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Eastern Europe's "Transitional Industry"?: Deconstructing the Early Streletskian

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Abstract

The Streletskian is central to understanding the onset of the Upper Palaeolithic on the East European Plain. Early Streletskian assemblages are frequently seen as marking the Neanderthal-anatomically modern human (AMH) anthropological transition, as well as the Middle-to-Upper Palaeolithic archaeological transition. The age of key Streletskian assemblages, however, remains unclear, and there are outstanding questions over how they relate to Middle and Early Upper Palaeolithic facies. The three oldest Streletskian layers—Kostenki 1 Layer V, Kostenki 6 and Kostenki 12 Layer III—were excavated by A. N. Rogachev in the mid-20th century. Here, we re-examine these layers in light of problems noted during Rogachev's campaigns and later excavations. Layer V in the northern part of Kostenki 1 is the most likely assemblage to be unmixed. A new radiocarbon date of 35,100 ± 500 BP (OxA- X-2717-21) for this assemblage agrees with Rogachev's stratigraphic interpretation and contradicts later claims of a younger age. More ancient radiocarbon dates for Kostenki 1 Layer V are from areas lacking diagnostic Streletskian points. The Kostenki 6 assemblage's stratigraphic context is extremely poor, but new radiocarbon dates are consistent with Rogachev's view that the archaeological material was deposited prior to the CI tephra (i.e. >34.3 ka BP). Multiple lines of evidence indicate that Kostenki 12 Layer III contains material of different ages. Despite some uncertainty over the precise relationship between the dated sample and diagnostic lithic material, Kostenki 1 Layer V (North) therefore currently provides the best age estimate for an early Streletskian context. This age is younger than fully Upper Palaeolithic assemblages elsewhere at Kostenki. Other "Streletskian" assemblages and Streletskian points from younger contexts at Kostenki are briefly reviewed, with possible explanations for their chronostratigraphic distribution considered. We caution that the cultural taxon Streletskian should not be applied to assemblages based simply on the presence of bifacially worked artefacts.

Keywords Middle Palaeolithic · Upper Palaeolithic · Anatomically modern humans · Neanderthals · Radiocarbon dating · Lithic assemblages

Introduction

The Streletskian and the Eastern European Middle-Upper Palaeolithic Transition

The Middle-to-Upper Palaeolithic transition (45–35 ka BP[1]) on the East European Plain is poorly characterised compared to other parts of Europe. Despite constituting a third of the European landmass, the region has few Late Middle Palaeolithic and Early Upper Palaeolithic (EUP) sites, and only a handful of these include evidence for multiple, stratigraphically separated occupations. In addition, the radiocarbon chronology of key sites is known to be problematic (Demidenko and Noiret 2012; Marom et al. 2012; Demidenko 2014; Haesaerts et al. 2017; Dinnis et al. 2019a). Establishing a sound chronocultural framework has therefore proved difficult. The unclear cultural taxonomy of key assemblages and the question of whether they are most likely to reflect late Neanderthal or early anatomically modern human (AMH) activity also pose problems.

One critical taxonomic unit, often thought to be directly relevant to the arrival of AMHs, is the Streletskian. Most Streletskian sites are found in European Russia, notably at the Kostenki-Borshchevo complex, which has at least five assemblages usually described as Streletskian (Kostenki 1 Layer V, Kostenki 6, Kostenki 11 Layer V, Kostenki 12 Layer III and Layer Ia). Together, these are thought to span a long period of time (Anikovich 1977a, 1992, 2005; Praslov and Rogachev 1982; Bradley et al. 1995; Haesaerts et al. 2017). Streletskian assemblages have also been found at Biriuch'ia Balka 2 in Rostov Oblast (Matyukhin and Sapelko 2009; Matyukhin 2012), Garchi 1 in the Urals (Pavlov 2010; Svendsen et al. 2010) and Vys' in Ukraine (Zaliznyak et al. 2008, 2013; Zaliznyak and Belenko 2011). Although not always referred to explicitly as 'Streletskian', other Russian assemblages have been linked culturally to Streletskian assemblages, notably Sungir' and Layer III of Kostenki 11 (Popov 1989; Anikovich 1992, 2001-2002; Bradley et al. 1995; Sinitsyn 2010; Dinnis et al. 2018) (Fig. 1).

Streletskian lithic assemblages are said to be characterised by a prevalence of flake (over blade) technology, albeit with some evidence for Upper Palaeolithic blade production at most sites (Anikovich 1977a; Rogachev and Anikovich 1984; Bradley et al. 1995; Anikovich et al. 2008). Assemblages contain sometimes large numbers of bifacially worked tools alongside various scrapers, with other artefact types (e.g. burins, splintered pieces) sometimes present but in low numbers (Rogachev 1957; Anikovich 1977a; Rogachev and Anikovich 1984; Anikovich et al. 2008). Two specific lithic artefact types have been argued to link Streletskian sites. The first is short endscrapers, often subtriangular in shape and sometimes bearing invasive, flat retouch facets on their ventral surface. Series of these artefacts are present in the collections from Kostenki 1 Layer V, Garchi 1 (Pavlov 2010) and Biriuch'ia Balka 2 (Matyukhin 2012). However, they are absent from other Streletskian assemblages and are also present in non-Streletskian assemblages at Kostenki such as Kostenki 14 Layer II, Kostenki 15 and Kostenki 12 Layer II (Rogachev and Sinitsyn 1982; Rogachev and Anikovich 1984), so their diagnostic value is unclear. The second and historically much more important type is the bifacially worked, triangular/subtriangular and usually concave-base

[1] Ages are reported as conventional radiocarbon ages 'BP', with BP representing before 1950 AD (Stuiver and Polach 1977).

Fig. 1 Location of Streletskian and related sites

'Streletskian point' (Fig. 2). In reality, most researchers have classified assemblages as Streletskian based on the presence of Streletskian points and an early age (i.e. >29 ka BP) (Anikovich 2001-2002; Sinitsyn 2010). It should be stressed that the technotypological profiles of the Kostenki assemblages in particular vary greatly. Historically, this variation has been explained as diachronic, and Streletskian layers have been assigned to different chronological phases (Rogachev 1957; Anikovich 1977a, 1992, 2005; Rogachev et al. 1982; Rogachev and Anikovich 1982a; Bradley et al. 1995). Generally speaking, Streletskian assemblages contain few if any osseous tools and items of personal ornamentation; this is especially the case for assemblages attributed to the Streletskian's earliest phase (Anikovich 2005; Anikovich et al. 2007, 2008; Sinitsyn 2012). This contrasts markedly with the rich assemblage of ivory, antler and bone tools and beads from Sungir' (Abramova 1995; Bader and Lavrushin 1998; White 1999; Trinkaus et al. 2014; Sinitsyn 2016).

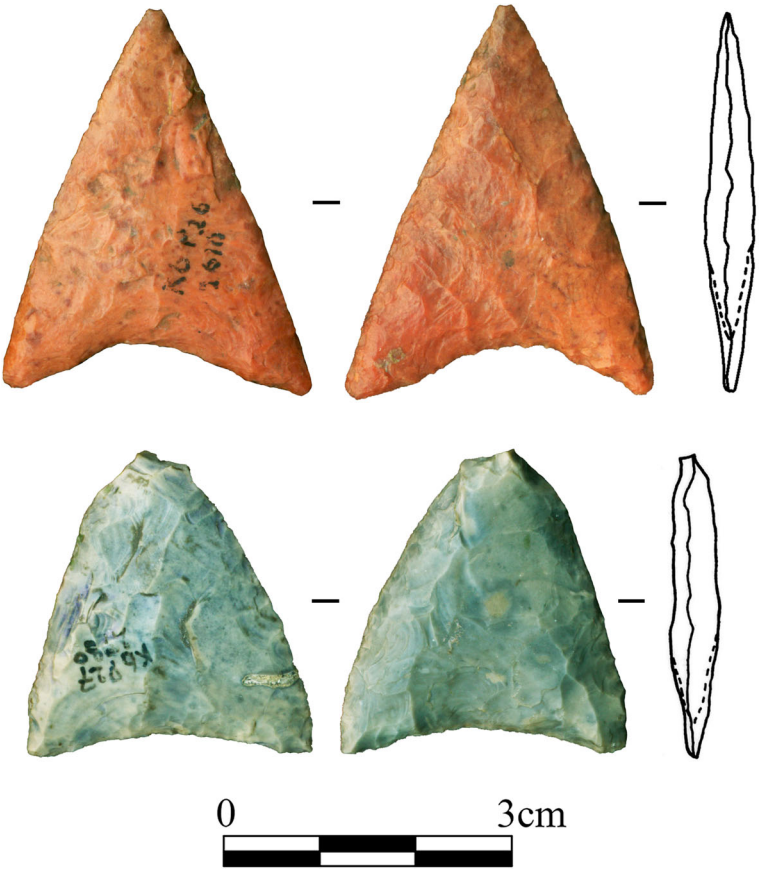

Fig. 2 Streletskian points from Kostenki 6. A 3D model of the top artefact can be viewed and downloaded from http://earlymodernhumaneurope.com/artefacts/kostenki-6-streletskian-point/

Due to the presence of characteristically Upper Palaeolithic blade production/artefact types and its dating to earlier than 29 ka BP, the Streletskian is usually described as belonging to the EUP (e.g. Anikovich et al. 2008; Sinitsyn 2010; Zwyns et al. 2012). The presence of typically Middle Palaeolithic artefacts, especially numerous bifaces, has however led to comparisons with Middle Palaeolithic (Micoquian) and/or Szeletian or "Eastern Szeletian" assemblages (Rogachev 1957; Rogachev and Anikovich 1982a; Chabai 2003; Monigal 2006; Anikovich et al. 2007; Bataille 2017; Bosinski 2017). The Streletskian has therefore been argued by some to have cultural roots in the Middle Palaeolithic (Rogachev 1957; Rogachev and Anikovich 1982a; Bradley et al. 1995; Anikovich 2001-2002; Kozłowski 2004, 2014; Vishnyatsky 2016; Bosinski 2017). This combination of Middle and Upper Palaeolithic features has further led to it being referred to as Eastern Europe's "transitional industry" (Cohen and Stepanchuk 1999; Anikovich et al. 2007; Sinitsyn 2010; Djindjian 2014; Kozłowski 2014), with the earlier Streletskian assemblages thought to be broadly coeval with the Neanderthal-AMH transition. Some view all Streletskian assemblages as probably attributable to early AMHs (e.g. Vishnyatsky and Nehoroshev 2004; Hoffecker 2009; Kozłowski 2014; Otte 2014; Vishnyatsky 2016), often due to a perceived cultural link to Sungir'

and its AMH burials. For others, the nature of the earlier assemblages may instead reflect the influence of incoming AMHs on Neanderthal populations (Anikovich 1999; Cohen and Stepanchuk 1999). All of these conclusions are tempered by the fact that no diagnostic human remains are currently known from any early Streletskian site.

A further complicating factor is the uncertain age of Streletskian sites. Until recently, the earliest assemblages were thought to date from ~38 ka BP (e.g. Zwyns et al. 2012); however, Haesaerts et al. (2017) have recently reported new dates of ~42.5 ka BP for Kostenki 1 Layer V, which they argue push back the age of the layer's Streletskian assemblage significantly. Haesaerts et al.'s (2017) conclusion raises the question of whether dated samples from an archaeological layer can necessarily be linked to specific archaeological material, as well as the related issues of the stratigraphic coherence of Streletskian sites and the degree to which assemblages are unmixed. Given the Streletskian's status as Eastern Europe's "transitional industry" and its relevance to the Neanderthal-AMH transition, these questions are especially important for the earliest sites. Here, we examine these issues for the three oldest Streletskian assemblages, all of which come from Kostenki.

Kostenki and the Early Streletskian

The Kostenki-Borshchevo complex of archaeological sites (Voronezh region, south-western Russia) lies within the villages of Kostenki and Borshchevo on the west bank of the Don river. The sites are positioned in and above ravines cutting the chalk plateau that meets the river's floodplain (Fig. 3). The geological context of the Kostenki archaeological material has been the subject of considerable research over many decades, and is now generally well understood (Rogachev 1957; Lazukov 1982; Holliday et al. 2007; Velichko et al. 2009; Sedov et al. 2010; Sinitsyn 2014; Hoffecker et al. 2016). The older archaeological assemblages lie within and between two paleosol complexes, traditionally called the Upper Humic Bed (UHB) and the stratigraphically lower Lower Humic Bed (LHB). At some sites these paleosol complexes are separated by deposits containing lenses or concentrations of volcanic ash. This ash has been identified at Kostenki 14 as the Campanian Ignimbrite (CI)/Y5 tephra, which is now dated via a combined series of radiocarbon dates to 34,290 ± 90 BP (~39–38.5 ka cal BP using IntCal 13; Pyle et al. 2006; Reimer et al. 2013; Giaccio et al. 2017). The CI tephra therefore serves as an important chronological marker. In reality, the geological sequence at Kostenki is complex and variable between the sites; at some sites, there are no ash deposits, and many of the older archaeological layers have been heavily disturbed by colluvial processes and by the formation of palaeoravines (Rogachev 1957; Velichko 1961; Holliday et al. 2007; Hoffecker et al. 2010; Panin et al. 2019).

Three Kostenki Streletskian layers are thought to have been found in deposits stratigraphically lower than the CI tephra, making them the oldest known Streletskian assemblages: Kostenki 1 Layer V, Kostenki 6 and Kostenki 12 Layer III (Fig. 3). All three, however, have question marks over their chronostratigraphic position within the Kostenki sequence and/or their status as unmixed assemblages. Layer V of Kostenki 1 is the only assemblage to contain numerous Streletskian points, but doubts have persisted about the pre-ash age of the largest Layer V lithic collection, and more generally about whether "Layer V" in different parts of the site represents the same

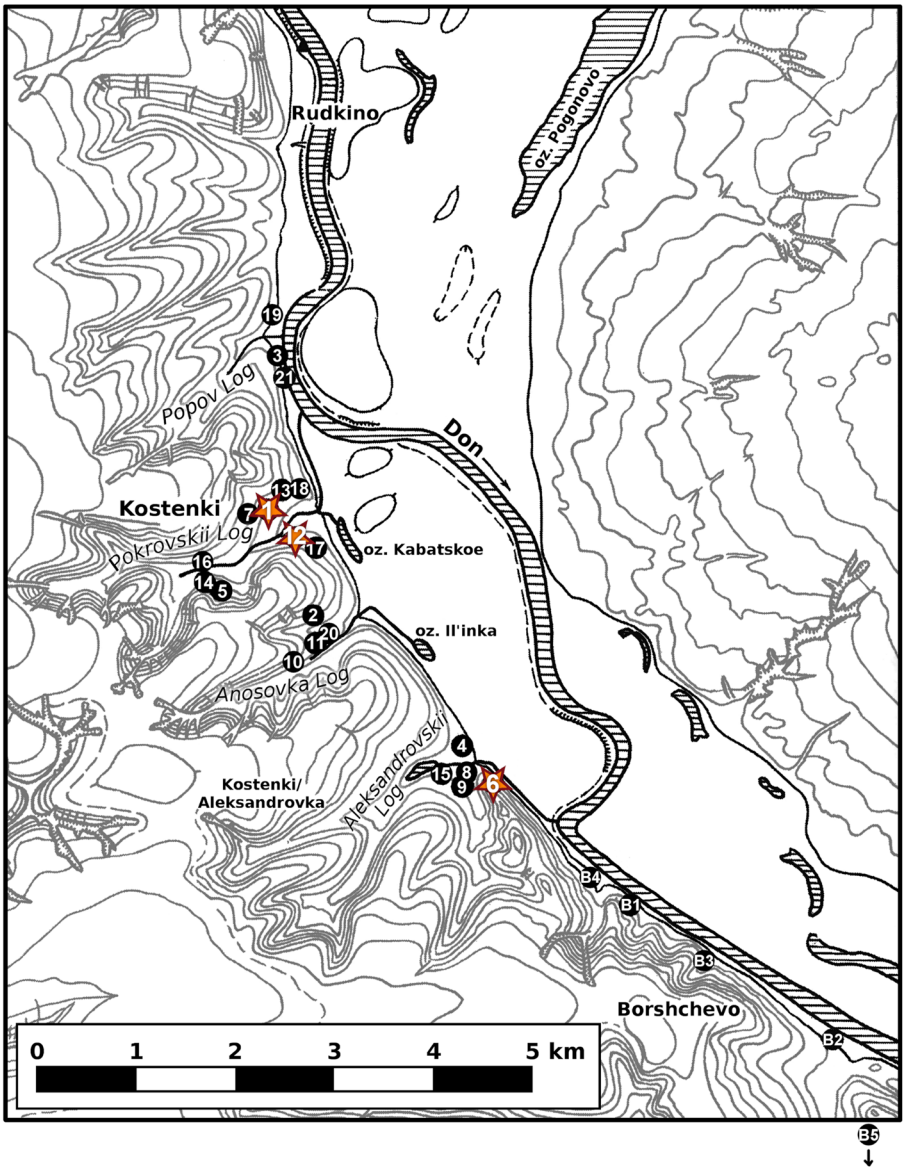

Fig. 3 Position of the Kostenki-Borshchevo sites on the west bank of the River Don, with the three early Streletskian sites (Kostenki 1, Kostenki 6 and Kostenki 12) highlighted

stratigraphic entity (Anikovich 1977a; Rogachev et al. 1982; Bradley et al. 1995; Anikovich et al. 2006, 2008; Hoffecker et al. 2016). Kostenki 6 has been suggested to have contained a mixture of different assemblages, and the pre-ash age of at least some archaeological material has been questioned (Praslov 1976; Rogachev and Anikovich 1982b; Anikovich 1992). Several periods of excavation at Kostenki 12 have demonstrated the problematic nature of Layer III (Rogachev 1957; Praslov and Rogachev 1974; Rogachev and Anikovich 1982a; Anikovich et al. 2004; Hoffecker

et al. 2005, 2010), and it is unclear how the layer's archaeological assemblage should be interpreted. These issues have hindered confident characterisation of the Kostenki early Streletskian.

Research Aims, Materials and Methods

In light of these problems, we re-examined Kostenki 1 Layer V, Kostenki 6 and Kostenki 12 Layer III. Our aim was to assess known and suggested stratigraphic problems, and in doing so shed light on whether these assemblages are unmixed accumulations of archaeological material deposited over a short period. As far as possible, we also sought to improve the chronology of unambiguously Streletskian material.

Our reassessment was made using archaeological archives housed in the Institute for the History of Material Culture, the Zoological Institute and the Peter the Great Museum of Anthropology and Ethnography (Kunstkamera), Saint Petersburg, and included a program of radiocarbon dating of bone material carried out at the Oxford Radiocarbon Accelerator Unit (ORAU).

Archaeological Archives

As well as published accounts of work at Kostenki 1, Kostenki 6 and Kostenki 12, we made use of unpublished excavation reports housed in the Institute for the History of Material Culture archive. These reports, completed after each stage of fieldwork, contain the maximum amount of detail from which to understand each stratigraphic issue. The archive materials also allowed us to identify/verify the context of some key artefacts.

In addition, we examined lithic assemblages from all major phases of excavation at Kostenki 1, Kostenki 6 and Kostenki 12. Unfortunately, the LHB-age Kostenki collections are generally unsuitable for taphonomic analysis through lithic refitting studies, for two reasons. First, most assemblages have undergone post-depositional movement and dispersal. Second, many collections are dispersed across multiple institutions, and in some cases it is unclear where much of the debitage is. Stratigraphic questions have instead previously been addressed by considering the distribution of raw material types and/or specific technological features (e.g. Anikovich 1977a, b; Rogachev and Anikovich 1982a). We also used this approach, but chiefly to assess previous post-excavation re-attribution of material to different layers.

Given its status as the Streletskian's defining feature, we determined where at each site each Streletskian point was found. This allowed assessment of the points' spatial relationships with other parts of each layer and with previously produced radiocarbon dates. It also meant we could target our own radiocarbon dating at samples found close to diagnostic pieces. We defined Streletskian points as lithic artefacts shaped to a triangular or subtriangular outline with bifacial retouch, and with an absence of any convexity at their base (i.e. only artefacts with straight or concave bases). Artefacts also required at least one invasive/covering facet on each face whose length is greater than one third of the width of the piece. This enabled exclusion of simple edge-retouched flakes with subtriangular outline. Complete/near complete points were accepted, as well as basal parts if they showed the characteristic concave base.

Our typological criteria for Streletskian points were deliberately strict. Previously, some artefacts not meeting the definition of Streletskian point have been interpreted as representing earlier stages of the same reduction process (e.g. Anikovich et al. 2008; p.104: fig. 55). While this cannot be ruled out, neither can it be demonstrated, at least based on current understanding of these artefacts. Such pieces were therefore not accepted here. We return to this issue in the "Discussion" section below.

To inform our assessment of the unmixed nature of the Kostenki 1, Kostenki 6 and Kostenki 12 assemblages, we also took note of artefacts that are diagnostic or particularly characteristic of different archaeological facies. This notably included pieces indicative of Upper Palaeolithic blade/let production and the creation/rejuvenation of bifacial tools.

Radiocarbon Dating

A program of radiocarbon dating on animal bones was designed to help address stratigraphic questions specific to each site. Like others (e.g. Hoffecker et al. 2010), we consider most animal bones at Kostenki to derive from human activity. A large majority of the animal bones are found in strata that contain cultural material; very few come from deposits lacking archaeological artefacts. Where possible we targeted horse and wolf bones. Some accumulations of the remains of these taxa in later periods are undoubtedly anthropogenic (Dinnis et al. 2018; Hoffecker et al. 2018).

Two different methods were used to prepare samples prior to their measurement by accelerator mass spectrometry (AMS). First, some were pre-treated following ORAU's routine procedure, as described by Brock et al. (2010). This comprises decalcification in acid, a base wash, a further acid wash, gelatinization and ultrafiltration (coded 'AF'). Samples that had been certainly or potentially preserved with glues were washed with solvents (acetone, methanol and chloroform) prior to the AF treatment (coded 'AF*'). Second, some samples were pre-treated using the compound-specific approach optimised at the ORAU (Devièse et al. 2018). This method involves the separation of the underivatized amino acids from hydrolysed bone collagen samples using preparative high-performance liquid chromatography (Prep-HPLC). The amino acid hydroxyproline, found almost uniquely in mammalian collagen, is isolated for AMS measurement. This pre-treatment approach (coded 'HYP') is, to date, the most efficient available technique to remove contaminants including, but not limited to, conservation materials (with the exception of collagen-based glue). In the work presented here, we used HYP pre-treatment for bones from contexts that were especially crucial to our research questions, and in one case to re-date a bone for which routine methods (i.e. AF*) had produced an age incompatible with its reported stratigraphic position.

A Note on the Use of Radiocarbon Dating to Address Stratigraphic Questions

Some bones for the period 50–30,000 years ago continue to produce incorrect radiocarbon ages because, in some cases, even if the sample passes all the quality controls in place in radiocarbon dating facilities, there may be contamination still present that affects the AMS measurement. Work is ongoing to develop new procedures to ensure that even trace remaining contaminants can be identified (e.g. Devièse et al. 2019). Until such methods are routinely used, using radiocarbon dating to address stratigraphic

questions creates an obvious methodological pitfall. However, we are confident in the validity of our approach here, thanks to our use of HYP pre-treatment, which permits the dating of a specific molecule, hydroxyproline, rather than a material, collagen, which may still contain some contamination.

Where HYP pre-treatment has been applied to sites dating to the Late Middle and Upper Palaeolithic, and particularly in cases where there are suspicions about the accuracy of previously obtained determinations, it has produced demonstrably accurate results. In some cases, new HYP results have aligned with other site-specific chronological information, and in other cases they have been consistent with chronological frameworks based on material culture comparisons. The HYP pre-treated AMS date for the Kostenki 14 EUP-age burial, for example harmonises with its position relative to the CI tephra, and with an ABOx-treated charcoal determination and the inferred age of microliths occupying a similar stratigraphic position at the site (Douka et al. 2010; Marom et al. 2012; Dinnis et al. 2019a). New HYP dates for Kostenki 17 are similarly consistent with their chronostratigraphic relationship with the CI tephra, and with an inter-regional chronocultural framework built on microlith forms (Dinnis et al. 2019a, 2019b). Likewise, HYP pre-treated AMS dates for Kostenki 18 and for Abri Blanchard are consistent with their chronology based on material culture comparison with better-dated sites nearby (Reynolds et al. 2017; Bourrillon et al. 2018). Given our use of HYP dating, we therefore view our approach as a valid tool to aid stratigraphic assessment of Kostenki's early Streletskian sites.

Kostenki 1, Layer V

Background, Excavations, Stratigraphy

Kostenki 1 is best known as the type site for the Mid Upper Palaeolithic (MUP) Kostenki-Avdeevo Culture, found in the extensively excavated uppermost Layer I (Efimenko 1958; Sinitsyn 2015). The first targeted investigation of Kostenki 1's lower layers began with A. N. Rogachev's 1938 test-pitting and his more substantial 1948–1953 work (Rogachev 1950, 1957; Rogachev et al. 1982) (Fig. 4). From 1948, Rogachev recognised a total of five archaeological layers, with the lower part of the sequence (Layers III–V) spanning two humic units separated by unhumified loam. Although no volcanic ash deposits were found, he interpreted these humic units as the UHB and LHB (Rogachev 1950, 1953, 1957).

Layer V, the site's lowermost layer, was found at a depth of 3.5–3.8m below the modern surface. It was found mostly at the base of the unhumified loam separating the two humic beds, but partly in underlying lenses of the LHB itself (Rogachev 1950, 1957; Rogachev et al. 1982). In some areas, a very sparse and apparently stratigraphically slightly higher Layer IV was identified, mostly contained within the unhumified loam. The more substantial Layer V contained lithic artefacts (Table 1), a few fragmentary bones/burned bones and remnants of ochre. Finds were clustered within an oval area of approximately 6 × 4.5m, concentrated on squares в-б-а-β–5-4-3-2-1 (Fig. 4) (Rogachev et al. 1982). Within the centre of this (squares б-а–4) was an accumulation of ash and charcoal that Rogachev interpreted as a redeposited hearth. Rogachev (1957: 36-37) was explicit about the evidence for post-depositional

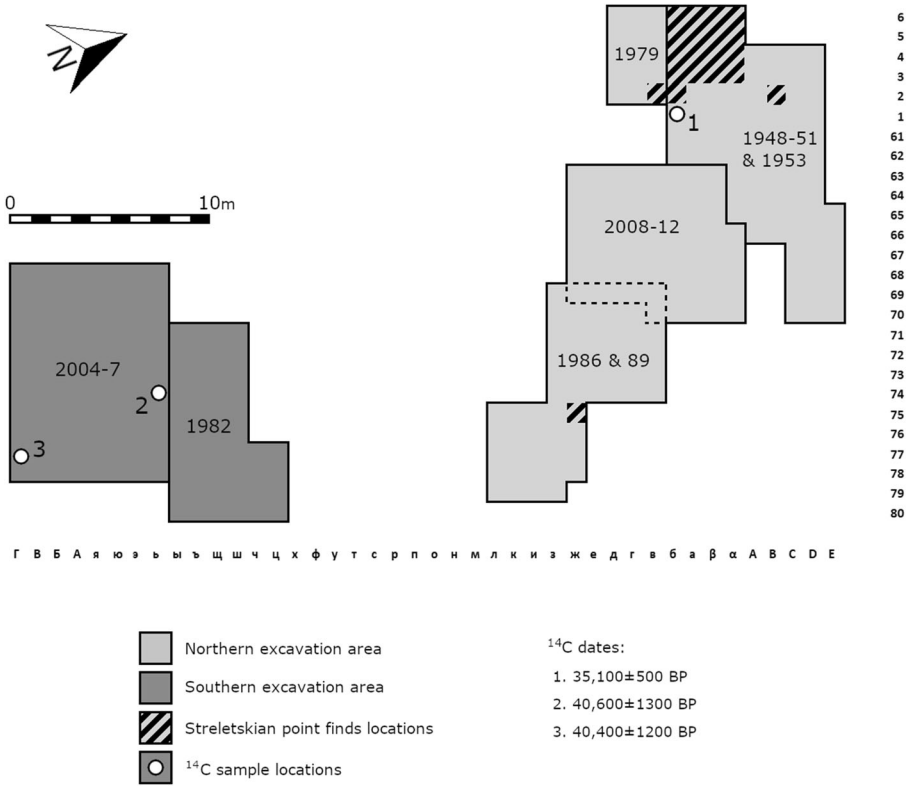

Fig. 4 Plan of excavations at Kostenki 1 that included work on the site's lower layers, showing the finds positions of Streletskian points in Layer V and of our dated bones. Modified from Dudin (2014)

deformation of the archaeological layer, including the fact that some lithic artefacts were found in vertical position. Despite this, he saw no reason to doubt the overall stratigraphic coherence of his archaeological sequence.

Although Rogachev correlated his Layer V with the top of the LHB, he identified no volcanic ash to corroborate this. Ash was first recognised in later test-pits, at a depth consistent with Rogachev's interpretation of his 1948–1951 sequence but ~20m away from the limits of his excavation (Abramova et al. 1971; Rogachev 1975; Rogachev et al. 1982). The lack of an ash marker closer to the 1948–1951 excavations left Rogachev's interpretation open to question. M. V. Anikovich in particular was unconvinced that Rogachev's Layer V derived from a stratigraphic position lower than the ash (Anikovich 1977a; Rogachev et al. 1982; Anikovich 1993; Bradley et al. 1995; Anikovich et al. 2006: 91-92; Anikovich et al. 2008: 94; Hoffecker and Holliday 2014). Anikovich suggested that Rogachev's Layer V belonged, instead, to the UHB, based on the stratigraphic closeness and weakly humified nature of Rogachev's two humic units, as well as differences between the sequences of Rogachev's excavations and the first test-pit to yield ash deposits. In support of this argument, he highlighted typological differences between Kostenki 1 Layer V and the other early Streletskian assemblages, as well as two radiocarbon dates of post-CI age for Layer V from the later 1986/89 excavations (see Fig. 4). Like Anikovich (1977a: 78-79), we see Rogachev's Kostenki

Table 1 Approximate counts for lithic pieces attributed to Kostenki 1 Layer V, Kostenki 6 and Kostenki 12 Layer III

Site	Layer	Total number	Retouched pieces	Notes	Reference(s)
Kostenki 1	Layer V North (see text)	>1500	~100	Excludes a small number of pieces collected during later excavations	Rogachev 1957; Rogachev et al. 1982
Kostenki 1	Layer Va South (see text)	777	22		
Kostenki 6		>1000	~50		Rogachev and Anikovich 1982b; Sinitsyn et al. 2019; Dinnis et al. accepted manuscript
Kostenki 12	III (1951–1974 excavations)	~1100	~160		Bradley et al. 1995
Kostenki 12	III (1999–2004 excavations)	~450	~50		Anikovich et al. 2004

1 Layer V assemblage as the most likely of Kostenki's Streletskian assemblages to be unmixed. The question of whether it belongs to the UHB or deposits below the volcanic ash is therefore crucial.

Later work at Kostenki 1 included further excavation of its lower layers. Although focused on the upper layers, N. D. Praslov's 1971–1994 work recovered a small assemblage attributed to Layer V (Anikovich et al. 2008; Dudin 2014). In 1979, an area of Layer V adjacent to Rogachev's trench was excavated (Fig. 4). Finally, large-scale excavations of the lower part of the sequence were undertaken in 2004–2012 by Anikovich and one of us (AD) (Fig. 4).

Broadly speaking, the stratigraphy as defined in later excavations agrees reasonably well with Rogachev's observations, particularly regarding the depths of the respective archaeological layers (Rogachev 1957; Hoffecker et al. 2016; Haesaerts et al. 2017). At the same time, recent work has added caveats to the stratigraphy. The later excavations enabled identification of volcanic ash, sometimes dispersed through the sequence but concentrated around the level of Layer IV, and thus broadly consistent with Rogachev's interpretation (Hoffecker et al. 2016). The 2008–2012 excavations provided additional data to contextualise Rogachev's work. A series of small palaeo-channels was recognised in the lower part of the archaeological sequence close to Rogachev's excavation area (Hoffecker et al. 2016: 312). Furthermore, judged by the raw material profile of the newly excavated small and sparsely distributed Layer IV assemblage, as well as its closeness to Layer V, it is possible that Rogachev's Layers IV and V actually derive from the same period of activity (AD, personal observation). With this in mind, it can be noted that Rogachev (1957: 35) himself highlighted the similarity of his few Layer IV lithic pieces to those in the larger Layer V assemblage. The 2004–2007 excavations in the southern part of the site similarly revealed stratigraphic complexity. Most notably, a redeposited accumulation of lithic material (squares Г-В-Б–76-77-78) was allocated to "Layer Va", due to its higher stratigraphic position relative to other (mainly faunal) Layer V material (Dudin 2007; Hoffecker et al. 2016). Compared to the 1948–1953 excavations, more recent work produced only small numbers of lithic artefacts. The only exception was the Layer Va assemblage (Table 1).

Collections

Considered in its totality, Layer V of Kostenki 1 can be split into two unconnected zones: north and south (Fig. 4) (henceforth Layer V North/South). The Layer V North collection comes mainly from Rogachev's excavations, and Rogachev et al.'s (1982) description fairly reflects the assemblage's contents. It is composed almost entirely of coloured cherts usually thought to be local to the site, with about 1% of the assemblage instead made up of quartzite and imported flint. Cores have flat flaking surfaces with (sub-)parallel arrises. The retouched assemblage totals 119 pieces, of which three lithic artefact types are important: there are 43 complete or fragmentary bifacial tools, including Streletskian points (Fig. 5c, d, e, i); 24 short endscrapers, often subtriangular in outline and many with flat ventral retouch (Fig. 5f, g, h); and five examples of a specific form of transverse burin (Fig. 5a, b) (Rogachev 1957; Rogachev et al. 1982). In addition, there are small numbers of various forms of end-/side-scraper and burin, as well as four splintered pieces and around 30 pieces with simple edge retouching.

Contrary to Anikovich's (2001-2002: 274-275) suggestion, we found no convincing evidence for Upper Palaeolithic blade production. However, the group of transverse burins

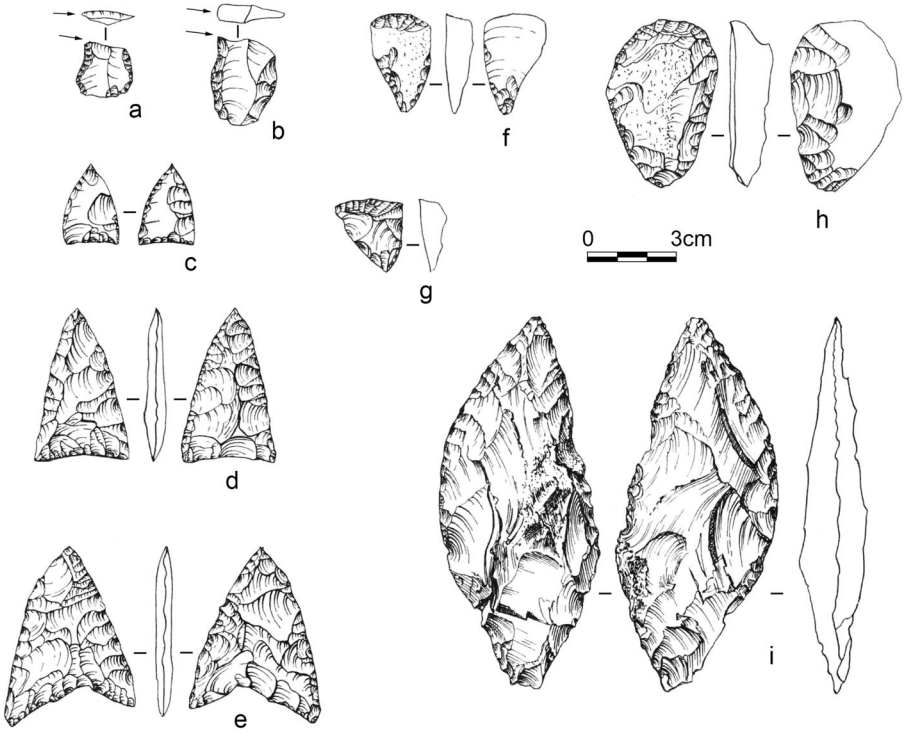

Fig. 5 Selected artefacts from Rogachev's collection from Layer V (North) of Kostenki 1: transverse burins (**a**, **b**); Streletskian points (**c**, **d**, **e**); sub/triangular scrapers (**f**, **g**, **h**); biface (**i**). Modified from Rogachev and Anikovich (1984)

and several burin spalls are undoubtedly of Upper Palaeolithic character. Evidence for bladelet production is limited to a few pieces of unpatinated black flint—a material that is uncharacteristic for the layer. The assemblage contains numerous bifaces as well as small biface thinning flakes (Bradley et al. 1995). Because the early Streletskian is often noted to lack items of personal ornamentation, an apparent pendant pre-form recovered from Layer V in 1979 (square д–4) (Praslov 1979; Rogachev et al. 1982) is noteworthy.

From the site's southern area, the Layer Va assemblage includes 22 retouched pieces (Table 1). Its relationship with the Layer V North assemblage is unclear. It shares some similarities, including the presence of bifacial tools and one short scraper with flat ventral retouch. None of the Layer Va artefacts, however, is a Streletskian point, and the Layer Va assemblage contains a much greater proportion of imported black flint.

Streletskian Points

In total, there are eight Streletskian points from Layer V of Kostenki 1. All eight are from Layer V North. Six were found during Rogachev's excavations: one from the "Lower Layer" ("н.с." = нижний слой) during his 1938 test-pitting; three from squares б-а-β-α–6-5-4-3 during the earlier phase of his more extensive excavations in 1948 (Rogachev 1950); and two during 1951 excavation of squares В–2 and б–2 (see Fig. 4). A further point was found in square в–6 in 1979, immediately adjacent to Rogachev's excavation

area (see Fig. 4) (Praslov 1979). The eighth Streletskian point comes from Praslov's 1989 excavation of square ж–75. Importantly, this example was found in the same square as a transverse burin matching those typical of Rogachev's Layer V assemblage. The association of these two artefact types in a square nearly 20m away from Rogachev's finds supports the coherence of his Layer V assemblage. One artefact from Layer V South has been described as a fragment of Streletskian point (Anikovich et al. 2006: 99, fig. 10:4), but is in fact a fragment of a large bifacial tool of unknown form.

Radiocarbon Dating

Previous radiocarbon dates for Kostenki 1's lowest layers (IV and V) are given in Table 2. Of eleven dates for Layer V, four (GIN-6247; LE-2030, LE-3542 and GrA-5557) are younger than their stratigraphic context. The remaining eight are from five charcoal samples from Praslov's 1981–1982 excavations, i.e. Layer V South (Fig. 4). They span the range 43–35 ka BP and are therefore consistent with the layer's position below the volcanic ash. However, their connection to Layer V North, and thus to an archaeological assemblage with Streletskian points, is unclear. Recent OSL dates from both sides of the site are consistent with the stratigraphic position of the ash and the archaeological layers (Hoffecker et al. 2016).

Our radiocarbon dating focused on two issues. Most importantly, we wanted to better establish the age of Layer V North, which is the only Kostenki assemblage containing numerous Streletskian points. The primary objective was to assess the longstanding assertion of Anikovich that the assemblage actually originated from deposits younger than the CI tephra (see above). Second, by way of comparison, we wanted to examine the chronology of Layer V South.

Three bones were sampled for radiocarbon dating (Table 3). The first was a fragment of horse pelvis from Rogachev's 1951 excavations (sample K1-01), which offered the best chance of a radiocarbon date from material close to his Streletskian assemblage. The bone came from square б–1, the same square as one of the typical transverse burins and adjacent to the finds position of a complete Streletskian point found in the same year (square б–2; Fig. 4). The bone is attributed to the "Lower Layer" ("н.с." = нижний слой). As it was excavated after Rogachev's recognition of the site's five layers, this attribution means that it belongs to his Layer V (see Rogachev 1957). However, Rogachev's (1951) excavation archives leave open the possibility that it may instead relate more closely to his Layer IV: he notes that the two layer(s) in this area were particularly poorly defined, and the bone is marked as coming from ~30cm higher than some of the Layer V lithics in adjacent squares. As described, there is some indication that Rogachev's Layers IV and V are actually part of the same accumulation; but irrespective of this, because Rogachev considered both his Layer IV and Layer V to stratigraphically underlie the UHB, this has no bearing on our main question: whether, as Anikovich has argued, Rogachev's Layer V assemblage actually belonged to the UHB rather than below the ash. To have maximum confidence in the result produced the sample was processed using HYP pre-treatment.

At face value our new date of 35,100 ± 500 BP (OxA- X-2717-21) is marginally older than the radiocarbon age of the CI tephra, although at 95.4% probability it overlaps with the tephra's age (Table 3). Our result therefore confirms this bone is the same age or, more likely, slightly older than the volcanic ash. This is consistent with Rogachev's view that Layer V underlay (but was close to) the stratigraphic position of

Table 2 Previous radiocarbon dates for Layers IV and V of Kostenki 1. ABA denotes a pre-treatment comprising a decalcification in acid, a base wash and a further acid wash, and is the routine method in most AMS and conventional laboratories (Brock et al. 2010). ABOx-SC is a more robust pre-treatment including an oxidation-stepped combustion (Bird et al. 1999; Wood et al. 2012)

Lab code	Layer	Provenance	Sample	Conventional radiocarbon age	Notes	Reference
GrA-53616	IV	1981 excavations	Charcoal	38,250 +700/−550	"A-1605: sample labelled CL-IV, 1981 (depth 3.00–3.10 m)" ABA pre-treatment	Haesaerts et al. 2017
CURL-15811b	IV	2011 excavations	Charcoal	31,020 ± 400 BP		Hoffecker et al. 2016
GIN-6247	V	?	Charcoal	>18,800 BP		Sinitsyn et al. 1997
LE-2030	V	1986/1989 excavations	Tooth (mammoth)	27,390 ± 300 BP		Sinitsyn et al. 1997; Anikovich et al. 2006
LE-3542	V	1986/1989 excavations	Charcoal	30,170 ± 570 BP		Sinitsyn et al. 1997; Anikovich et al. 2006
GrA-5557	V	?	Charcoal	32,300 ± 220 BP		Sinitsyn et al. 1997
GrA-5245	V	1982 (or 1981?) excavations	Charcoal	34,900 ± 350 BP	Two dates listed in Sinitsyn et al. (1997) with same lab code, but they are different samples (Haesaerts et al. 2017)	Sinitsyn et al. 1997
GrA-5245	V	1982 excavations	Charcoal	37,900 +2800/−2100 BP	Re-dated (using both ABOx-SC and ABA pre-treatment) by Haesaerts et al. (2017) Two dates listed in Sinitsyn et al. (1997) with same lab code, but they are different samples (Haesaerts et al. 2017)	Sinitsyn et al. 1997
GrA-53611	V	1982 excavations	Charcoal	39,200 +800/−750 BP	Same sample as GrA-5245 ABA pre-treatment	Haesaerts et al. 2017
OxA-26649	V	1982 excavations	Charcoal	42,150 ± 750 BP	Same sample as GrA-5245 ABOx-SC pre-treatment	Haesaerts et al. 2017
GrA-53616	V	1981 excavations	Charcoal	38,250 +700/−550 BP	ABA pre-treatment	Haesaerts et al. 2017

Table 2 (continued)

Lab code	Layer	Provenance	Sample	Conventional radiocarbon age	Notes	Reference
GrA-53612	V	1982 excavations	Charcoal	42,100 +1000/−700 BP	ABA pre-treatment	Haesaerts et al. 2017
OxA-26650	V	1982 excavations	Charcoal	42,800 ± 900 BP	Same sample as GrA-53612 ABOx-SC pre-treatment	Haesaerts et al. 2017

the tephra elsewhere at Kostenki. We also note that our date is older than the oldest radiocarbon dates from UHB deposits at Kostenki, which are a series of determinations of ~32.5 ka BP for Kostenki 1 Layer III (Sinitsyn et al. 1997; Hoffecker et al. 2016). Importantly, our result of 35,100 ± 500 BP is therefore inconsistent with Anikovich's assertion that Rogachev's Layer V derived from the UHB.

To compare the result for Layer V North with Layer V South, two bones from the 2004–2007 excavations were also sampled for dating. Most of the fauna found in Layer V during these excavations was mammoth, most of which was concentrated in squares ю-э-ь–71-72-73-74-75-76-77-78 (Hoffecker et al. 2016) and interpreted by Hoffecker et al. (2010, 2016) as mainly deriving from a single, subadult animal. We sampled one of these bones (sample K1-02). As glue was visible on the bone's surface a solvent wash was applied prior to pre-treatment using ORAU's standard pre-treatment procedures (i.e. AF*). We also wanted to obtain a date for a sample from as close to the Layer Va lithic assemblage as possible. Most of the Layer V bones (of mammoth, horse and reindeer) excavated in 2007 lay stratigraphically lower than the Layer Va lithic assemblage (Dudin 2007; Hoffecker et al. 2016). However, one horse bone attributed to Layer Va was sampled for dating. The bone's post-excavation history is known, and no glue or other chemical has been applied to it. We therefore used ORAU's standard pre-treatment method (AF).

These samples from Layers V and Va South produced results of 40,600 ± 1300 BP (OxA-33659) and 40,400 ± 1200 BP (OxA-36234) (Table 3). Both are older than our date for Layer V North, suggesting that at least some bone material attributed to Layer V in these two different areas of Kostenki 1 is not of the same age. It is also noteworthy that our two new dates for Layer V South agree well with the majority of Haesaerts et al.'s (2017) recent charcoal dates (Table 2; Table 3), which came from an adjacent area (Table 2; Table 3; Fig. 4).

Summary

- All Streletskian points from Kostenki 1 Layer V come from the site's northern excavations.
- Our new radiocarbon date of 35,100 ± 500 BP (OxA- X-2717-21) for Layer V North is consistent with Rogachev's interpretation that the assemblage was stratigraphically close to but underlay volcanic-ash-age deposits.
- Following Rogachev's Layer V attribution of the dated bone, this radiocarbon date is the first that can be linked to a coherent early Streletskian assemblage with Streletskian points.
- Our dates for material from Layer V/Va South agree with previous dates for material from this area, and are ~5500 ^{14}C years older than the material dated from Layer V North (between 2220 and 7200 cal years older at 95.4% probability using the Difference function in OxCal 4.2 [Bronk Ramsey 2009]).

Kostenki 6

Background, Excavations, Stratigraphy

Kostenki 6 comprises the adjacent sites of Streletskaya 1 and 2. Limited work at Streletskaya 1 in the 1920s and 1930s found only a few lithic artefacts and bones. In

Table 3 New radiocarbon dates for Layer V of Kostenki 1. No other radiocarbon dates (or failed dates) were produced for this context in the course of this work. P-Code refers to pre-treatment code: 'AG' is collagen; 'AF' is ultrafiltered collagen; 'HYP' denotes the extraction of hydroxyproline from hydrolysed bone collagen. Samples that had been preserved with glues, or samples for which we did not have complete knowledge of their post-excavation history, were also washed with solvents (acetone, methanol and chloroform) prior to the 'AG' or 'AF' treatment (coded 'AG*' or 'AF*'). Details of the methods can be found in Brock et al. (2010) and Devièse et al. (2018). The dates were calibrated using OxCal 4.3 (Bronk Ramsey 2009) and the INTCAL13 calibration curve (Reimer et al. 2013). Technical details for the samples are provided in Online Resource 1

Sample code	Layer	Excavation	Square/other info	Sample	P-code	P-number	Conventional radiocarbon age	Calibrated age range (95.4% probability)	OxA number
K1-01	V North (see text)	Rogachev, 1951	б–1	Horse, pelvis	HYP (on collagen extracted using AG*)	P41466	35,100 ± 500 BP	40,900–38,600 calBP	X-2717-21
K1-02	V South	Anikovich/Dudin, 2004	КБАЕ-1-04. 28.08. кв. ь-74. Н.О. -313. No. 12.	Mammoth, unknown element	AF*	P40622	40,600 ± 1300 BP	47,200–42,300 calBP	33659
K1-03	Va South	Anikovich/Dudin, 2007	К-1-2007 Г–77 Va к.с. ВК-154	Horse, first phalanx	AF	P43906	40,400 ± 1200 BP	46,600–42,300 calBP	36234

1952–1953, Rogachev undertook more substantial excavations at Streletskaya 2 (Fig. 6), ~60m south and upslope from Streletskaya 1.

Compared to Streletskaya 1, Streletskaya 2 contained a denser accumulation of lithic and faunal finds. In the main excavation area, these lay mostly within humic deposits, which in some areas underlay thick lenses of volcanic ash (Rogachev 1952, 1957). These humic sediments had been redeposited on the left bank of a palaeo-ravine, which in antiquity had run northwards through the eastern part of the site (Fig. 7). As a result, the position, thickness and nature of the archaeological layer differed markedly across the excavated area. To the west, it lay 0.8–1m below the present-day surface, was as thin as 10cm, and sloped relatively gently northwards, following the topography of the modern-day surface. In contrast, in the eastern part of the excavation, it was up to 4–6m below the modern-day surface, was up to 2m thick, and dipped sharply eastwards into the ravine. Except for a few bones and flakes, lithic and faunal material was found on the sloping bank of the palaeo-ravine to the east of the site, in squares П-Р-С-Т-У-Ф–30-29-28-27-26-25 and particularly squares Ф–30-29 (Rogachev 1952: 9; 1957) (Fig. 6).

With the exception of a few finds on the margins of the main excavation area (Rogachev 1957: 102-103), archaeological material was restricted to a stratigraphic position lower than the volcanic ash deposits. Although it was redeposited, Rogachev (1952: 9-10; 1957) viewed the archaeological horizon as related to activity prior to the deposition of the ash, and thus thought that the ash provides a *terminus ante quem* for the archaeological assemblage.

More recent small-scale excavations at Streletskaya 2 have confirmed Rogachev's description of Streletskaya 2's stratigraphy (Praslov 1976; Sinitsyn et al. 2019; Dinnis

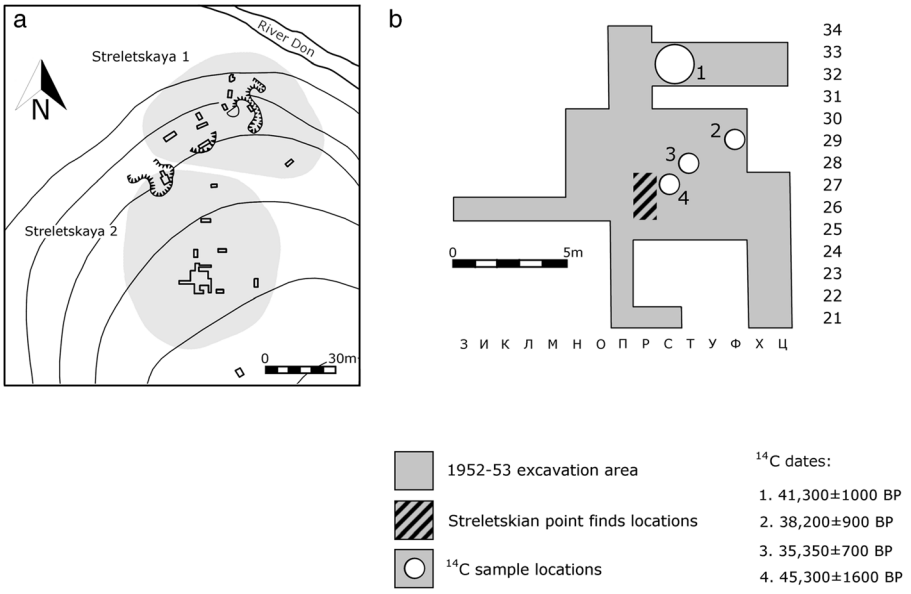

Fig. 6 Early excavations at Kostenki 6 (Streletskaya 1 and Streletskaya 2) (**a**), and the main excavation area of Streletskaya 2, showing the finds positions of Streletskian points and of our dated bones (**b**). Note only the HYP date for the bone from C-T–33-32 is shown (see text and Table 5). Modified from Rogachev (1957: 100, fig. 52)

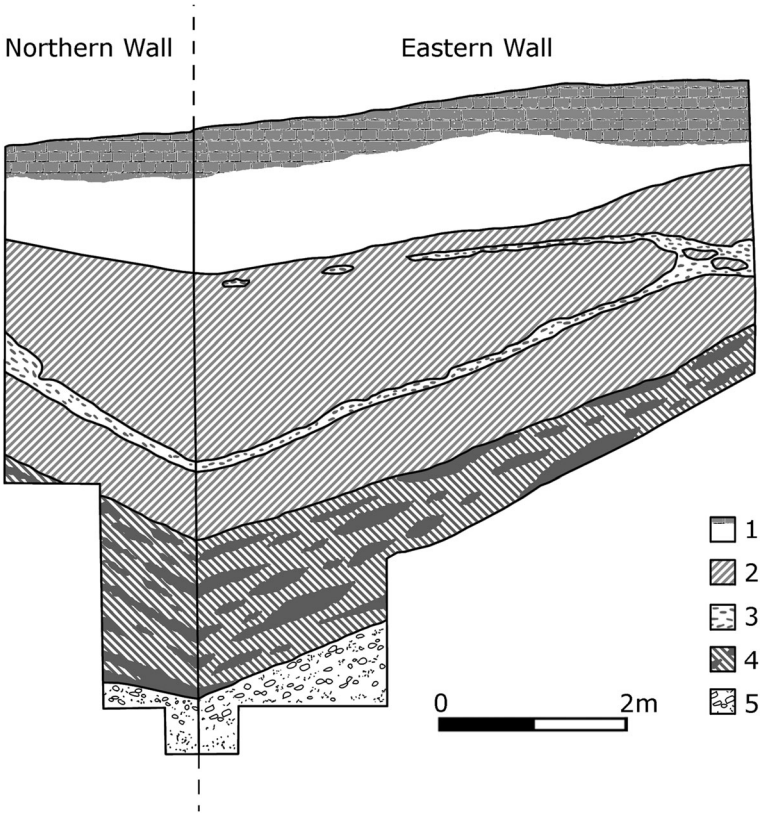

Fig. 7 Northern wall (south-facing section; У-Ф–31/30) and eastern wall (west-facing section; Ф/Х–30-25) from Rogachev's 1952 excavations of Kostenki 6 (after Rogachev 1957: 101, fig. 53). Key: 1, modern (Holocene) soil horizons; 2, non-humic loam; 3, volcanic ash; 4, redeposited humic/non-humic loams (=LHB), containing archaeological material; 5, Senonian sand with chalk pebbles. Note the sharp dip of the archaeological deposits, which have been redeposited into a large palaeo-ravine

et al. accepted manuscript), although different interpretations of the site have been offered. Whereas Rogachev (1957) viewed the assemblage as related to a single occupation, others have suggested it may include a mixture of material (e.g. Rogachev and Anikovich 1982b; Anikovich 1992: 241). In addition, the possibility has been raised that some material may originally have derived from above, rather than below, the volcanic ash deposits (Praslov 1976: 15). Some support for the latter view comes from radiocarbon dates younger than the CI tephra (Table 4).

Table 4 Previous radiocarbon dates for Kostenki 6 (Streletskaya 2)

Lab code	Sample	Conventional radiocarbon age	Reference
GIN-8023	Mammoth bone	21,100 ± 200 BP	Sinitsyn et al. 1997
GIN-8572	Horse bone	31,200 ± 500 BP	Sinitsyn et al. 1997

Collections

The lithic assemblage from Streletskaya 2's LHB archaeological layer contains ~50 retouched pieces (Table 1). This includes two Streletskian points (Fig. 8a, b), a naturally backed bifacial knife (Fig. 8c) and a small number of burins, scrapers and splintered pieces. The assemblage contains evidence for typically Upper Palaeolithic blade production (e.g. blade/let core tablets from Ц–22, С–27, П-Р-С–21 and Ф–29 [Fig. 8f]) as well as several small thinning flakes (e.g. from С-Т-У-Ф-Х-Ц–33-32 [Fig. 8d], Ф–28 and Р–28) showing biface manufacture/rejuvenation. Like Kostenki 1 Layer V North, local coloured cherts and non-chert materials form the majority of raw materials, but unlike Kostenki 1 Layer V North the assemblage also includes a significant quantity of black flint. The Kostenki 6 collection also contains one typical Dufour bladelet (Dufour subtype; Demars and Laurent 1992) (Fig. 8e). Although Rogachev thought that this ultimately derived from the main Streletskaya 2 assemblage, it was actually found downslope in one of his test-pits at Streletskaya 1 (Rogachev 1952). Its relationship with the Streletskaya 2 material is therefore unclear. No worked osseous pieces or pendants were recovered from Streletskaya 2's

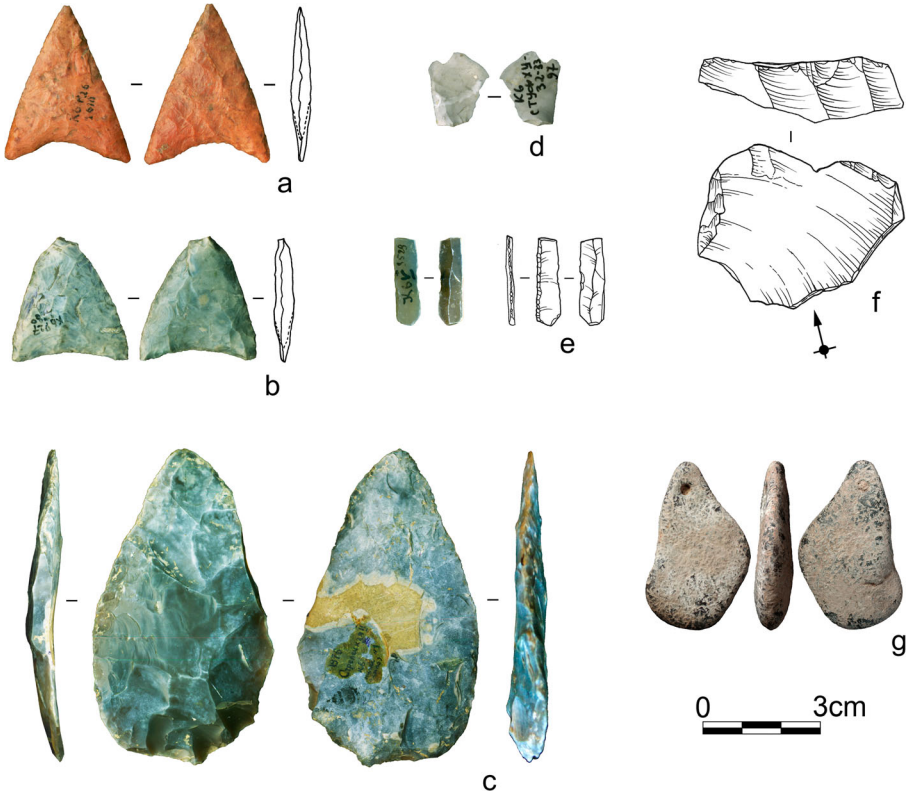

Fig. 8 Selected artefacts from Kostenki 6: Streletskian points (**a**, **b**), biface (**c**), biface thinning flake (**d**), Dufour bladelet (**e**), blade core tablet (**f**) and perforated pebble (**g**). Lithic illustrations by C. Williams. A 3D model of artefact a can be viewed and downloaded from http://earlymodernhumaneurope.com/artefacts/kostenki-6-streletskian-point/

archaeological layer, although a perforated shale pebble was found in Rogachev's backfill during the most recent excavations (Sinitsyn et al. 2019) (Fig. 8g).

Streletskian Points

The site's two Streletskian points were found close together in squares P–26 and P–27 in 1952 (Rogachev 1952) (Fig. 6). Rogachev (1952) records that both occupied a stratigraphic position lower than the ash deposits. The larger bifacial knife was found during later work on the northern part of Rogachev's excavation area, in squares П-P–34-33. It was likewise recorded as being found under the ash deposits (Praslov 1976).

Radiocarbon Dating

Two previous radiocarbon dates for Streletskaya 2 (Table 4) are younger than the CI tephra (i.e. <34.3 ka BP), which is inconsistent with Rogachev's conclusion that the assemblage pre-dated the ash deposits. Our work focused mainly on this question.

Five large mammal bones from the main Streletskaya 2 excavation area were sampled for radiocarbon dating (Table 5). Samples were selected with several issues in mind. First, we wanted to obtain dates for specimens found close to the Streletskian points. Bones from squares C–27, T–28 and T-У–28-27, close to the points' finds locations (P–26 and P–27) were therefore chosen. One bone from the main density of archaeological material (i.e. squares Ф–30-29) was also selected. Finally, by selecting a further sample from squares C-T–33-32 we could produce dates for material from across the main excavation area. This permitted a test of Rogachev's conclusion that all material pre-dates the volcanic ash. All samples produced enough collagen for dating with the exception of one, which failed due to low yield (Table 5).

All samples were processed using pre-treatments including solvent washes as a precaution, as we could not exclude the possibility that the bones have been treated with preservatives. Two of the three dates produced using AF* (OxA-34739 and OxA-33734) are older than the ash and one is younger (OxA-33733: 31,950 ± 450 BP). Two further dates were produced using HYP pre-treatment. The first of these (OxA-X-2730-8) was for the bone found in square C–27, i.e. immediately adjacent to the finds' locations of the Streletskian Points. The second (OxA-X-2717-22) was produced to re-date the sample that with AF* pre-treatment had produced an age younger than the ash (OxA-33733).

In line with other recent work dating bone from Kostenki (Dinnis et al. 2019a), the different ages produced for sample K6-02 (i.e. OxA-33733 and OxA-X-2717-22) demonstrate that standard pre-treatment methods can sometimes produce dates that are underestimates of samples' real ages. As a result, our two other results produced using standard pre-treatment methods (OxA-34739 and OxA-33734) should be viewed as minimum ages, as should the site's previous dates.

As OxA-X-2717-22 (HYP) supersedes OxA-33733 (AF*), all four dated samples produced results >34.3 ka BP, and therefore pre-dating the CI tephra. This is consistent with Rogachev's interpretation that the archaeological material was originally deposited prior to the deposition of the ash. Given the heavily redeposited nature of Kostenki 6's archaeological deposits, however, none of our results can be assumed to accurately date the Streletskian points.

Table 5 New radiocarbon dates for Rogachev's main excavation area at Kostenki 6 (Streletskaya 2). No other radiocarbon dates (or failed dates) were produced for this context in the course of this work. See caption for Table 3 for details about pre-treatment codes (P-code) and calibration. Technical details for the samples are provided in Online Resource 1

Sample code	Square/museum code	Sample	P-code	P-number	Conventional radiocarbon age	Calibrated age range (95.4% probability)	OxA number
K6-02	C-T–33-32	Horse, ulna (?)	AF*	40623	31,950 ± 450 BP	37,000–34,800 calBP	33733
			HYP (on collagen extracted using AG*)	41468	41,300 ± 1000 BP	46,900–43,000 calBP	X-2717-22
K6-06	T-У–28-27	Large mammal (horse?), long bone	AF*	40624	Failed due to low yield		
K6-08	Ф–29	Large mammal (horse?), long bone	AF*	41795	38,200 ± 900 BP	44,100–41,100 calBP	34739
K6-09	T–28	Large mammal (horse?), long bone	AF*	40625	35,350 ± 700 BP	41,450–38,600 calBP	33734
K6-10	C–27, mus. no. 25544	Horse ulna, right	HYP (on collagen extracted using AG*)	41469	45,300 ± 1600 BP	> 46,200 cal BP	X-2730-8

Summary

- The Kostenki 6 collection contains two Streletskian points, but given its heavily redeposited nature, it should not be treated as unmixed.
- Four bones from the assemblage produced radiocarbon dates older than the CI tephra. This supports Rogachev's view that the assemblage is older than the volcanic ash, and suggests that previous radiocarbon dates may be erroneously young.

Kostenki 12, Layer III

Background, Excavations, Stratigraphy

The first phase of fieldwork at Kostenki 12 was undertaken by Rogachev in 1950–1954 (Fig. 9). As well as finding archaeological material within the UHB, he identified two archaeological layers (Layers II and III) stratigraphically lower than ash deposits, within the LHB (Fig. 10). Layer II was found towards the top of the LHB, and was formed solely of occasional bones and lithic artefacts. The richer, stratigraphically lower Streletskian Layer III was found towards the base of the LHB at a depth of close to 4m below modern surface level. The archaeological layer had a thick vertical distribution, with lithic artefacts and animal bones found within lenses of black humic sediments. Concentrations of burned material within these lenses were interpreted as deriving from hearths (Rogachev 1957).

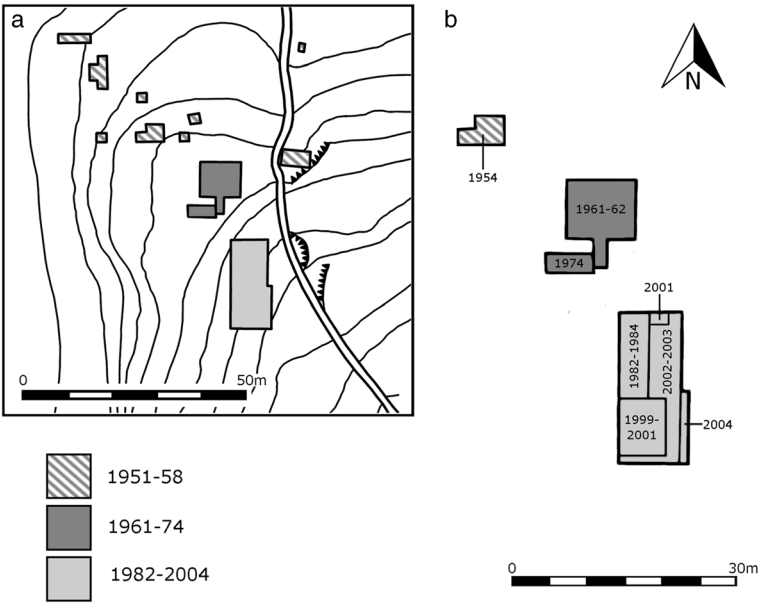

Fig. 9 Simplified plan of excavations at Kostenki 12 up to 2004 (**a**) (modified from Rogachev 1957: 62, fig. 27 & Anikovich et al. 2005: 73); and detail showing Rogachev's Excavation Area III (excavated in 1954) and later trenches to the south (**b**)

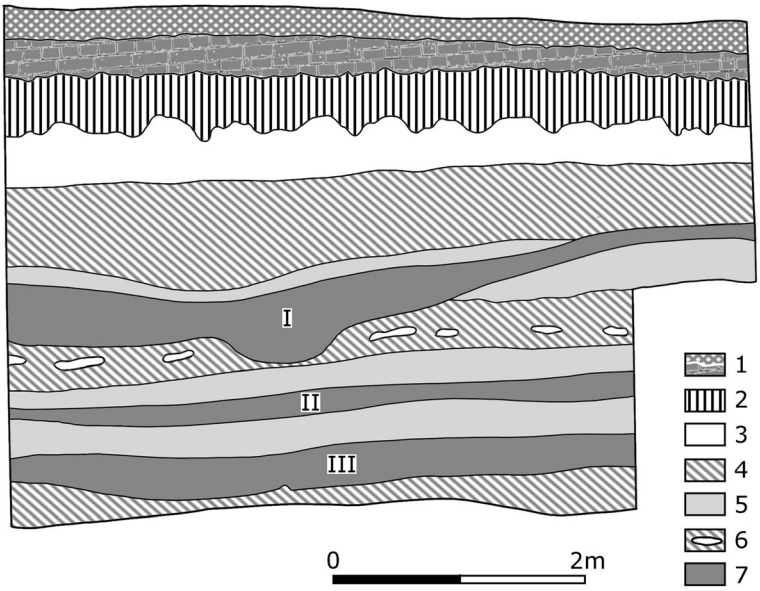

Fig. 10 Southern wall (north-facing section) of Rogachev's Excavation Area III of Kostenki 12. Key: 1, modern (Holocene) soil; 2, modern soil horizon B; 3, loess-like loam; 4, layered loams; 5, humic sediments (=UHB/LHB); 6, loam with lenses of volcanic ash; 7, archaeological layers (numbered I–III) (after Rogachev 1957: 63, fig. 28). Note the stratigraphic positions of archaeological layers II and III beneath volcanic ash deposits, and within underlying humic sediments interpreted as the LHB by Rogachev. Also note the infiltration of UHB Layer I material into a position lower than the volcanic ash, recognised in 1954 as the result of the formation of a palaeo-channel

Later fieldwork by Rogachev and others targeted the area south of and upslope from the 1950–1954 excavations (Fig. 9). A large area first test-pitted in the 1950s was excavated in the early 1960s and in 1974 (Rogachev 1962; Praslov and Rogachev 1974; Anikovich 1977a), but the most notable later excavations were in the south of the site, dug first during the 1980s and extended significantly by Anikovich in 1999–2004. In this area, an archaeological layer was found towards the top of humic deposits that were thought to correspond to the LHB. Although occupying a different position within the humic sediments, this layer was taken as the equivalent of Rogachev's Layer III (Anikovich et al. 2004). These later excavations also found small, stratigraphically lower assemblages, which were attributed to Layers IV and V (Anikovich et al. 2004).

Several major problems are evident in Kostenki 12's LHB-age archaeological deposits. Most importantly, Rogachev (1957; Rogachev and Anikovich 1982a: 137-138) identified a stratigraphically discrete Layer II only in his Excavation Area III (Fig. 9; Fig. 10), dug in 1953–1954. In Excavation Area III, Layer II was (in some areas) separated from the underlying Layer III by 20–40 cm of sterile deposits. In Rogachev's other excavated areas, Layer II was either absent or was conflated with Layer III (Rogachev 1957; Anikovich 1977a, b; Rogachev and Anikovich 1982a). As a result, much of Kostenki 12's Layer II and Layer III material was attributed to these layers only after excavation. Excavations since 1954 have failed to find a stratigraphically discrete equivalent of Rogachev's Layer II (Rogachev 1962; Praslov and Rogachev 1974; Anikovich 1977a, b; Rogachev and Anikovich 1982a; Anikovich et al. 2004).

Although it is probably the best-stratified part of the LHB at Kostenki 12, Rogachev's Excavation Area III was itself obviously problematic, with the humic sediments containing the archaeological material clearly redeposited (Rogachev 1954). Importantly, during his 1954 excavations Rogachev was able to recognise a palaeo-channel running through the area, which had evidently reworked UHB-age material to a depth lower than the ash deposits (Rogachev 1957) (Fig. 10). Although Rogachev (1957) ultimately concluded that this palaeo-channel was not deep enough to introduce UHB-age material into either of the LHB archaeological layers, it highlights serious stratigraphic complexities within even this part of Kostenki 12.

Later excavations confirmed problems with the Kostenki 12 LHB (Rogachev 1962; Praslov and Rogachev 1974; Anikovich 1977b; Anikovich et al. 2004; Hoffecker et al. 2005, 2010; Holliday et al. 2007). The area excavated from 1961–1974 (Fig. 9) was especially poorly stratified. Only the southwestern corner of the 1961–1962 trench had a coherent stratigraphy; archaeological material elsewhere in that trench and in the adjacent 1974 trench was without meaningful context and very clearly *ex situ* (Rogachev 1962; Praslov and Rogachev 1974; Anikovich 1977a). The 1999–2004 excavations confirmed the fragmentary nature of Layer III, and provided good evidence that at least some of the Layer III material was deposited by colluviation and modified by running water (Anikovich et al. 2004; Hoffecker et al. 2005, 2010). The layer's bones show a heavy weathering compared to those from some other Kostenki sites, and the different conditions of reindeer and horse bones in the layer indicate different depositional histories (Hoffecker et al. 2005). In some places, these taxa showed vertical patterning, with horse bones found stratigraphically lower (Hoffecker et al. 2005; Levkovskaya et al. 2015). Hoffecker and colleagues reasonably interpret this as evidence that Layer III contains material deriving from multiple periods of activity (Anikovich et al. 2004; Hoffecker et al. 2005; Hoffecker et al. 2010; Hoffecker and Holliday 2014).

Collections

The lithic assemblage attributed to Layer II (Fig. 11) is a typically Upper Palaeolithic blade-based industry, with a notable prevalence of edge-retouched blades and burins (Rogachev and Anikovich 1982a). The Layer III assemblage (Table 1) (Fig. 12) has been described as containing varied bifacial tools including Streletskian points (Rogachev and Anikovich 1982a; Anikovich et al. 2004), while also containing evidence of Upper Palaeolithic blade production (Anikovich et al. 2004). Starting with Rogachev (1957: 71), many have noted the greater prevalence of typically Middle Palaeolithic tool types and reduced prevalence of Upper Palaeolithic types relative to Kostenki's other Streletskian sites. The assemblage has therefore been considered the strongest evidence that the Streletskian arose out of Middle Palaeolithic technology (e.g. Rogachev and Anikovich 1982a; Rogachev et al. 1982; Bradley et al. 1995). A perceived greater prevalence of Middle Palaeolithic types has also been used as indirect evidence for its older age than Kostenki 1 Layer V (e.g. Rogachev et al. 1982).

A review of the collections and consideration of Kostenki 12's stratigraphy casts serious doubts on the homogeneity of Layer III material and the LHB layers more generally. As described, the stratigraphic separation of Layers II and III was recognised only in Rogachev's Excavation Area III (Fig. 9; Fig. 10). Because of this, Rogachev

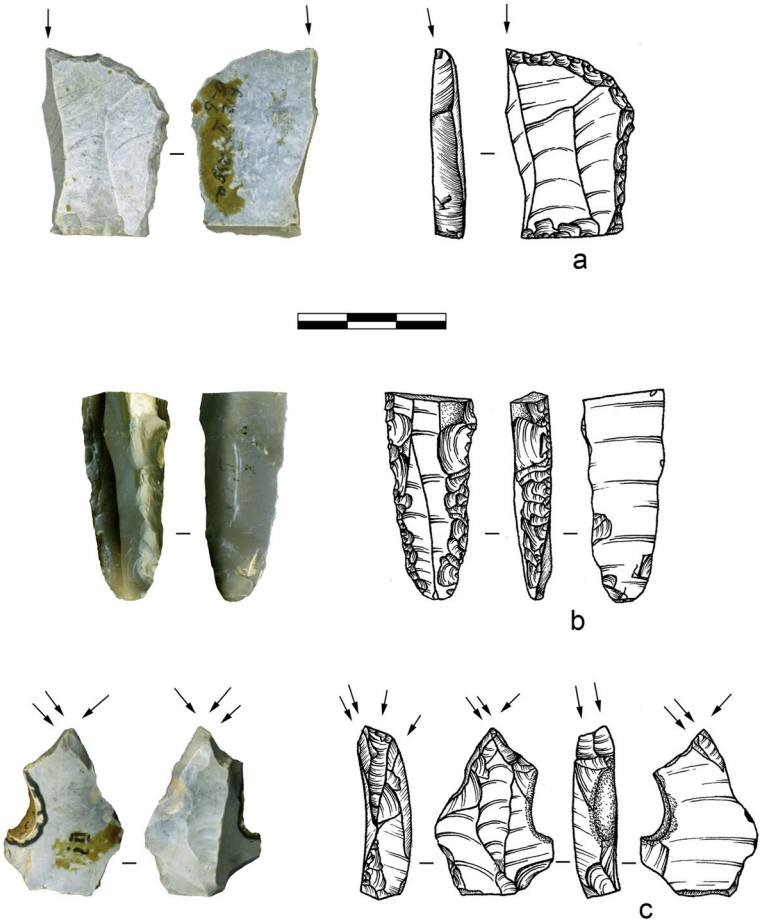

Fig. 11 Selected artefacts from Layer II of Kostenki 12: Burin (**a**); retouched blade (**b**); burin-core (?) (**c**). Lithic illustrations by AB

(and later Anikovich) used lithic material from Excavation Area III as the basis from which to allocate material from other excavated areas to Layers II and III (Rogachev 1954; Anikovich 1977a, b; Rogachev and Anikovich 1982a). This was done chiefly on the basis of lithic raw materials, after Rogachev observed that his Layer III was characterised by an almost complete absence of imported black flint, which was conversely the dominant material in Layer II. Material was therefore attributed to Layers II and III after excavation on the basis that it was made from, respectively, black flint or non-black-flint material. This already problematic situation was then exacerbated by the fact that, as part of his PhD research, Anikovich (1977a: 39-52, 95-96) re-attributed some artefacts from *within* Excavation Area III to different layers, moving to Layer II some artefacts marked as Layer III or as indeterminate between Layers III and II. This was done not only on the basis of raw material, but also on technological features of the two assemblages. As Anikovich's PhD supervisor, whether or not Rogachev agreed with this approach we assume that he saw it as at least

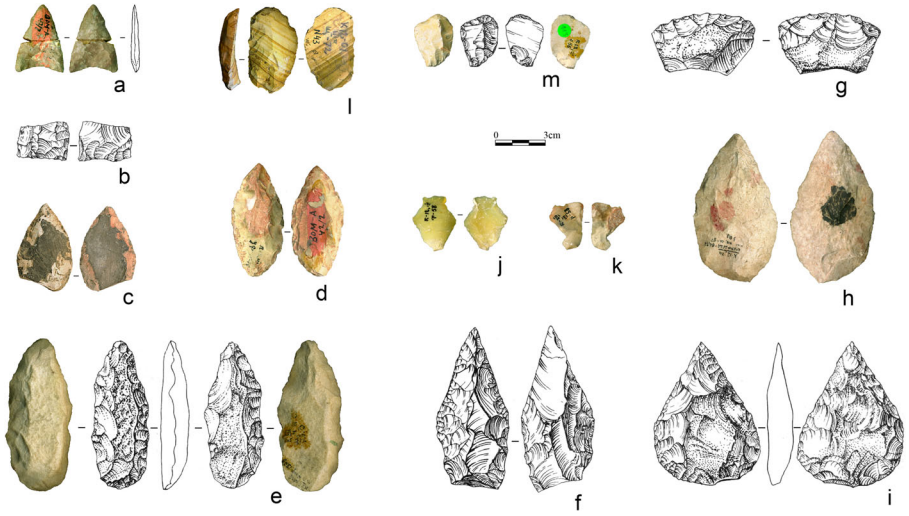

Fig. 12 Selected artefacts from Layer III of Kostenki 12: Bifacially flaked tools (**a**–**i**), including Streletskian points (**a**, **b**); biface thinning flakes (**j**, **k**); endscrapers (**l**, **m**). Illustrations modified from Rogachev and Anikovich (1984)

methodologically justifiable based on his understanding of the stratigraphic problems at Kostenki 12.

Although Anikovich separated out material from earlier excavations in this way, it should be noted that he did not do the same for his own, later excavations, despite the absence of a Layer II comparable to that excavated by Rogachev and despite indications in the faunal assemblage that the layer included material from multiple occupations (Anikovich et al. 2004; Hoffecker et al. 2010; Hoffecker and Holliday 2014; see above).

Given these significant and largely insurmountable problems, Kostenki 12 Layer III clearly cannot be treated as unmixed. Due to this we are wary of overinterpretation of the layer's assemblage; however, several useful observations can be made:

- Only two Streletskian points are recorded from Layer III of Kostenki 12: the first is composed of two refitting parts and the second is a basal fragment (Fig. 12a, b). Both are from Rogachev's 1962 excavation of the most problematic part of the site (Rogachev 1962; see above). An artefact from Layer III (1999–2001 excavations) described by Anikovich et al. (2004: 27) as a possible unfinished Streletskian point is in fact a fragment of bifacial tool of uncertain original form (3D model at http://www.earlymodernhumaneurope.com/artefacts/Kostenki-12-biface-fragment).
- Based on his 1999–2003 excavations, Anikovich et al. (2004: 28) suggested that Layer III is "less archaic" than previously thought (i.e. that it contains relatively more characteristically Upper Palaeolithic pieces). This is probably at least partly due to the post-excavation removal of typically Upper Palaeolithic material from previous Layer III assemblages (see above), a process not applied to his own Layer III collections.
- In technological and raw material profile the small Layer IV assemblage resembles that from Layer III of the same excavation area. Given the reworked nature of Layer

III, as well as the fact that Layers III and IV were separated by only 10–20cm (Anikovich et al. 2004), it is probable that both layers contain material from the same occupation(s).

- The deeper, basal Layer V collection contains 10 stone fragments. None is convincingly worked. The archaeological character of Layer V therefore rests on the origin of the small faunal assemblage.
- With regard to Rogachev's Excavation Area III, some unambiguously Upper Palaeolithic pieces that match the profile of the Layer II assemblage (i.e. robust blades bearing edge retouch and burin modification) were attributed to Layer III (Anikovich 1977a, b; e.g. see 3D model at http://www.earlymodernhumaneurope.com/artefacts/Kostenki-12-burin-on-truncation). Anikovich's (1977a, b) post-excavation removal of apparently intrusive Layer II material is therefore understandable and arguably appropriate. However, even after Anikovich's removal of this material, artefacts remain that probably also belong with the Layer II assemblage, notably a large segment of retouched blade reworked into a bladelet core (figured in Anikovich 2001-2002: 275, fig. 7, no. 4; 3D model at http://www.earlymodernhumaneurope.com/artefacts/Kostenki-12-retouched-blade).
- Layer III in the other two major excavation areas also contains unambiguous Upper Palaeolithic-type material, including typically Upper Palaeolithic blade(let) production (e.g. blade core tablet, 1962 excavation [K12-III-62 п–55]; blade core tablet, 2002 excavation [K12 2002 ы–88 III-139]).
- The overall similarity of a large part of Kostenki 12 Layer III to Middle Palaeolithic assemblages extends beyond a general prevalence of bifacial technology to classic types such as a cordiform biface (Fig. 12i; 1958 excavations, squares м-н–56-57 [Rogachev 1961], 3D model available at http://earlymodernhumaneurope.com/artefacts/kostenki-12-biface/) and a convergent scraper (1983 excavations, square ц–76, 3D model available at http://earlymodernhumaneurope.com/artefacts/kostenki-12-scraper/). We are unaware of such typical examples of these tool types in any Upper Palaeolithic assemblage or in other Streletskian assemblages.

Radiocarbon Dating

Previous radiocarbon dates for Kostenki 12's LHB layers (i.e. Layers III–V) are given in Table 6. With the exception of one date (31 760 ± 230 BP; OxA-X-2158-14), all are consistent with an age greater than that of the CI tephra (i.e. >34.3 ka BP). Luminescence dates agree well with their relationship to the CI tephra (Holliday et al. 2007). However, all of the radiocarbon and luminescence dates come from the site's southern excavation zone (i.e. 1982–2004 excavations). There are no dates from Rogachev's Excavation Area III, and therefore no dates for Layer II.

As the only area of Kostenki 12 to show separation of Layers II and III, we focused our dating work on Rogachev's Excavation Area III. Samples were chosen with two objectives in mind. First, because Layer III is usually regarded as the most "archaic" and Middle Palaeolithic-like of Kostenki's early Streletskian assemblages, we wanted a date for the layer in an area where it is least likely to be contaminated by younger material (but see above). Second, in light of the known stratigraphic issues in

Table 6 Previous radiocarbon dates for Kostenki 12 Layers III–V. Two of Housley et al.'s (2006) dates (OxA-X-2158-14 and OxA-X-2158-15) were "X-coded" because the samples had lower than expected percentage carbon upon combustion. These results should therefore be viewed as potentially problematic (Housley et al. 2006: 155). Note all samples come from the southern excavation zone (1982–2004 area)

Lab code	Layer	Sample	Conventional radiocarbon age	Reference
GIN-8021	III	Mammoth bone	>31,000 BP	Sinitsyn et al. 1997
OxA-X-2158-14	III	Charcoal	31,760 ± 230 BP	Housley et al. 2006
OxA-15482	III	Charcoal	35,820 ± 230 BP	Housley et al. 2006
GrA-5551	III	Charcoal	36,280 +360/−350 BP	Sinitsyn et al. 1997
OxA-15555	IV	Charcoal	35,540 ± 260 BP	Housley et al. 2006
OxA-X-2158-15	V	Charcoal	34,710 ± 330 BP	Housley et al. 2006
OxA-15902	V	Charcoal	38,410 ± 300 BP	Housley et al. 2006
OxA-15556	V	Charcoal	41,300 ± 450 BP	Housley et al. 2006

Excavation Area III, we sought to examine the validity of the stratigraphic separation of Layers II and III.

A total of six bones were sampled for dating: five from Layer III and one from Layer II (Table 7). Samples from four wolf bones from Layer III were processed using AF* pre-treatment. The solvent wash was precautionary, as we do not have complete knowledge of the specimens' curatorial history and therefore cannot exclude the possibility that they have been treated with preservatives. One of these four samples failed due to low yield. The three remaining samples produced results of 34–31.5 ka BP. These results contradict the samples' reported position beneath the ash. This may be evidence for intrusion of UHB-age material into lower levels. However, given that the pre-treatment methods employed have produced erroneously young ages for other material of broadly the same age (Dinnis et al. 2019a; also Kostenki 6 results, above) these three results should be treated as minimum ages only.

Two further samples were processed using HYP pre-treatment, and we can therefore have more confidence in the results. Both were from horse bones, one from Layer II and one from Layer III. The result for Layer III of 40,300 ± 830 BP (OxA-X-2717-24) is consistent with its stratigraphic position in the LHB. In contrast, the date of 30,000 ± 250 BP for the overlying Layer II sample is significantly younger than its reported stratigraphic position beneath the ash. The most likely reason for this is that UHB-age material had been reworked into a position deeper in the sequence. As noted above, Rogachev observed a palaeo-channel in Excavation Area III that had introduced UHB-age material into a lower stratigraphic level (see Fig. 10), underneath the layer of volcanic ash lenses but, in his view, above the level of Layer II. Our result is consistent with his general observation of downwards reworking of material but suggests that it was more pronounced than he realised, and that UHB-age material had infiltrated the stratigraphic position of Layer II. Future work could test and clarify this. If our dates for Layer III produced using AF* pre-treatment (Table 7) could be replicated with HYP pre-treatment, it would be strong evidence that downwards infiltration of UHB-age material extended to the depth of Layer III.

Table 7 New radiocarbon dates for Layers II and III of Kostenki 12. All samples come from Rogachev's Excavation Area III. (Note the grid system used by Rogachev for these early excavations differed from that used later, i.e. that in Fig. 5). With the exception of one sample (coded K12-10) that had a collagen yield too low for HYP dating, no other radiocarbon dates (or failed dates) were produced for this context in the course of this work. See caption for Table 3 for details about pre-treatment codes (P-code) and calibration. Technical details for the samples are provided in Online Resource 1

Sample code	Layer	Square/other info	Sample	P-code	P-number	Conventional radiocarbon age	Calibrated age range (95.4% probability)	OxA number
K12-02	III	K12 III б–7 25836	Wolf metatarsal	AF*	38753	31,550 ± 450 BP	36,400–34,600 calBP	32597
K12-03	III	K12 III б–7 25836	Wolf metatarsal	AF*	41796	Failed due to low yield		
K12-04	III	K12 III б–7 25836	Wolf metatarsal	AF*	38754	33,550 ± 550 BP	39,200–36,350 calBP	32598
K12-05	III	K12 III б–7 25836	Wolf metatarsal	AF*	38755	33,950 ± 550 BP	39,750–36,750 calBP	32666
K12-09	II	K12 Excavation area III б–5, 25830	Horse, ulna, right	HYP (on collagen extracted using AG*)	41470	29,990 ± 250 BP	34,600–33,650 calBP	X-2717-23
K12-11	III	K12 Excavation area III A–5, 25830	Horse first phalange	HYP (on collagen extracted using AG*)	41472	40,300 ± 800 BP	45,400–42,700 calBP	X-2717-24

Summary

- Beyond general concerns over its redeposited nature, evidence points to the "early Streletskian" Layer III being a mixture of material from multiple occupations. In some of Rogachev's excavation areas, "Layer III" was apparently a conflation of Layers II and III. In the later 1999–2004 excavations no equivalent of Rogachev's Layer II was found. In Layer III, the different conditions of horse and reindeer bones along with evidence for their different stratigraphic positions imply the presence of material of different ages.
- Despite being ostensibly the best-stratified part of the Kostenki 12 LHB, there is evidence for mixing between Layers II and III in Rogachev's Excavation Area III. Furthermore, our radiocarbon dating results indicate the presence of UHB-age material in a stratigraphic position lower than the ash deposits.
- There are only two Streletskian points reported from deposits thought to be stratigraphically lower than the CI tephra. Both are from an especially poor context and cannot be tied to any other material.
- In all major excavation areas, "Layer III" of Kostenki 12 contains typically Upper Palaeolithic artefacts. As it has been noted for many decades, it also contains characteristically Middle Palaeolithic material.

Discussion

Streletskian Point Assemblages and the Kostenki Early Upper Palaeolithic

Our results have numerous implications for interpreting Kostenki's three early Streletskian assemblages. Most importantly, they underscore the problematic stratigraphic context of all three; in all cases material attributed to each layer cannot *per se* be treated as related and unmixed. These problems are the clearest for Kostenki 12 Layer III, where diagnostic Streletskian points are limited to one especially poorly stratified excavation area, and where pronounced post-depositional disturbance across the site and the conflation of different assemblages into a single archaeological layer mean little chance of confidently isolating an unmixed assemblage. It follows that the layer should not be used to characterise the "early Streletskian". Similarly, the heavily redeposited Kostenki 6 assemblage should not be assumed to be unmixed. The best chance to characterise an early Streletskian assemblage is instead offered by Kostenki 1 Layer V, and particularly the Layer V North assemblage, because it includes Streletskian points. The relationship of this material to that from Kostenki 1 Layer V South, however, remains unclear: our results suggest that material attributed to Layer V overall spans a period of several thousand years. At present, it is therefore judicious not to view all archaeological material from Layer V as contemporary.

Despite these problems, our work provides additional evidence that Kostenki 1 Layer V, Kostenki 12 Layer III and Kostenki 6 all contain material that pre-dates the CI tephra. Confirmation of this for Kostenki 1 Layer V North is especially important, as it is the most likely early Streletskian lithic assemblage to be unmixed, and because its chronostratigraphic position has long been questioned. Our new determination of 35,100 ± 500 BP (OxA- X-2717-21) is consistent with the assemblage's

geochronological position as reported by its excavator. As described, there remains some uncertainty over the dated sample's precise stratigraphic relationship with the lithic assemblage, and more work is needed to confirm that it fairly reflects the layer's age. However, given the absence of reliable associations between radiocarbon dates and Streletskian points at other sites, this single date nonetheless currently provides the best age estimate for an early Streletskian assemblage.

Assuming our date of ~35 ka BP for Kostenki 1 Layer V North does fairly reflect the age of the layer's Streletskian point assemblage, it is notably younger than ages sometimes attributed to early Streletskian material (e.g. Zwyns et al. 2012; Haesaerts et al. 2017). It also appears younger than the oldest well-stratified and well-dated non-Streletskian Upper Palaeolithic assemblages from Kostenki. These are Kostenki 17 Layer II and Kostenki 14 Layer IVw, both of which thought to date to ~36 ka BP (Dinnis et al. 2019a). Both of these assemblages are fully Upper Palaeolithic in character, and neither is similar to that from Kostenki 1 Layer V. If we accept as reliable the evidence from Kostenki 1 Layer V North, it follows that Streletskian point assemblages at Kostenki may not be directly relevant to the very beginning of the Upper Palaeolithic here.

The Chronostratigraphic Distribution of Streletskian Points at Kostenki

Although here the focus has been the oldest Streletskian layers, other Kostenki layers have also been classified as Streletskian and/or have yielded Streletskian points (Table 8). In some cases, the classification of artefacts as Streletskian points is questionable, whereas in other instances Streletskian points cannot confidently be tied to the layer to which they have been assigned (Table 8). Other Streletskian points, however, are typical, and were found in layers whose geochronology is well understood. This is true for the Kostenki-Avdeevo Culture Layer I of Kostenki 14 (Table 8), which is understood to date to ~23.5–23 ka BP (Damblon et al. 1996; Sinitsyn et al. 1997; Douka and Higham 2017; Reynolds et al. 2017; Bessudnov 2019; Dinnis et al. forthcoming). New radiocarbon dates for the layer, on samples found close to its Streletskian point, are consistent with this age (Table 9).

How should we interpret the presence of Streletskian points in assemblages of significantly different ages? The first possibility is that it fairly represents their manufacture and use, and thus that they were part of hunter-gatherer toolkits multiple times during the EUP/MUP. Such convergence is certainly possible, especially given the long-recognised broad similarity of Streletskian points to some late pre-historic artefacts (e.g. Rogachev 1957). However, it is notable that Kostenki's younger Upper Palaeolithic assemblages lack technological context for their production. No bifacial thinning flakes like those described by Bradley et al. (1995; Anikovich et al. 1997, 1998) for the Streletskian assemblage of Kostenki 1 Layer V have so far been found in the younger assemblages from Kostenki 14 Layer I, Kostenki 1 Layer I or Kostenki 11 Layer III. In contrast, a degree of technological context in the form of small biface thinning flakes is evident in all three of Kostenki's early Streletskian assemblages.

The geochronological distribution of Kostenki's Streletskian points could instead hypothetically reflect their post-depositional reworking into different layers. Such processes can more reasonably be invoked for sites with compressed stratigraphies, and especially sequences with younger layers close to the CI tephra and to material

Table 8 Further Kostenki-Borshchevo assemblages from which Streletskian points have been reported up to 2019

Site/layer	Layer geochronology / chronology (BP)	Streletskian point(s) meeting our typological criteria?	Confidence of attribution of Streletskian point(s) with layer(s)	Details
Kostenki 1 Layer I	~23.5–23 ka	Y	Good (?)	One Streletskian point was found in 1973 in square д–64, just above the level of the base of dwelling-pit feature A (=squares е-ж-з-г-д–62-63-64) (Abramova et al. 1973). Abramova et al. (1973) state there is no evidence for krotovinas. They suggest the point may have been brought to the site by the Layer I occupants, or may derive from the underlying Layer III (although its recorded depth position is ~1m higher than Layer III: Rogachev et al. 1982; Hoffecker et al. 2016). (3D model of artefact available at earlymodernhumaneurope.com/artefacts/kostenki-1-streletskian-point/)
Kostenki 1 Layer III	UHB (=34–27.5 ka)	N	N/A	Anikovich et al. (2008: 102) describe "two fragments of bifacially worked points of Streletskaya type" (p.103: fig. 54, nos. 3 and 4) and one probably unfinished point with triangular shape (p.103: fig. 54, no. 11). None of these meets the definition of Streletskian point used here.
Kostenki 11 Layer III	24–23 ka	Y	Poor	One Streletskian point was found during 1965 excavation of a small trench east of the main excavation area (Rogachev and Popov 1982: 129; fig 42, no. 1). The excavated assemblage was allocated to Layer III, but the layer in this area was poorly defined and there is reason to doubt that Layer III across the site reflects a single period of activity (Rogachev and Popov 1982; Popov 1989; Dinnis et al. 2018).
Kostenki 11 Layer V	UHB (=34–27.5 ka)	Y	Unclear	The small Layer V assemblage from Kostenki 11 contains two Streletskian points (Rogachev and Popov 1982: 129; fig 42, nos. 24 and 25). They were discovered in 1960 in small test-pits in the northeast of the site (Rogachev 1960; Rogachev 1968; Rogachev and Popov 1982). Layer V is thought to belong to the UHB, but given the small size of the excavated areas its geochronological position is uncertain (Rogachev 1960, 1968; Anikovich 1977a; Lazukov 1982; Rogachev and Popov 1982; Rogachev and Anikovich 1984; Dinnis et al. 2018).

Table 8 (continued)

Site/layer	Layer geochronology / chronology (BP)	Streletskian point(s) meeting our typological criteria?	Confidence of attribution of Streletskian point(s) with layer(s)	Details
Kostenki 11 UHB	UHB (=34–27.5 ka)	Y	Unclear	One Streletskian point was found in 2014, in an excavation area unconnected to those in which Layer V was found previously. The artefact was found close to other pieces showing bifacial technology. Its stratigraphic position is provisionally correlated with Layer V of the earlier excavations, and therefore it is attributed to the UHB, but the absence of ash deposits and the unclear stratigraphy of this part of Kostenki 11's sequence make this correlation tentative.
Kostenki 12 Layer Ia	UHB (=34–27.5 ka)	Y	Poor	Two artefacts allocated to UHB assemblages at Kostenki 12 have been described as Streletskian points. The first, which meets the typological criteria used here (Rogachev 1957: 65, fig. 29, no. 1), was found during Rogachev's early phase of excavation. However, together with some other lithics thought to derive from the UHB upper layer, it was actually found in the Holocene chernozem (Rogachev 1957: 64). The second artefact, figured by Anikovich et al. (2008: 97, fig. 48, no. 6), was recovered from square y-91 during Anikovich's 2001 excavations. Unlike Streletskian points accepted here, it does not have invasive retouch, and therefore does not fulfil our typological criteria.
Kostenki 14 Layer I	~23.5–23 ka	Y	Good (?)	One Streletskian point was found in 2016 in square O-65, within a concentration of mammoth bones (Sinitsyn 2017: 68, fig. 12, 13). The artefact was apparently associated with a krotovina, but given the depth of Kostenki 14's stratigraphy, it is likely it is associated with the layer (see text).
Borshchevo 5 Layer IV	>34.3 ka	N	N/A	Two bifaces were recovered in 2017 from Borshchevo 5, in deposits thought to belong to the LHB (Lisitsyn 2018). However, both artefacts have convex bases, and therefore neither meets our criteria for Streletskian points.

Table 9 New radiocarbon dates for Layer I of Kostenki 14. The sampled bone comes from square H–63, approximately two metres away from the Streletskian point (square O-65) found in the same layer. No other radiocarbon dates (or failed dates) were produced for this context in the course of this work. See caption for Table 3 for details about pre-treatment codes (P-code) and calibration. Technical details for the samples are provided in Online Resource 1

Sample code	Layer	Square/other info	Sample	P-code	P-number	Conventional radiocarbon age	Calibrated age range (95.4% probability)	OxA number	Notes
K14-09	I	K14-I-16 H–63 N24	Juvenile mammoth, radius, fragment	AF	43066	23,020 ± 160 BP	27640–27030 calBP	36078	Refits to bone K14-10
K14-10	I	K14-I-16 H –63 N24	Juvenile mammoth, radius, fragment	AF	43067	22,590 ± 170 BP	27330–26460 calBP	X-2733-21	Refits to bone K14-09 OxA-X-coded due to low collagen yield (4.3mg from 700 mg of bone, =0.6%)

underlying the ash. Furthermore, natural mechanisms can more easily explain downwards movement of Streletskian points than they can upwards movement. Kostenki 14, however, shows that reference to natural processes alone cannot explain the Streletskian points' different geochronological positions: the Kostenki 14 Layer I example was found ~2m above the CI tephra and ~2m below the Holocene chernozem; it is extremely unlikely to have derived from either by way of natural processes.

Given the apparent lack of technological context in the younger assemblages, Streletskian points may instead have been found, collected and then left behind by later occupants, a suggestion made previously by Rogachev and Anikovich (1984) to explain the Kostenki 11 Layer III example and by Abramova et al. (1973) for the artefact from Kostenki 1 Layer I. There is precedent for similar behaviour at Kostenki, including at Kostenki 11, where the Layer Ia occupants collected blades from Layer II to exploit as bladelet cores (Popov 1989; Rodionov 2016). Given current evidence this could explain the Streletskian points found in Kostenki's MUP layers.

Some Comments on the Streletskian as a Cultural Taxon

Because of the marked technotypological variation in assemblages previously described as Streletskian, our study focused mainly on the context of Streletskian points as defined with strict typological criteria. This approach reflects what we perceive to be a broad problem of cultural taxonomy of the Kostenki EUP: attribution of EUP assemblages to the Streletskian—and with this explicit or implicit chronocultural connection to other assemblages—has sometimes been made largely or solely on the presence of bifacially flaked artefacts. This is the case for the assemblage from Layer III of Kostenki 12 recovered during the 1999–2004 excavations. As described above, none of the LHB collections from Kostenki 12 can be assumed to be unmixed, and the context of the two Streletskian points ostensibly from LHB deposits does not allow them to be related to other material. The 1999–2004 Layer III collection contains no Streletskian points, no characteristic ventrally spalled short scrapers and no transverse burins like those from Kostenki 1 Layer V North. Additionally, it contains notably more evidence for Upper Palaeolithic blade/let production than the better-stratified Kostenki 12 Layer III collection from Rogachev's Excavation Area III. Despite this, Anikovich et al. (2004) assigned the 1999–2004 Layer III assemblage to the Streletskian, in line with the Streletskian attribution of "Layer III" elsewhere at the site (Anikovich 1977b, 1992, 2001-2002; Rogachev and Anikovich 1982a; Bradley et al. 1995). Given the differences in the geological sequence between the 1999–2004 excavation area and those excavated previously (Anikovich et al. 2004), this chronocultural classification, and with it an explicit cultural connection with other excavation areas and other sites, rests largely on the presence of non-Streletskian point bifacial tools. In another example, Bosinski (2017) has related the Layer IVb assemblage from Kostenki 14 to the Streletskian, due to the presence of bifacially flaked artefacts of perceived Middle Palaeolithic character. Overall, however, Kostenki 14 Layer IVb is incomparable to Kostenki's Streletskian point assemblages, instead showing some similarity to (Proto-)Aurignacian lithic industries (Bataille et al. 2018; Dinnis et al. 2019b, 2020). In our view, the presence of bifacially flaked artefacts alone is insufficient to infer inter-assemblage and especially diachronic cultural connections,

particularly as these tools may be expedient solutions to activities that were recurrent through the Late Pleistocene (Hoffecker 2002; Hoffecker et al. 2018).

The fact that here we focused only on assemblages with Streletskian points does not, though, mean that we consider other assemblages to be necessarily unrelated. Other typological classes of bifacial tool are found alongside Streletskian points in possibly or probably unmixed assemblages from Kostenki 1 Layer V North, Biriuch'ia Balka 2 and Garchi 1, and some culturally related assemblages may therefore be expected to contain only non-Streletskian point bifaces. Further work characterising Streletskian biface manufacture and further comparison with other Middle Palaeolithic/EUP facies may help to establish diagnostic criteria that can distinguish the former when Streletskian points are absent. A new and thorough assessment of the ventrally spalled short scrapers characteristic of some Streletskian assemblages may prove similarly useful. These artefacts are found in significant numbers in Kostenki 1 Layer V North and Garchi 1—two Streletskian assemblages that, despite their geographical separation, show clear cultural similarity in their lithic assemblages (Rogachev et al. 1982; Bradley et al. 1995; Pavlov 2010). Establishing whether and how these scrapers can be treated as a cultural marker would therefore be particularly beneficial. Together, this work could help to clarify the cultural status of assemblages such as Kostenki 1 Layer Va South, which, while lacking Streletskian points, shows some similarities with the better characterised and contextualised assemblage from Layer V North.

What is the Oldest Archaeological Material at Kostenki?

With these issues in mind, the technotypological variety of bifacially flaked artefacts and uni-facial points attributed to early Streletskian assemblages, and especially to Kostenki 12 Layer III (Anikovich 1977a, b; Rogachev and Anikovich 1982a, 1982b; Rogachev et al. 1982; Bradley et al. 1995, Bataille 2017), is important. It has been frequently noted that some of the layer's artefacts bear particular similarity to Middle Palaeolithic/Szeletian material (Rogachev 1957; Grigor'ev 1963; Rogachev and Anikovich 1982a; Rogachev et al. 1982; Anikovich et al. 2007; Matyukhin 2012; Vishnaytsky 2014; this paper). As outlined above, while an Upper Palaeolithic component to the Kostenki 12 Layer III assemblage is undeniable, its relationship with other material in the layer is at the very least questionable: the post-depositional conflation of two layers into "Layer III"—the higher of which is clearly fully Upper Palaeolithic in character—was recognised in earlier excavations; and evidence from the more recent excavations similarly indicates that Layer III contains archaeological remains from at least two periods.

Known stratigraphic problems and the character of the Kostenki 12 Layer III lithic assemblage are therefore consistent with its being a mechanical mixture of Middle and Upper Palaeolithic material from at least two different periods, and thus that at least one Middle Palaeolithic occupation took place at Kostenki. This explanation is also consistent with our new radiocarbon dates of ≥40,000 BP for Kostenki 6, Kostenki 1 Layer V South and Kostenki 12 Layer III (Tables 3, 5 and 7). In our view, the dated horse and wolf bones from these assemblages are likely to be anthropogenic. The dates therefore suggest human activity at Kostenki prior to the appearance of fully Upper Palaeolithic blade/let technology anywhere in Europe, and contemporary with Szeletian/Middle Palaeolithic assemblages elsewhere (Davies and Hedges 2008-2009; Higham et al. 2014).

Conclusions

Here, we have presented a reassessment of the three assemblages widely considered to represent the earliest manifestations of the Streletskian: Kostenki 1 Layer V, Kostenki 6 and Kostenki 12 Layer III. Our results provide further evidence for the pre-ash age (>34.3 ka BP) of all three, but they also confirm that none can be treated uncritically. This is especially true for Kostenki 12 Layer III. Evidence from different parts of Kostenki 12 indicates that the layer contains material from at least two and possibly more occupations. The assemblage most likely to be unmixed is from Kostenki 1 Layer V North. Our new radiocarbon date for Kostenki 1 Layer V North, 35,100 ± 500 BP (OxA-X-2717-21), agrees with the excavator's observations and contradicts longstanding suggestions of a younger age. Although the association between the dated Layer V North bone and the layer's lithic assemblage is not entirely certain, this single date is nonetheless currently the best age estimate for an early Streletskian context with diagnostic Streletskian points. It is younger than ages some have proposed for early Streletskian material, and is also younger than some well-dated, non-Streletskian Upper Palaeolithic assemblages at Kostenki.

Our brief review of Streletskian assemblages and Streletskian points from younger contexts highlights further uncertainties. The appropriateness of this cultural attribution for some layers is questionable, and in other cases the relationship between Streletskian points and the rest of the layers' archaeological material is unclear. Given the apparent lack of associated thinning flakes, Streletskian points in MUP-age layers may have been collected from older deposits by Kostenki's MUP occupants. Our review also highlights broader problems of classification. Our study deliberately focused on Streletskian points as defined using strict typological criteria, but intra- and inter-site cultural links are sometimes drawn simply on the basis of bifacially flaked artefacts. In our view, more work is needed to clarify if and how aspects of Streletskian assemblages beyond Streletskian points can be treated as meaningful cultural markers.

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Data Availability The 3D models mentioned in the text are available via earlymodernhumaneurope.com and are also archived at DOI: 10.17605/OSF.IO/E2NJV

Declarations

Conflict of Interest The authors declare no conflict of interest.

References

Abramova, Z. A., Praslov, N. D., & Rogachev, A. N. (1971). *Otchet o rabote Kostenkovskoi ekspeditsii v 1971 godu.* Archive of IHMC RAS. F. 35, op. 1. 1971. D. 34.

Abramova, Z. A., Praslov, N. D., & Rogachev, A. N. (1973). *Otchet o rabotakh Kostenkovskoi ekspeditsii v 1973 godu.* Archive of IHMC RAS. F. 35, op. 1. 1973. D. 45.

Abramova, Z. A. (1995). *L'art paléolithique d'Europe orientale et de Sibérie*. Grenoble: Jérôme Million.

Anikovich, M. V. (1977a). *Pamyatniki streletskoi kul'tury v Kostenkakh*. Unpublished dissertation. Archive of IHMC RAS. F. 35, op. 2-d. 1977. D. 252.

Anikovich, M. V. (1977b). Kamennyi inventar' nizhnikh sloev Volkovskoi stoyanki. In N. D. Praslov (Ed.), *Problemy paleolita Vostochnoi i Tsentral'noi Evropy* (pp. 94–112). Leningrad: Nauka.

Anikovich, M. V. (1992). Early Upper Paleolithic industries of Eastern Europe. *Journal of World Prehistory, 6*, 205–245.

Anikovich, M. V. (1993). O znachenii Kostenkovsko-Borshchevskogo raiona v sovremennom paleolitovedenii. *Peterburgskii Arkheologicheskii Vestnik, 3*, 3–19.

Anikovich, M. V. (1999). The formation of Upper Palaeolithic cultures and anatomically modern humans: the East European perspective. *Anthropologie, 37*, 115–123.

Anikovich, M. V. (2001-2002). Proiskhozhdeniye kostenkovsko-streletskoy kul'tury i problema poiska kul'turno-geneticheskikh svyazei mezhdu srednim i verkhnim paleolitom. *Stratum Plus, 1*, 266–290.

Anikovich, M. V. (2005). Sungir' v kul'turno-istoricheskom kontekste i problema stanovleniya sovremennogo chelovechestva. *Archaeology, Ethnology and Anthropology of Eurasia, 2*(22), 37–47.

Anikovich, M. V., Bredli [Bradley], B, & Giria, E. Yu. (1997). Tekhnologicheskii analiz streletskikh nakonechnikov. In E. Yu Giria., *Tekhnologicheskii analiz kamennykh industrii. Chast' 2. Metodika mikro-makroanaliza drevnikh orudii truda* (pp. 152–161). Saint Petersburg: AkademPrint.

Anikovich, M. V., Bradley, B. A., & Giria, E. Y. (1998). Tekhnologicheskii analiz streletskikh treugol'nykh nakonechnikov. *Arkheologicheskiye vesti, 5*, 42–54.

Anikovich, M. V., Hoffecker, J. F., Popov, V. V., Kuz'mina, I. Y., Levkovskaya, G. M., Pospelova, G. A., Forman, S., & Holliday, V. T. (2004). Novyye dannyye o mnogosloinoi stoyanke Kostenki 12 (Volkovskaya). In M. V. Anikovich & N. I. Platonova (Eds.), *Kostenki i rannyaya pora verkhnego paleolita Evrazii: obshcheye i lokal'noye. Tezisy Mezhdunarodnoy konferentsii (23-26 of August, 2004)* (pp. 18–38). Istoki: Voronezh.

Anikovich, M. V., Hoffecker, J. F., Popov, V. V., & Platonova, N. I. (2005). Khronostratigrafiya mnogosloinoi stoyanki Kostenki 12 (Volkovskaya) v kontekste khronostratigrafii paleolita Kostenkovsko-Borshchevskogo raiona. In *Trudy Kostenkovsko-Borshchevskoi arkheologicheskoi ekspeditsii, 3* (pp. 66–86). Saint Petersburg: IIMK.

Anikovich, M. V., Popov, V. V., Anisyutkin, N. K., Hoffecker, J. F., Holliday, V. T., Forman, St, Karter, B., Lovlie, R., Dudin, A. E., Kuz'mina, I. E., Platonova, N. I., & Makarov, S. S. (2006). Novye dannyye o khronostratigrafii mnogosloinoi stoyanki Kostenki 1 (stoyanka Polyakova). In *Rannyaya pora verkhnego paleolita Evrazii: obshcheye i lokal'noye. Materialy mezhdunarodnoi konferentsii k 125-letiyu otkrytiya paleolita v Kostenkakh, 23–26 avgusta 2004 g.* (pp. 81–100). Saint Petersburg: Nestor-Istoriya.

Anikovich, M. V., Sinitsyn, A. A., Hoffecker, J. F., Holliday, V. T., Popov, V. V., Lisitsyn, S. N., Forman, S. L., Levkovskaya, G. M., Pospelova, G. A., Kuz'mina, I. E., Burova, N. D., Goldberg, P., Macphail, R. I.,

Giaccio, B., & Praslov, N. D. (2007). Early Upper Paleolithic in Eastern Europe and implications for the dispersal of modern humans. *Science, 315*, 223–226.

Anikovich, M. V., Popov, V. V., & Platonova, N. I. (2008). *Paleolit Kostenkovsko-Borshchevskogo raiona v kontekste verkhnego paleolita Evropy (Trudy Kostenkovsko-Borshchevskoi arkheologocheskoi ekspeditsii, 1)*. Saint Petersburg: Nestor-Istoriya.

Bader, N. O., & Lavrushin, Y. A. (Eds.). (1998). *Pozdnepaleoliticheskoye poseleniye Sungir' (pogrebeniya i okruzhayushchaya sreda)*. Moscow: Nauchnyi mir.

Bataille, G. (2017). Neanderthals of Crimea - creative generalists of the late Middle Paleolithic. Contextualizing the leaf point industry Buran-Kaya III, Level C. *Quaternary International, 435*, 211–236.

Bataille, G., Tafelmaier, Y., & Weniger, G.-C. (2018). Living on the edge – comparative approach for studying the beginning of the Aurignacian. *Quaternary International, 474*, 3–29.

Bessudnov, A. A. (2019). Le site du Gravettien récent, Kostenki 21 (Gmélinskaia): les résultats préliminaires des travaux archéologiques de sauvetage des années 2013–2016. *l'Anthropologie*, 123(2), 423-437.

Bird, M. I., Ayliffe, L. K., Fifield, L. K., Turney, C. S. M., Cresswell, R. G., Barrows, T. T., & David, B. (1999). Radiocarbon dating of 'old' charcoal using a wet oxidation-stepped combustion procedure. *Radiocarbon, 41*, 127–140.

Bosinski, G. (2017). Le Sungir-Streleckien. Le début du Paléolithique supérieur en Europe orientale. In S. Vasilyev, A. Sinitsyn & M. Otte (Eds.), *Le Sungirien* (pp. 21-45). Liège: ERAUL 147.

Bourrillon, R., White, R., Tartar, E., Chiotti, L., Mensan, R., Clark, A., Castel, J.-C., Cretin, C., Higham, T., Morala, A., Ranlett, S., Sisk, M., Devièse, T., & Comeskey, D. J. (2018). A new Aurignacian engraving from Abri Blanchard, France: implications for understanding Aurignacian graphic expression in Western and Central Europe. *Quaternary International, 491*, 46–64.

Bradley, B. A., Anikovich, M., & Giria, E. (1995). Early Upper Palaeolithic in the Russian Plain: Streletskayan flaked stone artefacts and technology. *Antiquity, 69*, 989–998.

Brock, F., Higham, T. F. G., Ditchfield, P., & Bronk Ramsey, C. (2010). Current pretreatment methods for AMS radiocarbon dating at the Oxford Radiocarbon Accelerator Unit (ORAU). *Radiocarbon, 52*(1), 103–112.

Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon, 51*(1), 337–360.

Chabai, V. (2003). The chronological and industrial variability of the Middle to Upper Paleolithic transition in Eastern Europe. In J. Zilhão & F. d'Errico (Eds.), *The chronology of the Aurignacian and of the transitional technocomplexes. Dating, stratigraphies, cultural implications* (pp. 71–86). Instituto Portugues de Arquologia: Lisbon.

Cohen, V. Y., & Stepanchuk, V. N. (1999). Late Middle and Early Upper Paleolithic evidence from the East European Plain and Caucasus: a new look at variability, interactions, and transitions. *Journal of World Prehistory, 13*, 265–319.

Damblon, F., Haesaerts, P., & van der Plicht, J. (1996). New datings and considerations on the chronology of Upper Palaeolithic sites in the Great Eurasiatic plain. *Préhistoire Européenne, 9*, 177–231.

Davies, W., & Hedges, R. (2008-2009). Dating a type site: fitting Szeleta Cave into its regional chronometric context. *Praehistoria, 9-10*, 35–45.

Demars, P.-Y., & Laurent, P. (1992). *Types d'Outils Lithiques du Paléolithique Supérieur en Europe*. Paris: CRNS.

Demidenko, Y. E. (2014). Siuren I rock-shelter: from the Late Middle Paleolithic and Early Upper Paleolithic to the Epipaleolithic in Crimea. In C. Smith (Ed.), *Encyclopedia of Global Archaeology* (pp. 6711–6721). New York: Springer.

Demidenko, Y. E., & Noiret, P. (2012). Radiocarbon dates for the Siuren I sequence. In Y. E. Demidenko, M. Otte & P. Noiret (Eds.), *Siuren I rock-shelter. from Late Middle Paleolithic and Early Upper Paleolithic to Epi-Paleolithic in Crimea* (pp. 49-53). Liège: ERAUL 129.

Devièse, T., Comeskey, D., McCullagh, J., Bronk Ramsey, C., & Higham, T. (2018). New protocol for compound-specific radiocarbon analysis of archaeological bones. *Rapid Communications in Mass Spectrometry, 32*, 373–379.

Devièse, T., Massilani, D., Yi, S., Comeskey, D., Nagel, S., Nickel, B., Ribechini, E., Lee, J., Tseveendorj, D., Gunchinsuren, B., Meyer, M., Pääbo, S., & Higham, T. (2019). Compound-specific radiocarbon dating and mitochondrial DNA analysis of the Pleistocene hominin from Salkhit Mongolia. *Nature Communications, 10*, 274.

Dinnis, R., Bessudnov, A. A., Reynolds, N., Douka, K., Dudin, A. E., Khlopachev, G. A., Sablin, M. V., Sinitsyn, A. A., & Higham, T. F. G. (2018). The age of the "Anosovka-Tel'manskaya Culture" and the issue of a late Streletskian at Kostenki 11. *Proceedings of the Prehistoric Society, 84*, 21–40.

Dinnis, R., Bessudnov, A., Reynolds, N., Devièse, T., Pate, A., Sablin, M., Sinitsyn, A., & Higham, T. (2019a). New data for the Early Upper Paleolithic of Kostenki (Russia). *Journal of Human Evolution, 127*, 21–40.

Dinnis, R., Bessudnov, A., Chiotti, L., Flas, D., & Michel, A. (2019b). Thoughts on the structure of the European Aurignacian, with particular focus on Hohle Fels IV. *Proceedings of the Prehistoric Society*, 85, 29–60.

Dinnis, R., Bessudnov, A., Reynolds, N., Pate, A., Sablin, M., & Sinitsyn, A. (2020). Response to Bataille et al.'s 'Technological differences between Kostenki 17/II (Spitsynskaya industry,Central Russia) and the Protoaurignacian: reply to Dinnis et al. (2019)' [J. Hum. Evol. (2019), 102685], Journal of Human Evolution, https://doi.org/10.1016/j.jhevol.2020.102792.

Dinnis, R., Bessudnov, A., Reynolds, N., Khlopachev, G. A., Sablin, M. V., Sinitsyn, A. A., Higham, T. F. G., & Douka, K. (Forthcoming). More insights into the tempo of cultural change in the Kostenki Upper Paleolithic. *Paper submitted to Radiocarbon.*

Dinnis, R., Bessudnov, A., Artyushenko, A., Lada, A., Sinitsyn, A., & Higham, T. (Accepted Manuscript). Kostënki 17 (Spitsynskaya) and Kostënki 6 (Streletskaya): recent fieldwork and new ^{14}C dates. *Quartär*

Djindjian, F. (2014). European Middle to Upper Paleolithic transitional industries: a socioeconomic approach. In C. Smith (Ed.), *Encyclopedia of Global Archaeology* (pp. 2670–2679). Springer: New York.

Douka, K., Higham, T., & Sinitsyn, A. (2010). The influence of pretreatment chemistry on the radiocarbon dating of Campanian Ignimbrite-aged charcoal from Kostenki 14 (Russia). *Quaternary Research, 73*, 583–587.

Douka, K., & Higham, T. (2017). The chronological factor in understanding the Middle and Upper Paleolithic of Eurasia. *Current Anthropology, 58*, 480–491.

Dudin, A. E. (2007). K voprosu o khronostratigraficheskoi korrelyatsii nizhnikh kul'turnykh sloev stoyanki Kostenki 1. *Verkhnedonskoi arkheologicheskii sbornik, 3*, 23–32.

Dudin, A. E. (2014). Stoyanka Kostenki 1, sloi III: novyye materialy i novyye problemy (predvaritel'nyye itogi raskopok 2004-2012 gg.). In S. A. Vasil'ev & E. S. Tkach (Eds.), *Verkhnii paleolit Severnoi Evrazii i Ameriki: pamyatniki, kul'tura, traditsii* (pp. 171–178). Saint Petersburg: Peterburgskoye vostokovedeniye.

Efimenko, P. P. (1958). *Kostenki I*. Moscow: Izdatel'stvo Akademii Nauk SSSR.

Giaccio, B., Hajdas, I., Isaia, R., Deino, A., & Nomade, S. (2017). High-precision ^{14}C and ^{40}Ar/^{39}Ar dating of the Campanian Ignimbrite (Y-5) reconciles the time-scales of climatic-cultural processes at 40 ka. *Scientific Reports, 7*, 45940.

Grigor'ev, G. P. (1963). Selet i kostenkovsko-streletskaya kul'tura. *Sovetskaya arkheologiya, 1*, 3–11.

Haesaerts, P., Damblon, F., van der Plicht, J., Otte, M., & Nigst, P. R. (2017). Additional data to the stratigraphy and the chronology of the Kostenki 1 (Poliakov) sequence, Voronezh, Russia. In S. A. Vasilyev, A. Sinitsyn & M. Otte (Eds.), *Le Sungirien* (pp. 135–142). Liège: ERAUL 147.

Higham, T., Douka, K., Wood, R., Ramsey, C. B., Brock, F., Basell, L., Camps, M., Arrizabalaga, A., Baena, J., Barroso-Ruíz, C., Bergman, C., Boitard, C., Boscato, P., Caparrós, M., Conard, N. J., Draily, C., Froment, A., Galván, B., Gambassini, P., Garcia-Moreno, A., Grimaldi, S., Haesaerts, P., Holt, B., Iriarte-Chiapusso, M.-J., Jelinek, A., Jordá Pardo, J. F., Maíllo-Fernández, J.-M., Marom, A., Maroto, J., Menéndez, M., Metz, L., Morin, E., Moroni, A., Negrino, F., Panagopoulou, E., Peresani, M., Pirson, S., de la Rasilla, M., Riel-Salvatore, J., Ronchitelli, A., Santamaria, D., Semal, P., Slimak, L., Soler, J., Soler, N., Villaluenga, A., Pinhasi, R., & Jacobi, R. (2014). The timing and spatiotemporal patterning of Neanderthal disappearance. *Nature, 512*, 306–309.

Hoffecker, J. F., & Holliday, V. T. (2014). Landscape archaeology and the dispersal of modern humans in Eastern Europe. In S. A. Vasil'ev & E. S. Tkach (Eds.), *Verkhnii paleolit Severnoi Evrazii i Ameriki: pamyatniki, kul'tura, traditsii* (pp. 140–170). Saint Petersburg: Peterburgskoe vostokovedeniye.

Hoffecker, J. F. (2002). *Desolate landscapes: Ice-Age settlement in Eastern Europe*. New Brunswick, NJ: Rutgers University Press.

Hoffecker, J. F. (2009). The spread of modern humans in Europe. *Proceedings of the National Academy of Sciences USA, 106*, 16040–16045.

Hoffecker, J. F., Kuz'mina, I. E., Anikovich, M. V., & Popov, V. V. (2005). Taphonomy of an early Upper Paleolithic bone bed at Kostenki 12 (Volkovskaya). In M. V. Anikovich (Ed.), *Problemy rannei pory verkhnego paleolita Kostenkovsko-Borshchevskogo raiona i sopredel'nykh territorii (Trudy Kostenkovsko-Borshchevskoi arkheologicheskoi ekspeditsii, 3)* (pp. 161–176). Saint Petersburg: IIMK RAN.

Hoffecker, J. F., Kuz'mina, I. E., Syromyatnikova, E. V., Anikovich, M. V., Sinitsyn, A. A., Popov, V. V., & Holliday, V. T. (2010). Evidence for kill-butchery events of early Upper Paleolithic age at Kostenki, Russia. *Journal of Archaeological Science, 37*, 1073–1089.

Hoffecker, J. F., Holliday, V. T., Anikovich, M. V., Dudin, A. E., Platonova, N. I., Popov, V. V., Levkovskaya, G. M., Kuz'mina, I. E., Syromyatnikova, E. V., Burova, N. D., Goldberg, P., Macphail, R. I., Forman, S. L., Carter, B. J., & Crawford, L. J. (2016). Kostenki 1 and the early Upper Paleolithic of Eastern Europe. *Journal of Archaeological Science: Reports, 5*, 307–326.

Hoffecker, J. F., Holliday, V. T., Stepanchuk, V. N., & Lisitsyn, S. N. (2018). The hunting of horse and the problem of the Aurignacian on the central plain of Eastern Europe. *Quaternary International, 492*, 53–63.

Holliday, V. T., Hoffecker, J. F., Goldberg, P., Macphail, R. I., Forman, S. L., Anikovich, M., & Sinitsyn, A. (2007). Geoarchaeology of the Kostenki-Borshchevo sites, Don River Valley, Russia. *Geoarchaeology, 22*, 181–228.

Housley, R. A., Higham, T. F. G., & Anikovich, M. V. (2006). New AMS radiocarbon dates from Kostenki 12. In *Rannyaya pora verkhnego paleolita Evrazii: obshcheye i lokal'noye. Materialy mezhdunarodnoi konferentsii k 125-letiyu otkrytiya paleolita v Kostenkakh, 23–26 avgusta 2004 g.* (pp. 152–156). Saint Petersburg: Nestor-Istoriya.

Kozłowski, J. K. (2004). Early Upper Paleolithic backed blade industries in Central and Eastern Europe. In P. J. Brantingham, S. L. Kuhn, & K. W. Kerry (Eds.), *The Early Upper Paleolithic Beyond Western Europe* (pp. 14–29). Berkeley CA: University of California Press.

Kozłowski, J. K. (2014). Europe: Early Upper Paleolithic. In C. Smith (Ed.), *Encyclopedia of Global Archaeology* (pp. 2570–2580). New York: Springer.

Lazukov, G. I. (1982). Kharakteristika chetvertichnykh otlozhenii raiona. In N. D. Praslov & A. N. Rogachev (Eds.), *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii* (pp. *13–37*). Leningrad: Nauka.

Levkovskaya, G. M., Shumilovskikh, L. S., Anikovich, M. V., Platonova, N. I., Hoffecker, J. F., Lisitsyn, S. N., Pospelova, G. A., Kuzmina, I. E., & Sanko, A. F. (2015). Supra-regional correlations of the most ancient paleosols and Paleolithic layers of Kostenki-Borschevo region (Russian Plain). *Quaternary International, 365*, 114–134.

Lisitsyn, S. N. (2018). Nakhodki artefaktov streletskogo kul'turnogo oblika na stoianke Borshchevo 5 v Kostenkovsko-Borshchevskom paleoliticheskom raione na Donu. *Zapiski IIMK, 17*, 55–61.

Marom, A., McCullagh, J. S. O., Higham, T. F. G., Sinitsyn, A. A., & Hedges, R. E. M. (2012). Single amino acid radiocarbon dating of Upper Paleolithic modern humans. *Proceedings of the National Academy of Sciences USA*, 109, 6878–6881.

Matyukhin, A. E. (2012). *Biryuch'ya Balka 2: mnogosloinyi paleoliticheskii pamiatnik v basseine Nizhnego Dona*. Saint Petersburg: Nestor-Istoriya.

Matyukhin, A. E., & Sapelko, T. V. (2009). Paleolithic site Biryuchya Balka-2: geology, chronology, and paleoecology. *Archaeology, Ethnology & Anthropology of Eurasia, 37*(4), 2–12.

Monigal, K. (2006). Transit lounge of Eastern Europe: multicultural Crimea during the Late Middle Paleolithic and Early Upper Paleolithic. In N. Conard (Ed.), *When Neanderthals and Modern Humans Met* (pp. 189–211). Tübingen: Kerns Verlag.

Otte, M. (2014). Europe: Middle to Upper Paleolithic transition. In C. Smith (Ed.), *Encyclopedia of Global Archaeology* (pp. 2586–2591). New York: Springer.

Panin, A. V., Sinitsyn, A. A., & Bessudnov, A. A. (2019). Vremya i prodolzhitel'nost' periodov erozii po razrezam paleoliticheskikh stoyanok kostenkovskoi gruppy. In A. A. Bessudnov (Ed.), *Drevneyshii paleolit Kostenok: khronologiya, stratigrafiya, kul'turnoye raznoobraziye (k 140-letiyu arkheologicheskikh issledovanii v Kostenkovsko-Borshchevskom raione). Materialy mezhregional'noi nauchno-prakticheskoi konferentsii (Voronezhskaya oblast', s. Kostenki, avgust 20-22)* (pp. 79–81). VGU.: Voronezh.

Pavlov, P. (2010). Stoyanka Garchi I – pamyatnik kostenkovsko-streletskoi kul'tury na Verkhnei Kame (Severnyi Ural). *Archeologicheskiye Vesti, 16*, 16–28.

Popov, V. V. (1989). *Razvitiye pozdnepaleoliticheskoi kul'tury Vostochnoi Evropy po materialam mnogosloinoi stoyanki Kostenki 11.* Unpublished PhD thesis, Leningrad State University, Leningrad.

Praslov, N. D. (1976). *Otchet o polevykh rabotakh Kostenkovskoi paleoliticheskoi ekspeditsii v 1976 godu.* Archive of IHMC RAS. F. 35, op. 1. 1976. D. 56.

Praslov, N. D. (1979). *Otchet o rabotakh Kostenkovskoi paleoliticheskoi ekspeditsii v 1979 godu*. Archive of IHMC RAS. F. 35, op. 1. 1979. D.32.

Praslov, N. D., & Rogachev, A. N. (1974). *Otchet o rabote Kostenkovskoi ekspeditsii LOIA AN SSSR v 1974 godu*. Archive of IHMC RAS. F. 35, op. 1. 1974. D. 32.

Praslov, N. D., & Rogachev, A. N. (1982). *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii*. Leningrad: Nauka.

Pyle, D., Ricketts, G., Margari, V., van Andel, T., Sinitsyn, A., Praslov, N., & Lisitsyn, S. (2006). Wide dispersal and deposition of distal tephra during the Pleistocene 'Campanian Ignimbrite/Y5' eruption, Italy. *Quaternary Science Reviews, 25*, 2713–2728.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Ramsey, C. B., Buck, C. E., Cheng, H., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A, Turney, C. S. M., & van der Plicht, J. (2013). IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon, 55*, 1869–1887.

Reynolds, N., Dinnis, R., Bessudnov, A. A., Devièse, T., & Higham, T. (2017). The Kostënki 18 child burial and the cultural and funerary landscape of Mid Upper Palaeolithic European Russia. *Antiquity, 91*, 1435–1450.

Rodionov, A. M. (2016). *Kamennaya industriya kak istochnik dlya izucheniya drevnikh tekhnologii i khozyaistvennoi deyatel'nosti naseleniya pozdnego paleolita (na primere stoyanki Kostenki 11, Ia kul'turnyi sloi).* Unpublished PhD thesis, Voronezh State University, Voronezh.

Rogachev, A. N. (1950). O nizhnem gorizonte kul'turnykh ostatkov Kostenok 1. *Kratkiye soobchsheniya Instituta istorii material'noi kul'tury, 31*, 64–74.

Rogachev, A. N. (1951). *Polevyye chertezhi k otchetu*. Archive of IHMC RAS. F. 35, op. 1. 1951. D. 1209.

Rogachev, A. N. (1952). *Otchet o rabotakh paleoliticheskoi ekspeditsii v Kostenkakh v 1952 g.* Archive of IHMC RAS. F. 35, op. 1. 1952. D. 84.

Rogachev, A. N. (1953). Raskopki Kostenok I. *Kratkiye soobshcheniya Instituta istorii material'noi kul'tury, 51*, 3–15.

Rogachev, A. N. (1954). Polevoi dnevnik raskopok stoyanok na Markinoi gore (Kostenki 14), pogrebeniya negroida, Kostenki 12, 16, 18 s polevymi chertezhami i opis'yu nakhodok. Archive of IHMC RAS. F. 35, op. 1. 1954. D. 89.

Rogachev, A. N. (1957). Mnogosloinyye stoyanki Kostenkovsko-Borshevskogo raiona. *Materialy i issledovaniya po arkheologii SSSR, 59*, 10–134.

Rogachev, A. N. (1960). *Otchet o rabote paleoliticheskoi ekspeditsii v 1960 g.* Archive of IHMC RAS. F. 35, op. 1. 1960. D. 293.

Rogachev, A. N. (1961). *Otchet o rabote paleoliticheskoi ekspeditsii Instituta arkheologii AN SSSR v Kostenkakh v 1961 godu*. Archive of IHMC RAS. F. 35, op. 1. 1961. D. 282.

Rogachev, A. N. (1962). *Otchet o rabote Kostenkovskoi paleoliticheskoi ekspeditsii v 1962 godu.* Archive of IHMC RAS. F. 35, op. 1. 1962. D. 232.

Rogachev, A. N. (1968). Treugol'nye nakonechniki kopii v Kostenkakh. In B. A. Rybakov (Ed.), *Arkheologicheskiye otkrytiya 1967 goda* (pp. 29–30). Moscow: Nauka.

Rogachev, A. N. (1975). *Otchet o rabote Kostenkovskoi paleoliticheskoi ekspeditsii v 1975 godu*. Archive of IHMC RAS. F. 35, op. 1. 1975. D. 44.

Rogachev, A. N., & Anikovich, M. V. (1982a). Kostenki 12 (Volkovskaya stoyanka). In N. D. Praslov & A. N. Rogachev (Eds.), *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii* (pp. 132–140). Leningrad: Nauka.

Rogachev, A. N., & Anikovich, M. V. (1982b). Kostenki 6 (Streletskaya). In N. D. Praslov & A. N. Rogachev (Eds.), *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii* (pp. 88–91). Leningrad: Nauka.

Rogachev, A. N., & Anikovich, M. V. (1984). Pozdnii paleolit Russkoi ravniny i Kryma. In P. I. Boriskovskii (Ed.), *Paleolit SSSR* (pp. 162–271). Moscow: Nauka.

Rogachev, A. N., & Popov, V. V. (1982). Kostënki 11 (Anosovka 2). In N. D. Praslov & A. N. Rogachev (Eds.), *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii* (pp. 116–132). Leningrad: Nauka.

Rogachev, A. N., & Sinitsyn, A. A. (1982). Kostenki 14 (Markina gora). In N. D. Praslov & A. N. Rogachev (Eds.), *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii* (pp. 145–162). Leningrad: Nauka.

Rogachev, A. N., Praslov, N. D., Anikovich, M. V., Belyayeva, V. I., & Dmitriyeva, T. N. (1982). Kostenki 1 (stoyanka Polyakova). In N. D. Praslov & A. N. Rogachev (Eds.), *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu, 1879-1979: Nekotoryye itogi polevykh issledovanii* (pp. 42–66). Leningrad: Nauka.

Sedov, S. N., Khokhlova, O. S., Sinitsyn, A. A., Korkka, M. A., Rusakov, A. V., Ortega, B., Solleiro, E., Rozanova, M. S., Kuznetsova, A. M., & Kazdym, A. A. (2010). Late Pleistocene paleosol sequences as an instrument for the local paleographic reconstruction of the Kostenki 14 key section (Voronezh Oblast) as an example. *Eurasian Soil Science, 43*(8), 876–892.

Sinitsyn, A. A. (2010). The Early Upper Palaeolithic of Kostenki: chronology, taxonomy, and cultural affiliation. In C. Neugebauer-Maresch & L. R. Owen (Eds.), *New Aspects of the Central and Eastern European Upper Palaeolithic – Methods, Chronology, Technology and Subsistence. Symposium by the Prehistoric Commission of the Austrian Academy of Sciences; Vienna, November 9-11, 2005. Mitteilungen der Prähistorischen Kommission 72* (pp. 27–48). Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

Sinitsyn, A. A. (2012). Figurative and decorative art of Kostenki: chronological and cultural differentiation. In J. Clottes (Ed.). *L'art pléistocène dans le monde* (pp. 1339-1359). Tarascon-sur-Ariège: Société Préhistorique Ariège-Pyrénées.

Sinitsyn, A. A. (2014). L'Europe Orientale. In M. Otte (Ed.), *Neandertal/Cro-Magnon. La Rencontre* (pp. 189–220). Paris: Éditions Errance.

Sinitsyn, A. A. (2015). Perspectives on the Palaeolithic of Eurasia: Kostënki and related sites. In N. Sanz (Ed.), *Human Origin Sites and the World Heritage Convention in Eurasia* (pp. 163–189). Paris & Mexico City: UNESCO.

Sinitsyn, A. A. (2016). Rannii verkhnii paleolit Vostochnoi Evropy: ukrasheniya i voprosy estetiki. In G. A. Khlopachev (Ed.), *Verkhnii paleolit: obrazy, simboly, znaki. Katalog predmetov iskusstva malykh form i unikal'nykh nakhodok verkhnego paleolita iz arkheologicheskogo sobraniya MAE RAN* (pp. 320–337). Ekstraprint: Saint Petersburg.

Sinitsyn, A. A. (2017). Kostenki 14 (Markina gora). In N. E. Chalykh (Ed.), *Arkheologicheskiye issledovaniya v Tsentral'nom Chernozem'ye 2016* (pp. 66–69). Lipetsk: Novyi vzglyad.

Sinitsyn, A. A., Praslov, N. D., Svezhentsev, Y. S., & Sulerzhitskii, L. D. (1997). Radiouglerodnaya khronologiya verkhnego paleolita Vostochnoi Evropy. In A. A. Sinitsyn & N. D. Praslov (Eds.), *Radiouglerodnaya khronologiya paleolita Vostochnoi Evropy i Severnoi Azii. Problemy i perspektivy* (pp. 21–66). IIMK RAN: Saint Petersburg.

Sinitsyn, A. A., Bessudnov, A. A., Lada, A. R., & Artyushenko, A. A. (2019). Issledovaniya Kostenkovskoi arkheologicheskoi ekspeditsii IIMK RAN. In M. V. Ivashov (Ed.), *Arkheologicheskiye issledovaniya v Tsentral'nom Chernozem'ye 2018* (pp. 80–87). Lipetsk: Novyi vzglyad.

Stuiver, M., & Polach, H. A. (1977). Discussion: reporting of C-14 data. *Radiocarbon, 19*, 355–363.

Svendsen, J. I., Heggen, H. P., Hufthammer, A. K., Mangerud, J., Pavlov, P., & Roebroeks, W. (2010). Geo-archaeological investigations of Palaeolithic sites along the Ural Mountains – on the northern presence of humans during the last Ice Age. *Quaternary Science Reviews, 29*(23–4), 3138–3156.

Trinkaus, E., Buzhilova, A. P., Mednikova, M. B., & Dobrovolskaya, M. V. (2014). *The people of Sunghir: burials, bodies, and behavior in the Earlier Upper Paleolithic*. New York: Oxford University Press.

Velichko, A. A. (1961). *Geologicheskii vozrast verkhnego paleolita tsentral'nykh raionov Russkoi ravniny. Moscow: izdatel'stvo AN SSSR.*

Velichko, A. A., Pisareva, V. V., Sedov, S. N., Sinitsyn, A. A., & Timireva, S. N. (2009). Paleogeography of Kostenki 14 (Markina gora). *Archaeology, Ethnology & Anthropology of Eurasia, 37*, 25–50.

Vishnyatsky, L. B., & Nehoroshev, P. E. (2004). The beginning of the Upper Paleolithic on the Russian Plain. In P. J. Brantingham, S. L. Kuhn, & K. W. Kerry (Eds.), *The Early Upper Paleolithic Beyond Western Europe* (pp. 80–96). Berkeley CA: University of California Press.

Vishnyatskii, L. B. (2014). Treugol'nyye bifasial'nyye nakonechniki s vognutym osnovaniyem i diskussiya o kornyakh streletskoi kul'tury. In S. A. Vasil'ev & E. S. Tkach (Eds.), *Verkhnii paleolit Severnoi Evrazii i Ameriki: pamyatniki, kul'tura, traditsii* (pp. 107–112). Saint Petersburg: Peterburgskoye vostokovedeniye.

Vishnyatsky, L. B. (2016). Smena naseleniya v Evrope na rubezhe srednego i verkhnego paleolita i problema kul'turnoi preemstvennosti. *Stratum Plus, 1*, 17–28.

White, R. (1999). Intégrer la complexité sociale et opérationnelle: la construction matérielle de l'identité sociale à Sungir. In M. Julien, A. Averbough, D. Ramseyer, C. Bellier, D. Buisson, P. Cattelain, M. Patou-Mathis, & N. Provenzano (Eds.), *Préhistoire d'os. Recueil d'études sur l'industrie osseuse préhistorique offert à Henriette Camps-Fabrer (pp. 319-331)*. Publications de l'Université de Provence.

Wood, R. E., Douka, K., Boscato, P., Haesaerts, P., Sinitsyn, A., & Higham, T. F. G. (2012). Testing the ABOx-SC method: dating known age charcoals associated with the Campanian Ignimbrite. *Quaternary Geochronology, 9*, 16–26.

Zaliznyak, L. L., Belenko, M. M., & Ozerov, P. I. (2008). Stoyanka Vys' ta ïï mistse u pizn'omu paleoliti Ukraïny. *Kam"yana doba Ukraïny*, 11, 59–74.

Zaliznyak, L. L., & Belenko, M. M. (2011). Stoianka seletskogo kruga na rechke Vys' v Tsentral'noi Ukraine (issledovaniya 2007 i 2008 gg.). *Stratum Plus, 1*, 261–273.

Zaliznyak, L. L., Belenko, M. M., & Ozerov, P. I. (2013). Stoyanka Vys' ta ïï mistse u verkhn'omu paleoliti Ukraïny. *Kam"yana doba Ukraïny*, 15, 75–105.

Zwyns, N., Roebroeks, W., McPherron, S. P., Jagich, A., & Hublin, J.-J. (2012). Comment on "Late Mousterian persistence near the Arctic Circle". *Science, 335*, 167.

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