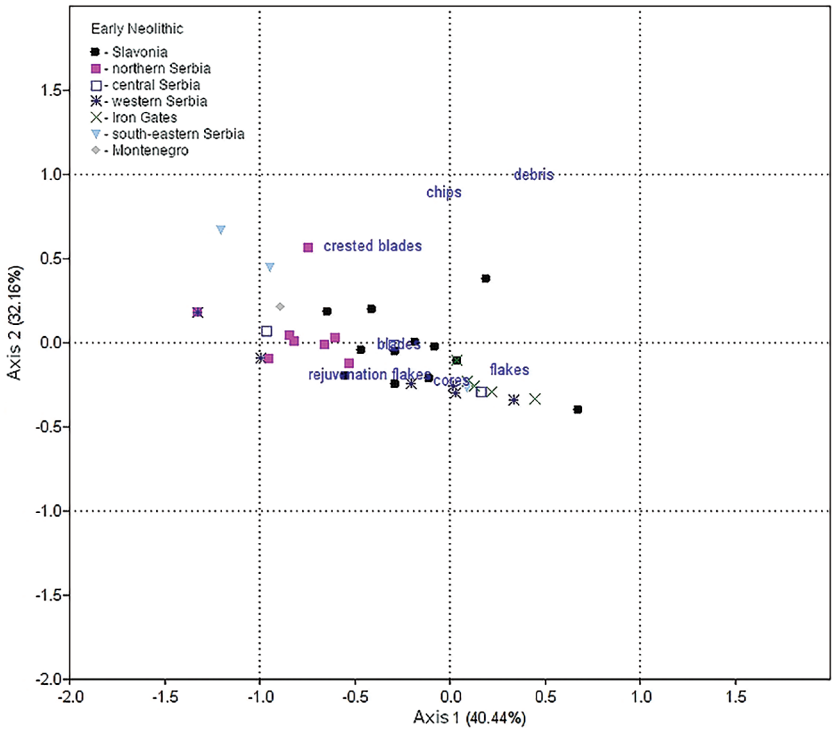


Fig. 5. Correspondence analysis of technological categories from Early Neolithic sites. The analysis is based on frequency; data are classified into seven different regions (figure by I. Jovanović).

To identify the main trend in Early Neolithic tool production across the entire research area, the assemblages were first compared based on the frequency of different tool types using CA (Fig. 9). The first axis represents 38.10% of total variation, and the second 23.57% (Eigenvalues 0.22 and 0.14 respectively; raw data in Tab. 19). Laterally retouched blades are separated from all other tool types along axis 1, and denticulates, backed blades, and endscrapers along axis 2. The spatial distribution of the sites with regard to the tool types indicates that the majority of the regions overlap and cluster together. Laterally retouched blades were the most frequently made and used

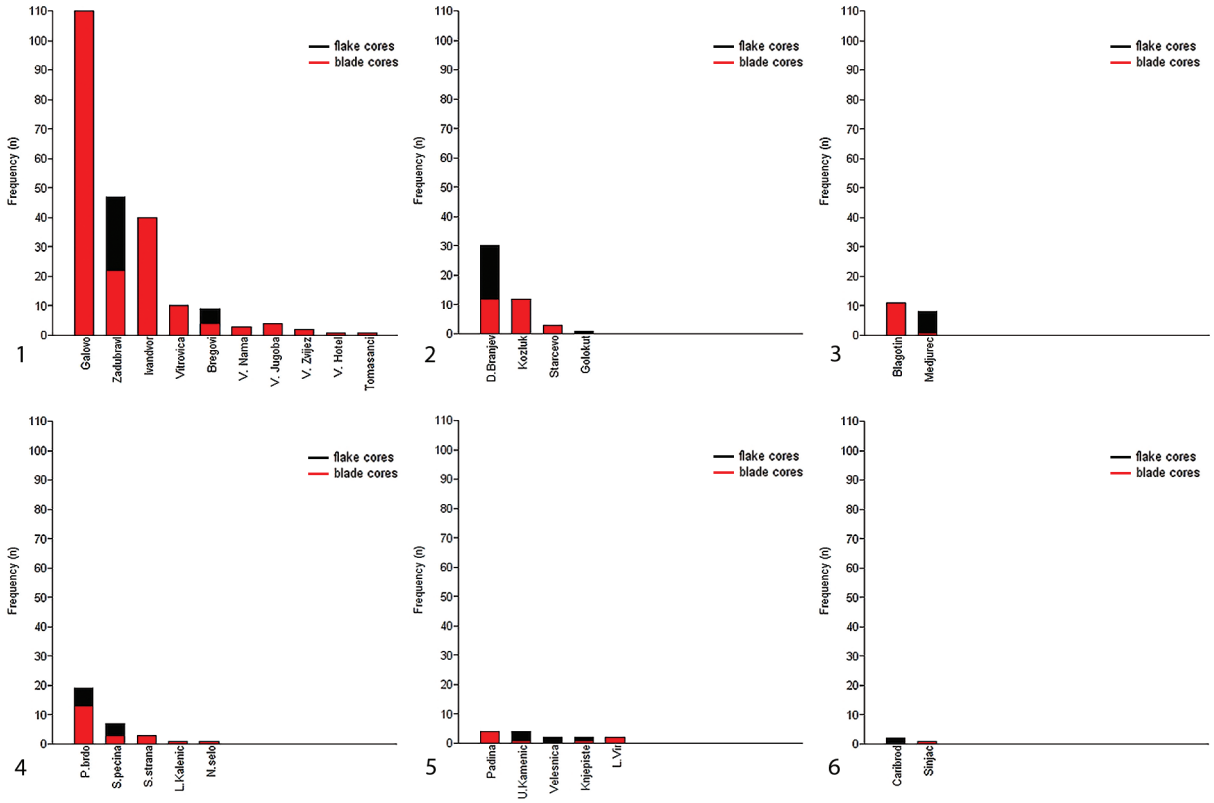


Fig. 6. Flake and blade cores from Early Neolithic sites shown by regions.* 1 *Slavonia;* 2 *northern Serbia;* 3 *central Serbia;* 4 *western Serbia;* 5 *The Iron Gates;* 6 *south-eastern Serbia (figure by I. Jovanović).

tools during the Early Neolithic in the western Balkans, followed by truncations and laterally retouched flakes. Endscrapers were also widely used across the whole region, with the largest proportion recorded at Popovića brdo in western Serbia (see Appendix, Tab. 19).

The assemblages were further compared using PERMANOVA (TSS=10.15, Ssw=8.47, F=1.022, p=0.4249). The results (Tab. 6; F-values are given in the Appendix, Tab. 20) indicate that the range and use of tools in the western Balkans were very coherent during the Early Neolithic. The only difference is noted between the Iron Gates and western Serbia. This is probably caused by a generally small number of retouched specimens found in western Serbia (see Appendix, Tab. 19). The only site in this region with a large amount of tools is Popovića brdo, where the range and frequency of tools are in accordance with the main trends occurring across the entire area.

Late Neolithic

Due to the heterogeneity of information amongst published data, which also differ to a certain extent from

	Slavonia	northern Serbia	central Serbia	western Serbia	Iron Gates	south-eastern Serbia	Montenegro
Slavonia		0.3414	0.9984	0.0936	**0.0152**	0.1359	0.7895
northern Serbia	0.3414		0.6366	0.6426	**0.0198**	0.4754	0.7836
central Serbia	0.9984	0.6366		0.3996	**0.019**	0.5015	1
western Serbia	0.0936	0.6426	0.3996		**0.006**	0.5705	0.6128
Iron Gates	**0.0152**	**0.0198**	**0.019**	**0.006**		**0.0168**	0.1691
south-eastern Serbia	0.1359	0.4754	0.5015	0.5705	**0.0168**		0.5045
Montenegro	0.7895	0.7836	1	0.6128	0.1691	0.5045	

Tab. 5. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of technological categories from Early Neolithic sites. Significant p-values are shown in bold (figure by I. Jovanović).

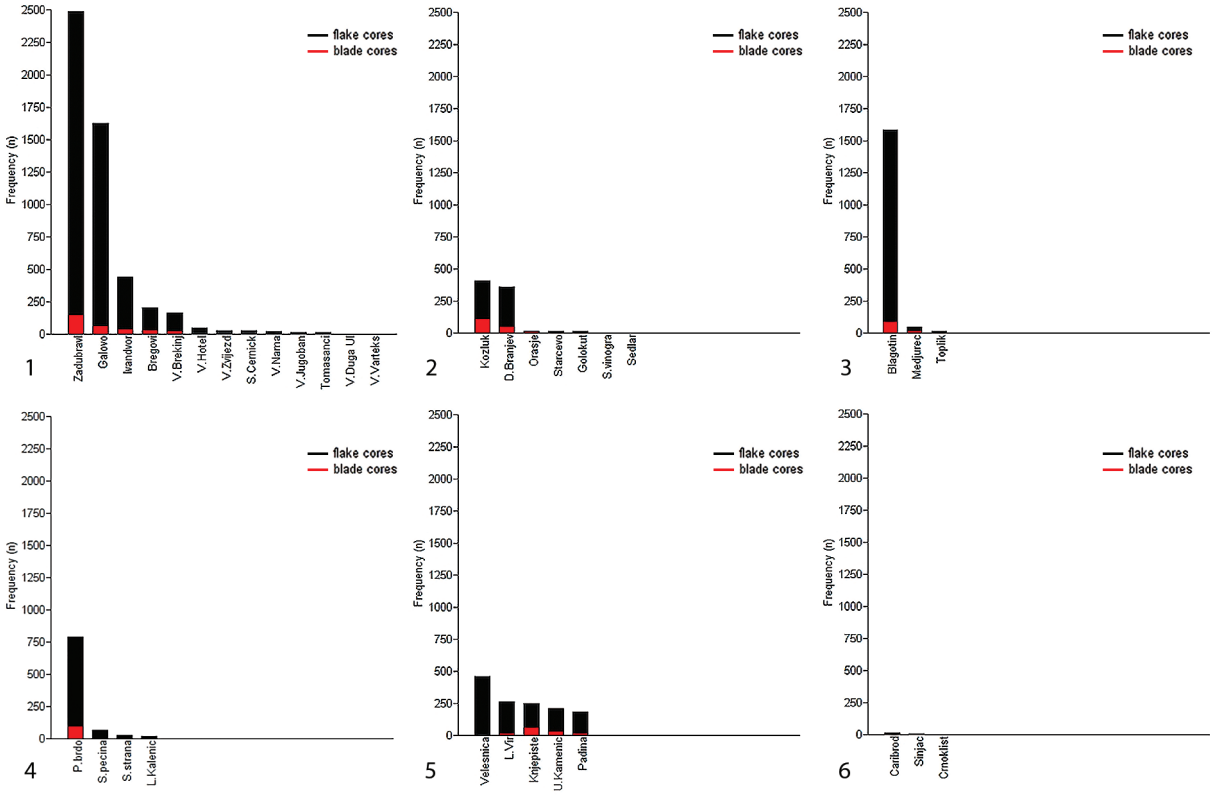


Fig. 7. Ratio of the total number of flakes and retouched flakes from EN sites by regions:* 1 *Slavonia;* 2 *northern Serbia;* 3 *central Serbia;* 4 *western Serbia;* 5 *The Iron Gates;* 6 *south-eastern Serbia (figure by I. Jovanović).

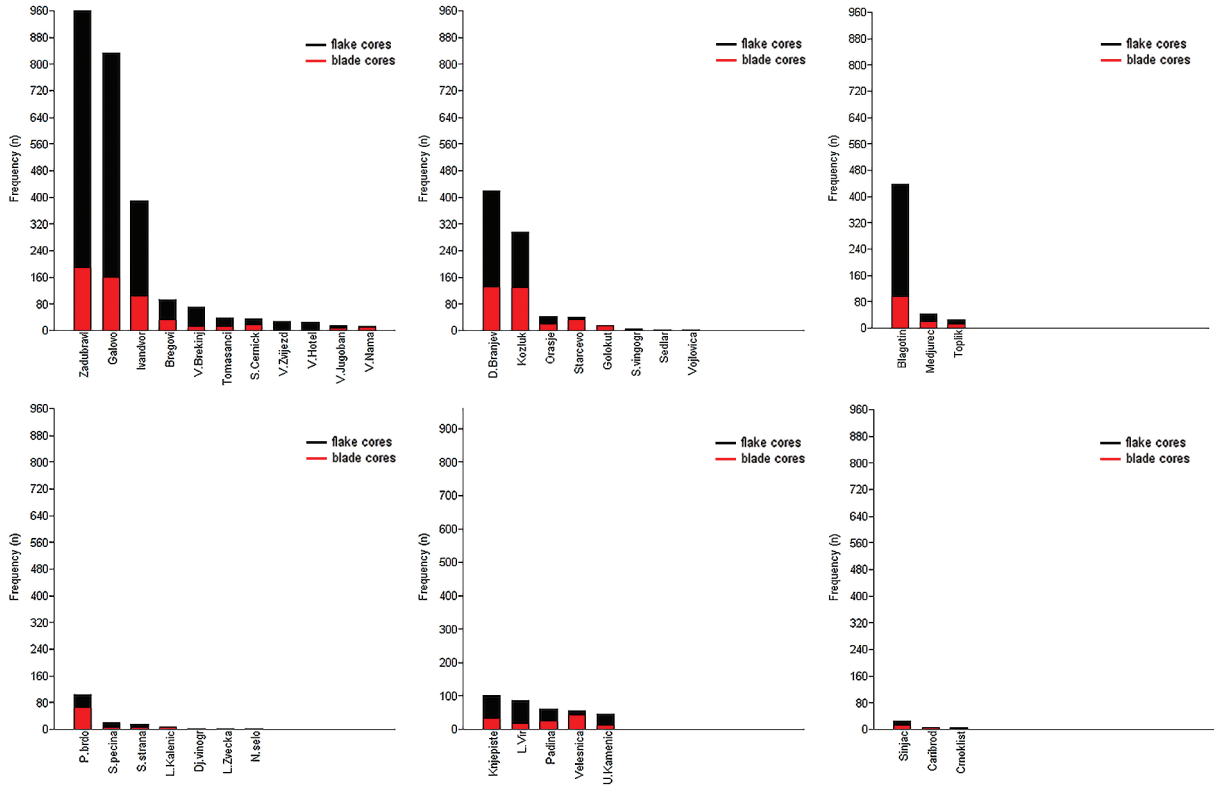


Fig. 8. Ratio of the total number of blades and retouched blades from EN sites by regions:* 1 *Slavonia;* 2 *northern Serbia;* 3 *central Serbia;* 4 *western Serbia;* 5 *The Iron Gates;* 6 *south-eastern Serbia (figure by I. Jovanović).

newly obtained data, it was not possible to follow exactly the same procedure as for the Early Neolithic datasets, particularly the *chaîne opératoire* approach. Thus, the comparison focuses on raw material and tool types exclusively, since these features were rather consistently recorded across the entire research area. In order to identify the main patterns and trends in Late Neolithic lithic technology in the western Balkans, all three datasets – Early Vinča, Late Vinča and Sopot – were compared. Vinča sites were further compared based on their spatial distribution and the geographical properties of the areas where the sites are located.

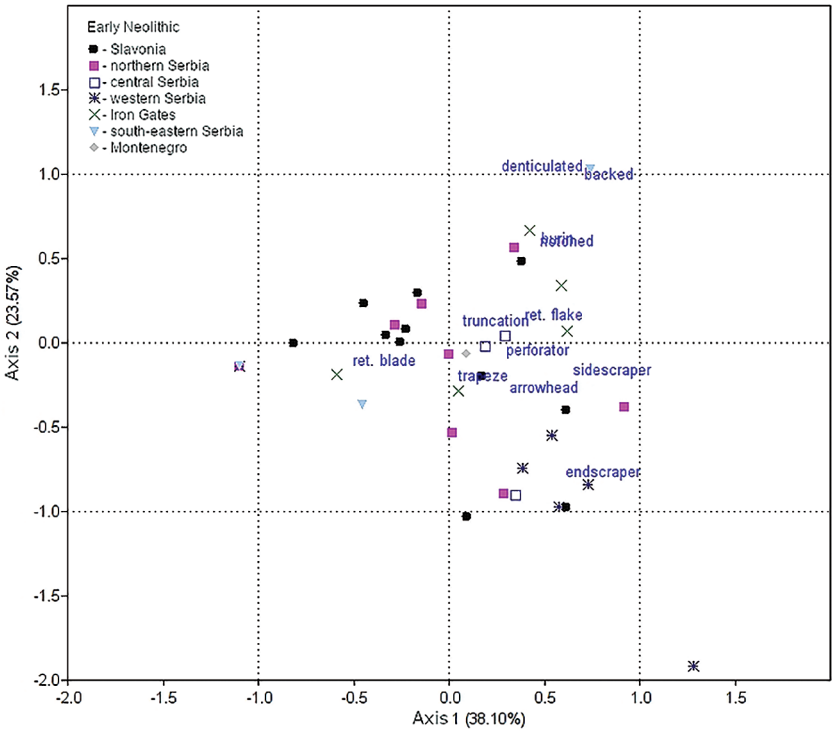


Fig. 9. Correspondence analysis of tool types from Early Neolithic sites. The analysis is based on frequency; data are classified into seven different regions (figure by I. Jovanović).

Raw materials

Macroscopic analysis of the Late Neolithic assemblages shows a similar selection of raw materials as in the previous period, with the exception of silicified limestone, which is now lacking. To explore the main trends and organisation of raw material economy, assemblages were compared using CA (Fig. 10). The first CA axis accounts for 30.91% of variation, and the second one for 22.90% (Eigenvalues 0.37 and 0.27 respectively; raw data in Appendix, Tab. 21). The distribution of data along axis 1 suggests no significant differences in the dataset, while axis 2 underlines the distinction between obsidian and other materials. The plot shows that the Early and Late Vinča datasets greatly overlap, indicating the continuity in choice and use of raw materials throughout the entire Vinča sequence, with a slightly broader range during its late phase. White soft stone was clearly a trend distinctive for all Vinča assemblages, however, various kinds of opals and cherts were also regularly used for tool-making. Sopot assemblages form a distinct cluster, differing from both Late and especially Early Vinča assemblages, and reflecting considerably lower variability of raw materials amongst the sites, with radiolarites and cherts as the main resources.

As the Sopot sites are distributed in a geographically different region from the Vinča sites, apart from Visoko brdo (see Fig. 3), further analysis focuses on identifying potential regional variations amongst Vinča sites.

	Slavonia	northern Serbia	central Serbia	western Serbia	Iron Gates	south-eastern Serbia	Montenegro
Slavonia		0.8403	0.852	0.1281	0.327	0.4425	1
northern Serbia	0.8403		0.8524	0.4375	0.2309	0.4906	0.8881
central Serbia	0.852	0.8524		0.1829	0.9627	0.1997	0.7557
western Serbia	0.1281	0.4375	0.1829		**0.0123**	0.7608	0.6356
Iron Gates	0.327	0.2309	0.9627	**0.0123**		**0.0198**	0.5032
south-eastern Serbia	0.4425	0.4906	0.1997	0.7608	**0.0198**		0.7458
Montenegro	1	0.8881	0.7557	0.6356	0.5032	0.7458	

Tab. 6. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of tool types from Early Neolithic sites. Significant p-values are shown in bold (figure by I. Jovanović).

Figure 11 presents the results of a CA analysis on raw materials from Vinča sites, with the first axis accounting for 34.75% of the total variation, and the second CA axis 19.92% (Eigenvalues 0.38 and 0.21, respectively; raw data in Appendix, Tab. 22). Both axes separate obsidian and radiolarite from all other raw material types. Regarding the relation between the sites, CA shows that northern Serbia is very different from the rest of the research area. This is a region where obsidian occurs at both Early and Late Vinča sites, which implies that this raw material was an important component of stone tool production throughout the entire Vinča sequence in northern Serbia. Another feature that distinguishes this area from the southern regions is a complete lack of quartz and a minor presence of white soft stone. Apart from Montenegro, all other groups are mainly clustered around the centre of the first axis. They slightly overlap, signalling the existence of certain inter-regional variabilities in raw material preferences.

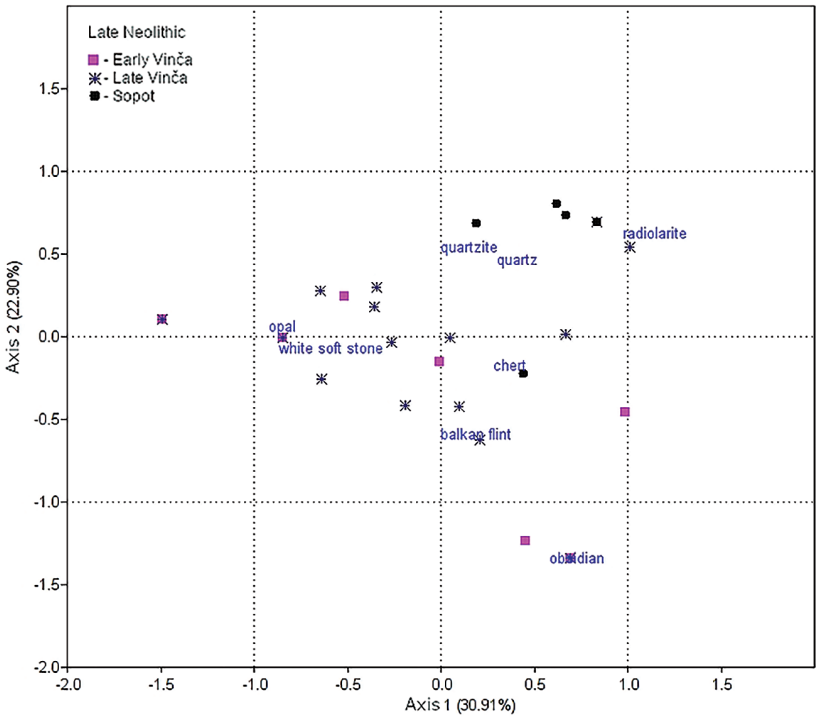


Fig. 10. Correspondence analysis of raw materials from Late Neolithic sites. The analysis is based on presence/absence (figure by I. Jovanović).

To assess variability within and between different regions, the same dataset (Appendix, Tab. 22) was analysed by PERMANOVA. Results indicate that at least one group of sites significantly differs from the others (TSS=2.89, SSw=1.323, F=4.74, p=0.0012). To evaluate which groups are significantly dissimilar, a posteriori pairwise comparison was performed (Tab. 7; F-values are given in the Appendix, Tab. 23). It confirms that the region of northern Serbia is significantly different from almost all regions located south of it, apart from Montenegro. The results also indicate that central Serbia is statistically significantly different from the region of eastern & southeastern Serbia; the main difference between these two regions is reflected in the complete absence of quartz, quartzite, and radiolarite amongst eastern and southeastern Serbia assemblages.

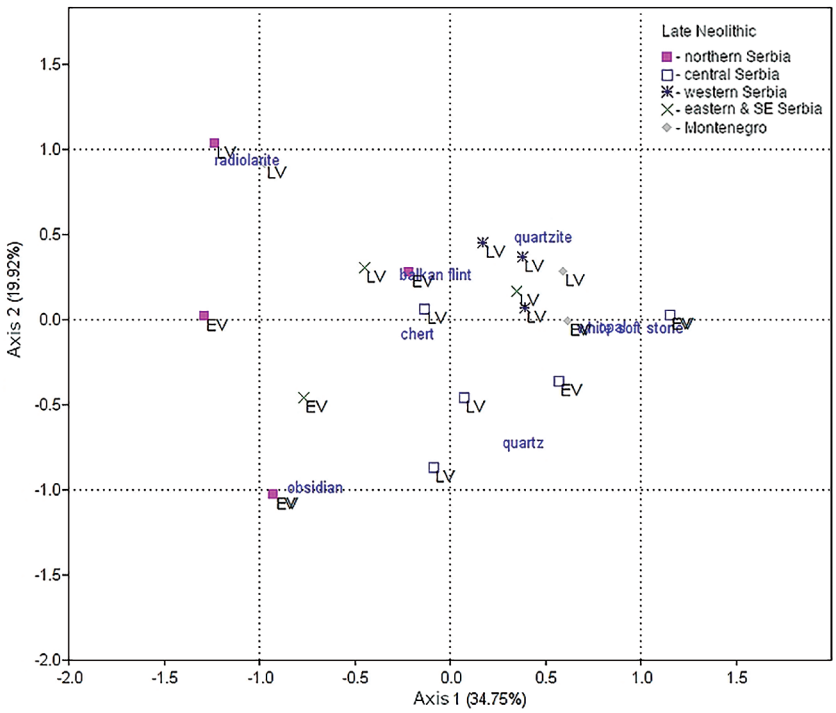


Fig. 11. Correspondence analysis of raw materials from Early Vinča (EN) and Late Vinča (LN) sites. The analysis is based on presence/absence; data are classified into five different regions (figure by I. Jovanović).

In order to appraise a potential chronological development during the Vinča sequence, PERMANOVA analysis was performed on

Early and Late Vinča sub-datasets separately. The results show no regional differences in raw material use between Early Vinča assemblages (TSS=1.054, SSw=0.2251, F=3.684, p=0.1243; see Tab. 8; F-values are given in Appendix, Tab. 24), while statistically significant differences only appear between central and western Serbia for the Late Vinča (TSS=1.77, SSw=0.8692, F=2.333, p=0.0458; Tab. 9; F-values are given in Appendix, Tab. 25).

Tools

As the type of blanks used for making tools had not been consistently recorded amongst published data, with much of the information being descriptive, inter-site comparisons of Late Neolithic tools were purely based on the frequency of tool types. Unlike previous analyses based on the presence/absence of raw materials, the inter-site comparisons of tools were applied to count data (see the Appendix, Tab. 26). To explore the range and main trends in tool production during the Late Neolithic in the western Balkans, assemblages were initially compared using CA. Figure 12 shows the corresponding results, with the first CA axis accounting for 42.82% of the variation, and the second CA axis 22.83% (Eigenvalues 0.40 and 0.21, respectively). Axis 1 separates laterally retouched blades and perforators from the rest of the tool types. Axis 2 groups all types into three clusters: 1. laterally retouched blades and perforators; 2. truncations and endscrapers; 3. a wide range of tool types. Regarding the relation between the sites, the plot shows that most of the data overlaps and clusters together. The range of tool types remained very uniform throughout the entire Vinča sequence, with endscrapers, truncations, laterally retouched blades, and perforators among the most common types. The frequency of perforators increased during the Late Neolithic (see the Appendix, Tab. 26). The Sopot dataset, however, provides less typological diversity, with endscrapers and laterally retouched blades as the main tool types.

Figure 13 presents a CA biplot for the entire Vinča dataset. The first CA axis represents 44.69% of variation, and the second CA axis 23.32% (Eigenvalues of 0.42 and 0.21, respectively; raw data in the Appendix, Tab. 27). As in the previous case (Fig. 12), axis 1 separates laterally retouched blades and perforators from the rest of the tool types. There are also three major clusters along axis 2, including: 1. sidescrapers, denticulates, and laterally retouched flakes; 2. laterally retouched blades, perforators, notches, burins, and arrowheads; 3. endscrapers and truncations. The plot

	central Serbia	E & SE Serbia	N Serbia	W Serbia	Montenegro
central Serbia		**0.0358**	**0.0070**	0.0637	0.2490
E & SE Serbia	**0.0358**		**0.0367**	0.0993	0.2232
N Serbia	**0.0070**	**0.0367**		**0.0161**	0.0743
W Serbia	0.0637	0.0993	**0.0161**		0.5408
Montenegro	0.2490	0.2232	0.0743	0.5408	

Tab. 7. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of raw materials from Vinča sites. Significant p-values are shown in bold (figure by I. Jovanović).

PERMANOVA	central Serbia	E & SE Serbia	N Serbia	Montenegro
central Serbia		0.3392	0.101	1
E & SE Serbia	0.3392		1	1
N Serbia	0.101	1		0.2511
Montenegro	1	1	0.2511	

Tab. 8. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of raw materials from Early Vinča sites. Significant p-values are shown in bold (figure by I. Jovanović).

PERMANOVA	central Serbia	E & SE Serbia	N Serbia	W Serbia	Montenegro
central Serbia		0.1361	0.0689	**0.0293**	0.3875
E & SE Serbia	0.1361		0.3313	0.0955	0.5945
N Serbia	0.0689	0.3313		0.0959	0.2972
W Serbia	**0.0293**	0.0955	0.0959		0.8035
Montenegro	0.3875	0.5945	0.2972	0.8035	

Tab. 9. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of raw materials from Late Vinča sites. Significant p-values are shown in bold (figure by I. Jovanović).

(Fig. 13) also shows that all regional groups greatly overlap, indicating coherent tool production across the entire Vinča distribution. Central Serbia reflects the greatest amount of variation in range and frequencies of tools. Besides the dominant types observed in the previous CA (*i.e.* laterally retouched blades, endscrapers, and truncations), sidescrapers, laterally retouched flakes, denticulates, and perforators were also widely used in this area. A very similar signal can be seen amongst a group of sites from western Serbia, however, perforators are absent here. Other regions show less diversity, and they do not deviate much from the main trend of the Vinča tool typology. Results of the PERMANOVA indicate that at least one geographical region significantly differs from the others (TSS=5.113, SSw=3.464, F=1.904, p=0.021). A posteriori pairwise comparison reveals that northern Serbia shows fewer similarities with western Serbia and Montenegro, likewise Montenegro with central Serbia (Tab. 10; F values are given in the Appendix, Tab. 28).

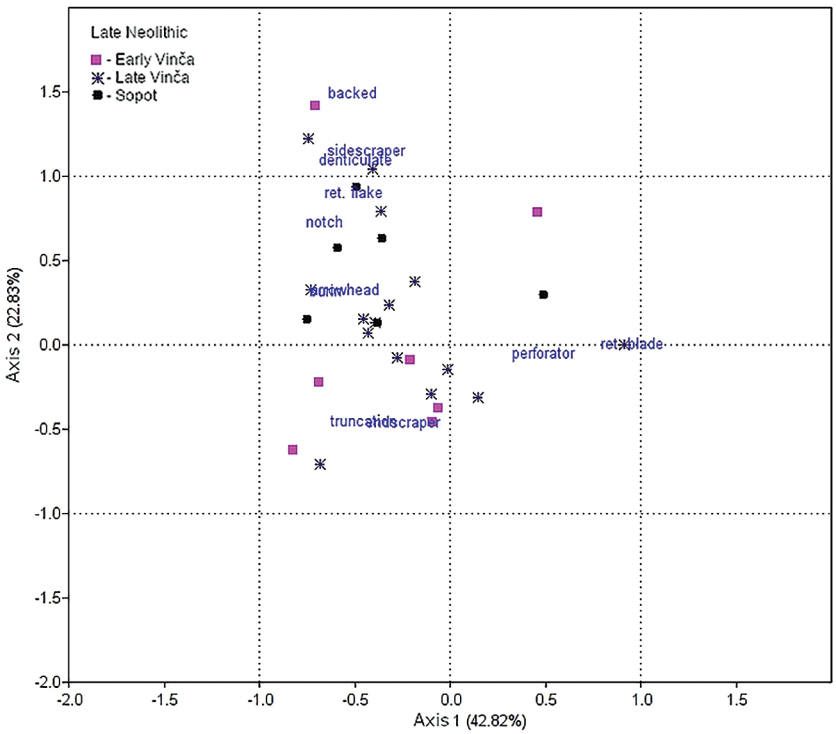


Fig. 12. Correspondence analysis of tools from Late Neolithic sites (figure by I. Jovanović).

PERMANOVA of both Early Vinča assemblages (TSS=1.877, SSw=0.7486, F=1.508, p=0.1633; Tab. 11; F-values are given in the Appendix, Tab. 29) and Late Vinča assemblages (TSS=3.012, SSw=1.734, F=1.659, p=0.0567; Tab. 12; F-values in the Appendix, Tab. 30) shows no regional differences.

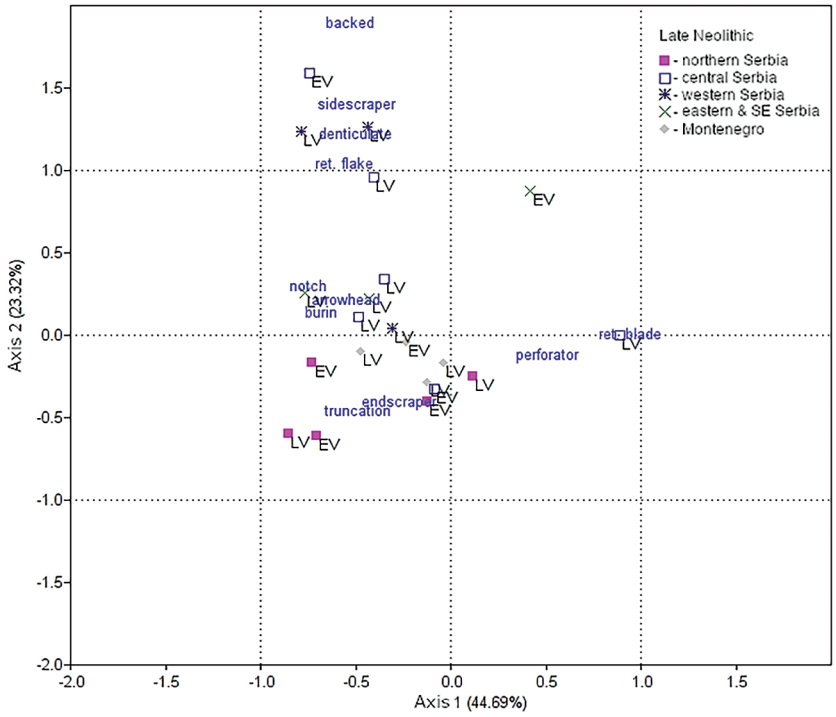


Fig. 13. Correspondence analysis of tools from Early Vinča (EN) and Late Vinča (LN) sites. The analysis is based on presence/absence; data are classified into five different regions (figure by I. Jovanović).

Discussion

The results presented above reveal several interconnected patterns in raw material procurement, lithic production strategies and organisation of technology across the Early and Late Neolithic assemblages of the western Balkans. Together, these patterns provide important insight into the organisation of lithic economies and the mechanisms through which technological knowledge circulated among Neolithic

communities in the region. The following discussion synthesises these results in order to evaluate the hypotheses proposed in this study concerning the relative homogeneity of Early Neolithic lithic technology and the emergence of greater diversity and regional traditions during the Late Neolithic.

Lithic production systems in the Early Neolithic

Early Neolithic lithic technology shows a high degree of similarity across the analysed assemblages. Blade production represents the dominant technological strategy, and the overall structure of the *chaînes opératoires* appears broadly comparable throughout the region. Blades were predominantly made from the unidirectional cores by indirect percussion (Fig. 15). At the same time, a flake-oriented *chaîne opératoire* coexisted alongside blade production. Flakes were mainly produced from locally available raw materials, particularly cherts and quartzite, and the extensive quartzite flake industries were especially characteristic of Starčevo communities in central and eastern Serbia, including the Danube gorge region. Both flakes and blades were used almost equally as tool blanks, except in southeastern Serbia where tools were made exclusively on blades. The overall composition of the Early Neolithic toolkit was very uniform across the western Balkans and predominantly consisted of laterally retouched blades, truncated blades, endscrapers, and notches. This technological consistency indicates that the core principles of lithic technology were widely shared across the region, which supports the hypothesis that lithic technology formed a relatively homogeneous technological package during the Early Neolithic expansion of farming communities in the western Balkans.

However, regional differences emerge in the procurement and circulation of raw materials. The eastern part of the study area (Serbia and northern Montenegro) shows a strong presence of Balkan flint, while also relying on locally available raw materials such as chert, opal, and quartzite (Fig. 14). Balkan flint represents one of the most widely distributed non-local raw materials in Early Neolithic assemblages across the western Balkans. Previous provenance studies suggested that these artefacts most likely derive from sources located in northern Bulgaria (*Gurova* et al. *2016*), indicating the existence of structured long-distance procurement and distribution systems through which this material circulated, linking communities over considerable distances (*Jovanović, in prep.*). The eastern group of Starčevo settlements was also participating in the exchange

	central Serbia	E & SE Serbia	N Serbia	W Serbia	Montenegro
central Serbia		0.3485	0.3213	0.1622	**0.0408**
E & SE Serbia	0.3485		0.0516	0.7041	0.4087
N Serbia	0.3213	0.0516		**0.0372**	**0.0152**
W Serbia	0.1622	0.7041	**0.0372**		0.3167
Montenegro	**0.0408**	0.4087	**0.0152**	0.3167	

Tab. 10. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of tools from Vinča sites. Significant p-values are shown in bold (figure by I. Jovanović).

PERMANOVA	central Serbia	E & SE Serbia	N Serbia	Montenegro
central Serbia		0.6674	0.2974	1
E & SE Serbia	0.6674		0.2497	1
N Serbia	0.2974	0.2497		0.2407
Montenegro	1	1	0.2407	

Tab. 11. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of tools from Early Vinča sites. Significant p-values are shown in bold (figure by I. Jovanović).

PERMANOVA	central Serbia	E & SE Serbia	N Serbia	W Serbia	Montenegro
central Serbia		0.1329	0.9343	0.0557	**0.0319**
E & SE Serbia	0.1329		0.6622	0.6073	0.6031
N Serbia	0.9343	0.6622		0.1985	0.1941
W Serbia	0.0557	0.6073	0.1985		0.2988
Montenegro	**0.0319**	0.6031	0.1941	0.2988	

Tab. 12. PERMANOVA. A grouped Bray-Curtis dissimilarity matrix of tools from Late Vinča sites. Significant p-values are shown in bold (figure by I. Jovanović).

of exotic goods – obsidian from Carpathian sources – although to a small extent.

By contrast, assemblages from the western part of the region (northern Bosnia and Herzegovina and north-east Croatia) demonstrate a strong preference for a distinctive type of chert – reddish brown silicified limestone (Fig. 14.5) – originating from northern Bosnia and Herzegovina (*Halamić, Šošić Klindžić 2009; Šošić Klindžić 2010a*). This group appears to have developed a system for exploiting this raw material but maintained limited interaction with communities to the west and north, as suggested by the scarcity of non-local raw materials, primarily Balkan flint and obsidian.

The technological similarities observed across Early Neolithic assemblages suggest that lithic knowledge was transmitted through well-established social traditions among farming communities spreading across the western Balkans. In this context, it is useful to distinguish between different mechanisms of cultural transmission that may have structured lithic production systems. Vertical transmission refers to the transfer of technological knowledge within established social groups or cultural traditions, typically resulting in relatively stable and standardised technological practices. Horizontal transmission, by contrast, occurs through interactions between communities, such as exchange networks, occasional contacts, or other forms of social interaction, and may facilitate the spread of materials, techniques, or technological concepts across wider regions (*Cavalli-Sforza, Feldman 1981; Boyd, Richerson 1985; Eerkens, Lipo 2007*).

The strong technological similarities observed in Early Neolithic blade production across the region suggest that lithic knowledge was primarily transmitted vertically within established cultural traditions associated with the continental stream of Neolithisation. This mode of transmission likely contributed to the relatively homogeneous character of Early Neolithic lithic technology observed in the analysed assemblages. At the same time, the circulation of certain non-local raw materials indicates the existence of broader interaction networks that facilitated contacts between communities. The distribution of obsidian, for example, reflects long-distance connections linking the western Balkans with the Carpathian Basin. Such exchange networks may have provided opportunities for horizontal transmission of technological knowledge and materials, although the available evidence suggests that these contacts played a secondary role in shaping the overall technological organisation of lithic production during the Early Neolithic.

Transformations in lithic production during the Late Neolithic

While the Early Neolithic lithic record of the western Balkans is characterised by a relatively homogeneous technological organisation and widespread circulation of particular non-local raw materials such as Balkan flint, the Late Neolithic reveals a more complex and regionally differentiated pattern. Changes in raw material procurement, technological organisation, and interaction networks reflect the gradual embedding of farming communities within local landscapes and the development of distinct regional traditions. The following section, therefore, examines the main transformations observed in lithic production during the Late Neolithic.

Late Neolithic lithic technology shows both continuity with earlier traditions and significant transformations in raw material procurement and technological organisation. Blade production remained the dominant aspect of lithic technology, and the overall structure of the *chaînes opératoires* continued to follow established principles. However, important changes are visible in the increasing standardisation of blade production, the wider use of the pressure technique (Fig. 17), and the diversification of raw material use (Fig. 16). These developments are closely linked to the intensification of agricultural practices and the rising demand for crop harvesting tools (*Gaastra* et al. *2019*).

A major shift concerns raw material procurement strategies. Around 5500 BC, the role of Balkan flint significantly decreased, while a broader range of locally available materials came into use across the western Balkans. At the same time, obsidian increased in importance, indicating the strengthening of long-distance interaction networks with the communities to the north. Vinča assemblages are characterised by a diverse raw material range, combining locally available cherts and opals with imported resources, particularly obsidian (Fig. 16). The most distinctive material is the so-called white soft stone (Fig. 16.1), a group of light-coloured siliceous rocks widely used for the production of standardised blades and tools on blades. Its widespread occurrence across Vinča sites suggests the existence of well-established procurement and exchange networks, comparable in significance to the role of Balkan flint in the Early Neolithic, or obsidian during the early Vinča phase.

Within the Vinča culture, clear regional differences in raw material procurement strategies can be observed. The northern Vinča communities relied on a wider range of raw materials and were more actively engaged in long-distance exchange networks, especially those involving obsidian. Sites such as Potporanj and Vinča–Belo brdo appear to have played an important role in the acquisition, production, and distribution of obsidian artefacts, especially during the early phase of the Vinča culture. In contrast, southern Vinča communities show a stronger reliance on locally available raw materials, particularly white soft stone, and a lower presence of obsidian. These differences correspond to previously identified variations in settlement structures and presence of exotic materials, such as *Spondylus* (*Dimitrijević, Tripković 2006*), and have been inter-



Fig. 14. Main raw materials in the Early Neolithic:* 1 *Balkan flint (blades from Kozluk, Serbia);* 2 *opal (blades and flakes from Međureč, Serbia);* 3 *obsidian (blades from Kozluk, Serbia);* 4 *quartzite (flakes and a blade from Međureč, Serbia);* 5 *silicified limestone (core from Bregovi nad Bakarama, Bosnia & Herzegovina) (figure by I. Jovanović).

preted as reflecting different socio-economic strategies, often described as network-oriented societies in the north and corporate-oriented societies in the south (*Tripković 2009.295; Porčić 2012.175*).

By contrast, Sopot assemblages display a more restricted raw material spectrum and a stronger reliance on locally available resources, particularly radiolarites and other siliceous rocks often obtained from secondary deposits such as river pebbles (*e.g., Šošić, Karavanić 2004; Halamić, Šošić Klindžić 2009; Šošić Klindžić 2011*). The previously dominant reddish-brown silicified limestone, characteristic of the Starčevo period in northern Bosnia and Herzegovina and Croatia, was

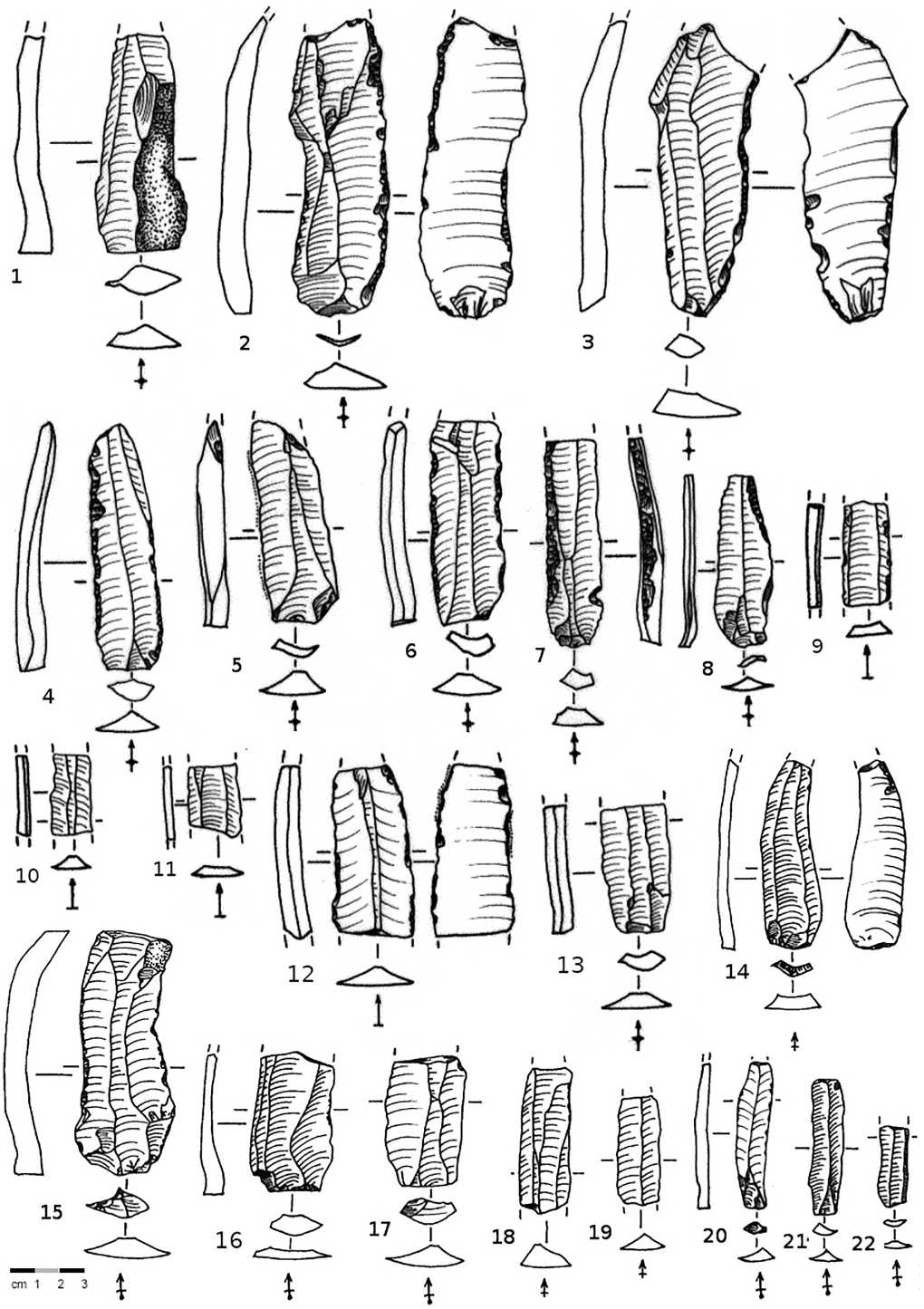


Fig. 15. Early Neolithic unmodified and laterally retouched blades from Crnoklište (chert:* 1–3*), Međureč (opal:* 4–6, 8–13*; Balkan flint:* 7*), Bregovi nad Bakarama (silicified limestone:* 14–22*) (figure by I. Jovanović).

largely abandoned. The transition towards a stronger reliance on local raw materials appears to have begun at the end of the Starčevo period (*Šošić, Karavanić 2004*). It has been suggested that this shift resulted from a breakdown in communication between areas north of the Sava River and regions to the south where sources of silicified limestone are located (*Šošić Klindžić 2011; Šošić Klindžić* et al. *2018*). However, the presence of Sopot sites in northern Bosnia and Herzegovina, including Kulište (*Belić 1965; 1988*), Lanište (*Truhelka 1906; 1914; Benac 1964.40–42)*, Kočićevo and Kosjerovo (*Marriner* et al. *2011; Pandžić, Vander Linden 2014*), indicates that such connections may not have been entirely absent. The low representation of silicified limestone in these assemblages suggests that this raw material was known but not deliberately exploited. At the same time, technological analyses demonstrate that similar blade production methods were applied to both silicified limestone and radiolarite (*Jovanović 2022.441–449*), indicating continuity in technological practices. These observations suggest that raw material selection in the Sopot culture was not determined solely by availability or access but was also influenced by cultural traditions or social practices.

Technological analysis indicates that blade production remained the major technological concept during the Late Neolithic, particularly within the Vinča culture. While indirect percussion continued to be widely used, the most significant innovation is the broader application of the pressure technique (Fig. 17), especially for high-quality raw materials such as obsidian and white soft stone. Pressure technique was particularly important in the production of micro-blades (see *Jovanović 2022.Pl. 12,13:1–6,14:4–14,17:4–14*), as documented at sites such as Drenovac and Potporanj (see *Jovanović 2022.189,Fig. 5.17, 287, Fig. 7.24*). At the same time, flake production intensified, especially in later phases (*e.g.,* Potporanj), and was primarily associated with locally available materials. This combination of highly standardised blade production and increased flake production represents a distinctive feature of the Late Vinča lithic technology, as previously disclosed by Vera Bogosavljević Petrović (*2018*).

Typological patterns further reflect both continuity and diversification. Vinča toolkits largely retain the same basic tool types as in the Early Neolithic, with laterally retouched blades remaining the dominant form. However, greater variability is observed in certain regions, particularly in central and western Serbia, where tools such as sidescrapers, denticulates and retouched flakes occur more frequently. In contrast, Sopot assemblages show lower typological diversity, with laterally retouched blades and endscrapers as the dominant tool types. The absence of clear evidence for specialised workshops in both cultural groups suggests that lithic production was generally organised at the household or community level, although increasing standardisation may indicate the development of specialised skills.

These patterns suggest that, in contrast to the Early Neolithic, lithic production in the Late Neolithic was shaped by a more complex interplay of technological traditions and interaction networks. While vertical transmission remained important in maintaining core technological principles, particularly in blade production, horizontal transmission played a more significant role than before. The circulation of obsidian and the spread of pressure blade technology indicate intensified contacts between communities, facilitating the exchange of materials, ideas, and technical knowledge across wider regions.

Overall, the Late Neolithic lithic record demonstrates increased variability in raw material use, production strategies and regional organisation, while maintaining continuity in fundamental technological concepts. These patterns support the hypothesis that, unlike the relatively homogeneous Early Neolithic lithic technology, the Late Neolithic was characterised by the emergence of more regionally differentiated and locally embedded lithic production systems.

Concluding remarks

This study demonstrates that stone tool production in the western Balkans underwent significant transformations during the process of Neolithisation. The results highlight the interplay of multiple factors in shaping lithic technology, including adaptation to new environments, socio-economic developments, and culturally embedded technological traditions. The analyses confirm that Early Neolithic lithic technology across the western Balkans formed a relatively homogeneous technological package. Blade production based on similar technological principles and the widespread circulation of Balkan flint, indicate strong technological cohesion among Early Neolithic communities associated with the continental stream of Neolithisation. At the same time, regional differences in raw material procurement suggest the existence of structured exchange networks linking communities across the re-

gion. In contrast, the Late Neolithic lithic record reveals increased variability and stronger regional differentiation. The growing reliance on locally available resources, the diversification of raw material economies, and the emergence of distinct technological practices among Vinča and Sopot communities reflect the development of more locally embedded production systems. These patterns suggest that while core technological principles were maintained through vertical transmission within cultural traditions, intensified interaction networks facilitated the horizontal circulation of materials and technological knowledge across wider regions.

Overall, the results demonstrate that lithic technology in the western Balkans evolved from a relatively uniform Early Neolithic technological system towards more regionally differentiated and socially embedded



Fig. 16. Main raw materials in the Late Neolithic:* 1 *white soft stone (blades from Trnje, Montenegro);* 2 *obsidian (blades from Potporanj, Serbia);* 3 *radiolarite (a blade and a core from Kosijerovo, Bosnia & Herzegovina);* 4 *flint and chert (a blade and a core from Trnje, Montenegro);* 5 *chert with inclusions (a core and a blade from Potporanj, Serbia);* 6 *opal (blades from Potporanj, Serbia) (figure by I. Jovanović).

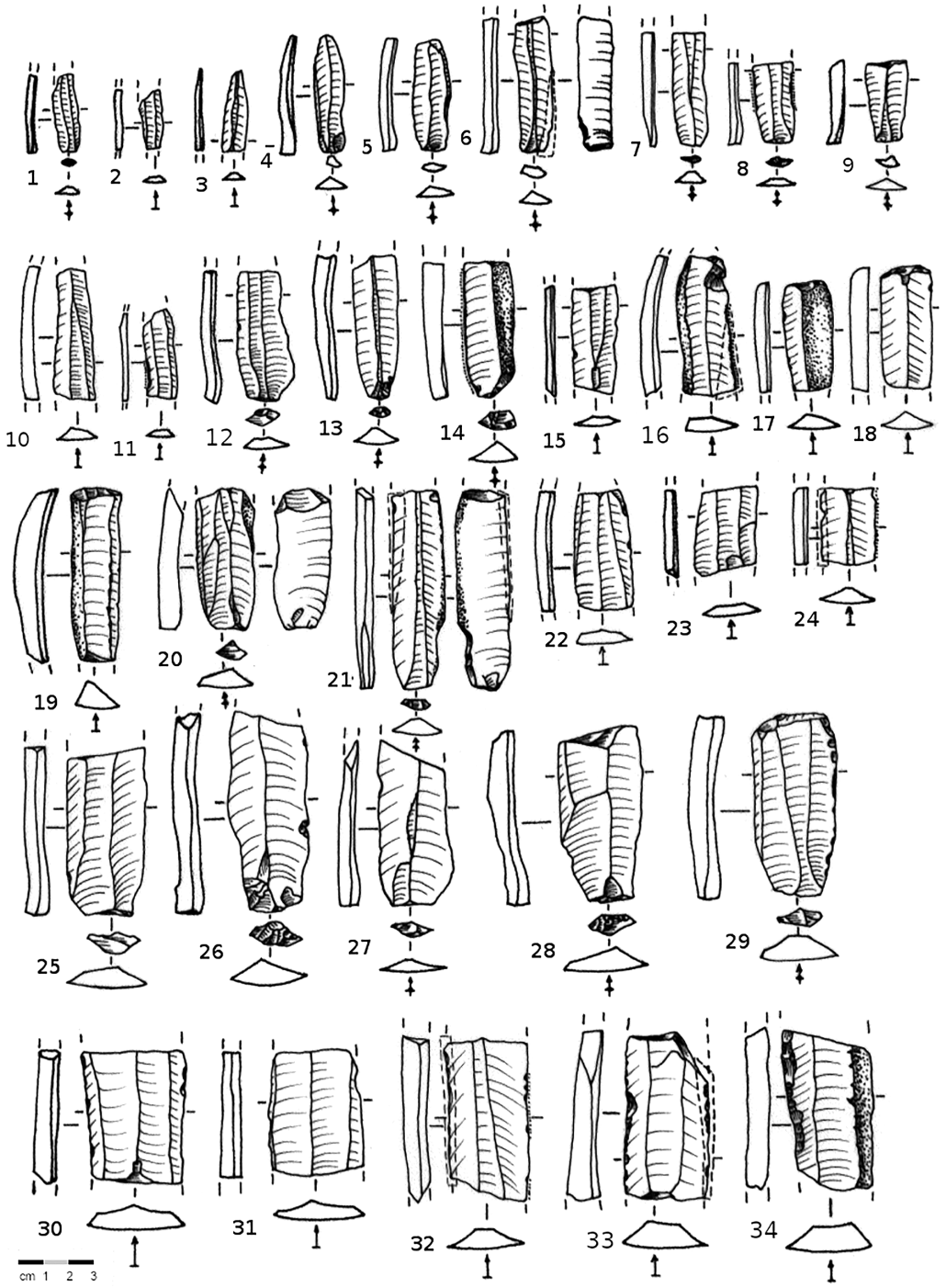


Fig. 17. Late Neolithic unmodified blades from Drenovac, made of white soft stone (figure by I. Jovanović).

production strategies during the Late Neolithic. These findings highlight the importance of lithic technology as a key indicator of broader socio-economic organisation, interaction networks, and cultural dynamics during the Neolithic. Future research integrating provenance analyses with multi-proxy archaeological approaches will be essential for refining our understanding of raw material circulation and technological transmission. Expanding comparative studies across neighbouring regions will further contribute to understanding the role of lithic technology in wider processes of Neolithic social and economic transformation.

Data availability
Tables 13–30 are available in Appendix online https://doi.org/10.4312/dp.53.12

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Author Contributions
Ivana Jovanonović: conceptualisation, methodology, data curation, formal analysis, investigation (lead), project administration (lead), visualisation, writing – original draft (lead), writing – review and editing (lead), resources.
Marc Vander Linden: funding acquisition (lead), investigation (supporting), project administration (supporting), writing – original draft (supporting), writing – review and editing (supporting).

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Tab. 2. Early Neolithic assemblages included in the analysis (figure by I. Jovanović).

n	Site	Region	Latitude	Longitude	Phase	^{14}C date cal BC	Excavated area (m^2)	Chipped stone (n)	Reference on lithics
1	Šagovina Cernička	Slavonia	45.313	17.323			50	63	*Šošić Klindžić 2010a*
2	Virovitica Brekinja	Slavonia	45.832	17.386			5400	251	*Šošić Klindžić 2010a*
3	Galovo	Slavonia	45.163	18.012			200	2746	*Šošić Klindžić 2010a*
4	Zadubravlje	Slavonia	45.163	18.154			6200	4119	*Karavanić* et al. *2009*
5	Ivandvor	Slavonia	45.273	18.348			8000	896	*Šošić Klindžić 2010a*
6	Tomašanci Palača	Slavonia	45.386	18.415			4000	59	*Šošić Klindžić 2010a*
7	Vinkovci Hotel	Slavonia	45.288	18.806			2100	77	*Šošić Klindžić 2010a*
8	Vinkovci Nama	Slavonia	45.288	18.806			2680	37	*Šošić Klindžić 2010a*
9	Vinkovci Duga Ulica 23	Slavonia	45.288	18.806			76	2	*Šošić Klindžić 2010a*
10	Vinkovci Varteks	Slavonia	45.288	18.806			360	1	*Šošić Klindžić 2010a*
11	Vinkovci Zvijezda	Slavonia	45.288	18.806			332	58	*Šošić Klindžić 2010a*
12	Vinkovic Jugobanka	Slavonia	45.288	18.806			3660	34	*Šošić Klindžić 2010a*
13	Bregovi nad Bakrama	Slavonia	45.112	18.066	Starčevo ?		128	327	*Jovanović 2022*
14	Donja Branjevina	N SRB	45.452	19.217	Proto-Starčevo; Starčevo		<860	837	*Šarić 2005; 2014*
15	Stari vinogradi	N SRB	45.251	20.826	Starčevo II		19	7	*Šarić 2012; 2014*
16	Golokut	N SRB	45.169	19.45	Starčevo III		353.5	27	*Kaczanowska, Kozłowski 1985; Šarić 2014*
17	Kozluk	N SRB	45.14	21.338	Starčevo ?		?	725	*Jovanović 2022*
18	Starčevo-Grad	N SRB	44.807	20.705	Starčevo ?		95	57	*Živković, Medović, Jovanov 2011*
19	Vojlovica	N SRB	44.845	20.683	Starčevo III			2	*Šarić 2012; 2014*
20	Sedlar	N SRB	44.822	20.73	Starčevo III		16	3	*Šarić 2012; 2014*
21	Orašje	N SRB	44.7	21.04	Proto-Starčevo			58	*Šarić 2014*
22	Toplik	Central SRB	44.555	21.289	Proto-Starčevo			35	*Šarić 2014*
23	Međureč	Central SRB	43.952	21.188	Proto-Starčevo	6210–6040 6232–6087		128	*Jovanović 2022*
24	Blagotin	Central SRB	43.721	21.096	Proto-Starčevo II	6231–6034	235	2348	*Šarić 2014*
25	Livade-Kalenić	W SRB	44.496	20.204	Starčevo ?			31	*Šarić 2014*
26	Popovića brdo	W SRB	44.63	19.69	Starčevo II		10	927	*Šarić 2014*
27	Simića strana	W SRB	44.429	19.967	Starčevo II			45	*Šarić 2014*
28	Lug-Zvečka	W SRB	44.644	20.17	Proto-Starčevo		10	3	*Šarić 2014*
29	Novo selo	W SRB	44.589	20.14	Starčevo ?		44	3	*Šarić 2014*
30	Šalitrena pećina	W SRB	44.191	20.078	Starčevo II		41	120	*Šarić 2002; 2014*

Tab. 2. Continued

31	Đurića vinogradi	W SRB	44.617	20.1	Starčevo III		<300	3	*Šarić 2014*
32	Padina	Iron Gate	44.607	22.001	Starčevo ?		2400	251	*Mihailović 2004*
33	Lepenski Vir	Iron Gate	44.553	22.027	Starčevo III		3800	358	*Kozłowski, Kozæowski 1984; Šarić 2014*
34	Velesnica	Iron Gate	44.51	22.55	Proto-Starčevo		712	524	*Šarić 1997; 2014*
35	Ušće Kameničkog potoka	Iron Gate	44.384	22.478	Starčevo III		458	262	*Šarić 1997; 2014*
36	Knjepište	Iron Gate	44.365	22.5	Starčevo III		72.2	357	*Šarić 1997; 2014*
37	Caribrod	SE SRB	43.021	22.783	Proto-Starčevo I		604	24	*Jovanović 2022*
38	Crnoklište	SE SRB	43.223	22.464	Proto-Starčevo II		450	7	*Jovanović 2022*
39	Sinjac	SE SRB	43.231	22.428	Starčevo II	6226–6079	200	37	*Jovanović 2022*
40	Kremenštice	MNE	42.838	19.899	Proto-Starčevo II		78	75	*Jovanović 2022*

Tab. 3. Late Neolithic assemblages included in the analysis (figure I. Jovanović).

n	Site	Region	Lat.	Long.	Phase	^{14}C date cal BC	Excavated area (m^2)	Chipped stone(n)	Reference on lithics
Early Vinča									
1	Beran Krš I	MNE	42.859	19.864	Vinča A–B		25	53	*Jovanović 2022*
2	Divlje Polje	C SRB	43.703	20.75	Vinča B		210	244	*Bogosavljević 1990; Bogosavljević Petrović 1992; 2015*
3	Grivac IV	C SRB	44.004	20.698	Vinča A			16	*Bogosavljević Petrović 2008; 2015*
4	Gomolava Ia	N SRB	44.889	19.749	Vinča B		4400	394	*Kaczanowska, Kozłowski 1986; Bogosavljević Petrović 2015*
5	Potporanj	N SRB	45.019	21.247	Vinča B	5231–4999		4092	*Jovanović 2022*
6	Vinča-Belo brdo	N SRB	44.762	20.623	Vinča A–B		1625	2488	*Radovanović* et al. *1984; Bogosavljević Petrović 2015*
7	Zbradila-Korbovo	E SRB	44.538	22.43	Vinča B		600	30	*Šarić 2013*
Late Vinča									
8	Anatema	W SRB	44.258	19.748	Vinča		15	130	*Mihailović 2001a*
9	Beran Krš II	MNE	42.859	19.864	Vinča C–D	4083–3921	25	74	*Jovanović 2022*
10	Crkvine-Mali Borak	W SRB	44.462	20.224	Vinča D		144	2027	*Bogosavljević Petrović 2011; Šarić, Cvetković 2013*
11	Crkvine-Stubline	W SRB	44.586	20.129	Vinča D	4850–4650/4600		74	*Antonović, Šarić 2011*
12	Divlje Polje F–H	C SRB	43.703	20.75	Vinča C–D			1122	*Bogosavljević 1990; Bogosavljević Petrović 1992; 2015*
13	Divostin II	C SRB	44.024	20.833	Vinča D		210	1888	*Tringham* et al. *1988; Bogosavljević Petrović 2015*
14	Drenovac	C SRB	43.761	21.433	Vinča D	5300–4500	60	1575	*Jovanović 2022*
15	Gomolava Ia–b	N SRB	44.889	19.749	Vinča C–D		4400	1167	*Kaczanowska, Kozłowski 1986; Bogosavljević Petrović 2015*
16	Grivac V–VI	C SRB	44.004	20.698	Vinča C–D			833	*Bogosavljević Petrović 2008; 2015*
17	Obrenovac-Srećkovo	SE SRB	43.037	22.719	Vinča D		290	24	*Jovanović 2022*
18	Torine	MNE	42.938	19.981	Vinča/Nakovanska			282	*Jovanović 2022*
19	Trnje	MNE	43.109	19.798	Vinča/ Bubanj-Hum			102	*Jovanović 2022*
20	Vinča-Belo brdo	N SRB	44.762	20.623	Vinča C–D		1625	581	*Radovanović* et al. *1984; Bogosavljević Petrović 2015*
21	Visoko brdo	N BiH	44.947	17.861	Vinča D	4685–4488		110	*Jovanović 2022*
22	Zbradila-Korbovo	E SRB	44.538	22.43	Vinča C		600	500	*Šarić 2013*
Sopot									
23	Kočićevo	N BiH	45.073	17.393		5208–4590		437	*Jovanović 2022*
24	Kosjerovo	N BiH	44.971	17.394		5291–4374		461	*Jovanović 2022*
25	Kulište	N BiH	45.006	18.431		4618–4460		112	*Jovanović 2022*
26	Lanište	N BiH	45.058	18.116		4703–4541		65	*Jovanović 2022*
27	Sarvaš	E CRO	45.526	18.839				26	*Balen 2005*
28	Slavča	E CRO	45.271	17.373				564	*Šošić, Karavanić 2004*