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From the Bay of Naples to the River Don: the Campanian Ignimbrite eruption and the Middle to Upper Paleolithic transition in Eastern Europe

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ABSTRACT

The Campanian Ignimbrite (CI) eruption, dated by $^{40}Ar/^{39}Ar$ and various stratigraphic methods to ca. 39,000 cal BP, generated a massive ash plume from its source in southern Italy across Southeastern and Eastern Europe. At the Kostenki-Borshchevo open-air sites on the Middle Don River in Russia, Upper Paleolithic artifact assemblages are buried below, within, and above the CI tephra (which is redeposited by slope action at most sites) on the second terrace. Luminescence and radiocarbon dating, paleomagnetism, and soil and pollen stratigraphy provide further basis for correlation with the Greenland and North Atlantic climate stratigraphy. The oldest Upper Paleolithic occupation layers at Kostenki-Borshchevo may be broadly correlated with warm intervals that preceded the CI event and Heinrich Event 4 (HE4; Greenland Interstadial: GI 12–GI 9) dating to ca. 45,000–41,000 cal BP. These layers contain an industry not currently recognized in other parts of Europe. Early Upper Paleolithic layers above the CI tephra are correlated with HE4 and warm intervals that occurred during 38,000–30,000 cal BP (GI 8–GI 5), and include an assemblage that is assigned to the Aurigancian industry, associated with skeletal remains of modern humans.

The chronology of the Middle to Upper Paleolithic transition in Europe

Deposits in European sites dating to between 50,000 and 40,000 cal BP contain the earliest known artifact assemblages assigned to the Upper Paleolithic. These deposits were laid down during the age-equivalent of Marine Isotope Stage 3 (MIS 3), the lower and upper temporal boundaries of which are placed at ca. 60,000 and 30,000 cal BP, respectively. According to the Greenland and North Atlantic records, climates in the northern hemisphere during MIS 3 were characterized by a series of brief warm and cool oscillations (Bond et al., 1993; Dansgaard et al., 1993; Grootes et al., 1993; Genty et al., 2003). A major cold interval (Heinrich Event 4 [HE4]) followed the Campanian Ignimbrite volcanic eruption in southern Italy at ca. 39,000 cal BP (De Vivo et al., 2001; Ton-That et al., 2001). The ash plume created by this massive eruption spread across much of southeastern Europe and deposited a tephra layer that provides a widespread stratigraphic marker in this portion of the continent (Giaccio et al., 2006).

The Upper Paleolithic and underlying Middle Paleolithic were originally defined during the late 19th century on the basis of stratified sequences of artifact assemblages in Western Europe—primarily from rockshelters in southwestern France. Although subject to some refinement during the early and middle 20th century, the definitions of the Upper and Middle Paleolithic have not undergone fundamental change (e.g., Peyrony, 1930; de Sonneville-Bordes, 1960; Bordes, 1961, 1968). In Europe, the Middle Paleolithic may be equated with the Mousterian Industrial Complex, based largely (although not wholly) on the production of flakes, and comprising assemblages with high percentages of retouched tools in the form of side-scrapers and points. Some Middle Paleolithic assemblages contain at least modest numbers of small bifaces, and some contain high percentages of notches and denticulates (Bordes, 1968: 98–120; Laville et al., 1980: 140–147; Mellars, 1996).

The most widespread industry of the early Upper Paleolithic (antedating 30,000 cal BP) is known as the Aurignacian. It offers

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a sharp contrast to the preceding Mousterian. The early phase of this industry (Aurignacian I) is characterized by high-backed or carinate end-scrapers, Aurignacian blades, and backed bladelets. Burins are less common. The most diagnostic artifact is the split-base point of bone or antler (Laville et al., 1980: 220–223; Harrold, 1989: 697–705; Mellars, 2006: 167–169). Another early Upper Paleolithic industry is recognized in Mediterranean Europe and may be slightly older than the Aurignacian. The former is widely known as the "Proto-Aurignacian," and is dominated by small-to-medium bladelets retouched into lamelles Dufour and Font-Yves points, along with modest numbers of classic Aurignacian forms (e.g., carinate scrapers). Some assemblages contain numerous ornaments in the form of perforated marine shells (Bartolomei et al., 1992; Kuhn and Bietti, 2000: 60–66; Mellars, 2006: 169–170).

The early Aurignacian is broadly associated with deposits that accumulated during the cold HE4 (Laville et al., 1980: 228–229; Mellars, 2006: 168) dating to roughly 40,000–38,000 cal BP. The Proto-Aurignacian assemblages appear to be somewhat older and underlie the Campanian Ignimbrite tephra at several sites in Italy (e.g., Serino, Castelcivita Cave [Fedele et al., 2003: 307–309]). Both the stratigraphic position and calibrated radiocarbon dates of these assemblages indicate an age of 43,000–41,000 cal BP. They are associated with several brief warm intervals that are designated Greenland Interstadials 11–9 (GI 11–GI 9) in the GISP2 ice core record (Giaccio et al., 2006).

During the early 20th century, a group of assemblages was discovered in France and northern Spain comprising typical elements of both the Middle and Upper Paleolithic. These assemblages are most widely known today as the Chatelperronian. They contain a high proportion of blades struck from prismatic cores and diagnostic Chatelperron points, as well as end-scrapers, burins, and truncated pieces, along with side-scrapers, notches, and denticulates (Harrold, 1989). The relative stratigraphic position and dating of the Chatelperronian is disputed. Some argue that it is interstratified—and at least broadly contemporaneous—with the early Aurignacian (Laville et al., 1980: 226–229; Harrold, 1989: 684–690; Mellars, 1996: 412–418), but others maintain that the Chatelperronian antedates the latter (as well as the Proto-Aurignacian) and 42,000 cal BP (e.g., Zilhão, 2006: 185–186).

While the Chatelperronian is geographically confined to the Franco-Cantabrian region, early Upper Paleolithic industries containing both typical Middle and Upper Paleolithic artifact forms are present in other areas of Europe. (Although these industries are sometimes labeled "archaic" or "transitional," they are more objectively characterized as "combined.") They vary by region and include the Uluzzian (southeastern Europe), Szeletian (Central Europe), Bohunician (east-central Europe), and others (Svoboda et al., 1996: 107–114; Kuhn and Bietti, 2000: 57–60). The Uluzzian is probably the best dated combined industry outside the Franco-Cantabrian area, because assemblages are buried in stratified sequences that underlie the CI tephra in Italy. At several sites, Uluzzian assemblages directly underlie the CI tephra and antedate 40,000 cal BP, while at Castelcivita Cave, they are buried below Proto-Aurignacian levels that underlie the tephra and date to roughly 44,000–42,000 cal BP (Kuhn and Bietti, 2000: 60; Giaccio et al., 2006, 2007). The dating of combined industries in other parts of Europe is complicated by a scarcity of deeply stratified sequences that can be correlated with the climato-stratigraphy for the northern hemisphere (in a time range outside the effective range of the radiocarbon method). There is a consensus, nevertheless, that these industries—like the Uluzzian—both antedate and overlap with the Aurignacian and Proto-Aurignacian industries (Svoboda et al., 1996; Kozlowski, 2000).

In Europe—with isolated and problematic exceptions—only skeletal remains of Neandertals (*Homo neanderthalensis*) are associated with artifact assemblages of the Middle Paleolithic. The remains of both Neandertals and Anatomically Modern Humans (*Homo sapiens*), however, are found in layers containing early Upper Paleolithic industries. Early Aurignacian assemblages apparently are associated only with modern human remains (Gambier, 1989; Churchill and Smith, 2000; Bailey and Hublin, 2005; Wild et al., 2005), and although Proto-Aurignacian assemblages lack unambiguous association with fossil humans, they also are widely assumed to have been made by modern humans (Mellars, 2006: 177). Chatelperronian assemblages are associated with Neandertal remains at several key sites in France (Harrold, 1989: 646), but combined industries in other parts of Europe lack a clear association with Neandertals or modern humans; while some or all of them are often assumed to have been produced by Neandertals (e.g., Allsworth-Jones, 1990; Zilhão, 2006: 189), this has yet to be confirmed.

Although roughly half the land area of Europe lies east of the Carpathian Mountains, the Paleolithic record of Eastern Europe has never been fully integrated with that of Western Europe. Both the character and timing of the Middle to Upper Paleolithic transition have been difficult to establish in Eastern Europe. This is due in part to the low archaeological visibility of sites occupied during MIS 3 in a region dominated by landscapes with few natural shelters. While later Upper Paleolithic sites are well known—often associated with large concentrations of mammoth bone—early Upper Paleolithic and late Middle Paleolithic sites are rare (Hoffecker, 2002). Deeply stratified occupation sequences are uncommon—many open-air locations lacked the consistent attraction of a natural shelter. The application of radiocarbon dating to East European sites has been slow, and the results have been complicated by a heavy reliance on bone (in paleo-landscapes where wood was sometimes scarce [Hoffecker, 1988: 248]).

The most widely-known early Upper Paleolithic industry—the Aurignacian—is present but comparatively rare in Eastern Europe (Kozlowski, 2000; Hoffecker, 2002). On the other hand, there are several industries assigned to the early Upper Paleolithic that are unknown in other parts of Europe (e.g., Gorodtsovskaya on the central plain [Anikovich et al., 2007a]). They include possible analogs to the combined industries found in other parts of Europe (e.g., Streletskaya; see Allsworth-Jones, 1990: 222–229; Anikovich et al., 2007a).

The identification of the CI tephra at the Kostenki-Borshchevo sites (Pyle et al., 2006) provides an opportunity to improve integration of the Paleolithic record on the central plain of Eastern Europe with other parts of the continent (Anikovich et al., 2007b; Giaccio et al., 2007). A series of early Upper Paleolithic occupation layers lie below, within, and above the CI tephra at these sites. Supporting chronometric analyses—luminescence dating, paleomagnetism, and radiocarbon—combined with soil and pollen stratigraphy offer potential correlation with the Greenland and North Atlantic climate records for the MIS 3 age equivalent.

The Campanian Ignimbrite eruption

Approximately 39,000 cal BP, a massive volcanic eruption took place in southern Italy, spewing a plume of ash across large areas of south-central and Eastern Europe. The CI eruption deposited a tephra horizon that represents a major chrono-stratigraphic marker for the Middle to Upper Paleolithic transition. Because the tephra is dated in a variety of contexts (Ton-That et al., 2001; Pyle et al., 2006), it provides a temporal marker that is not based on radiocarbon. The CI tephra also represents a catastrophic event that had significant effects on plant and animal life and may have played some role in the transition process (Fedele et al., 2003: 313–316, 2008).

The CI eruption has been described by various authors (Barberi et al., 1978; Rosi et al., 1999; Giaccio et al., 2007). The source is the

Phlegrean Field located west of Naples in southern Italy. The CI eruption may have caused a caldera collapse of an estimated 230 km^2 that included the modern city of Naples and the northwestern portion of the Bay of Naples (Orsi et al., 1996), while pyroclastic flow deposits covered an area of 30,000 km^2 (up to 80 km from the vent; Fisher et al., 1993). The CI eruption generated a "sustained plinian eruption column" of debris that achieved an estimated maximum altitude of 44 km (Rosi et al., 1999; Fedele et al., 2003: 305), and a plume of ash that covered an area of approximately 5,000,000 km^2 (Giaccio et al., 2006).

The ash plume produced by the CI eruption extended 1,000–1,800 km south and east into the Mediterranean Sea (where it is represented by the C-13 and Y5 marine tephras [Ton-That et al., 2001]) and more than 2500 km northeast across the Balkans and onto the East European Plain (Giaccio et al., 2006, their Fig. 1; Pyle et al., 2006). The chemical composition of the pumices and glass shards is variable and reflects an eruption comprising two chemically different magmatic layers—a more evolved upper magma layer and a less evolved lower layer (Civetta et al., 1997). The peculiar character of the CI tephra has rendered it easy to identify in distal settings (Giaccio et al., 2007).

In the Greenland ice record, the CI eruption is represented in GISP2 by a sulphate peak (375 ppb) at the boundary of GI 9 and Greenland Stadial (GS) 9 with an age of approximately 40,000 cal BP (Fedele et al., 2003: 310–311). This position corresponds to the Laschamp paleomagnetic excursion, ^{10}Be peak, and the onset of HE4. The age of the CI event is supported by ^{40}Ar/^{39}Ar dates from the C-13 marine tephra deposits in the Tyrrhenian Sea (Ton-That et al., 2001) and on CI rocks from various locations within the area of the ash plume (De Vivo et al., 2001). It should be noted that ^{14}C dates on the CI tephra consistently yield ages of about 32,000 ^{14}C BP (Giaccio et al., 2006; Pyle et al., 2006: 2722–2723) and that—even when corrected with recently-developed calibration curves (e.g., Fairbanks et al., 2005)—these dates underestimate the age of the tephra (Anikovich et al., 2007b: 224).

In southeastern Europe, the CI tephra has been identified in natural shelters and open-air archaeological sites and has been used as a marker to construct perhaps the most reliable regional chronologic framework for the transition in Europe (Fedele et al., 2003; Giaccio et al., 2006). As already noted, assemblages assigned to the Proto-Aurignacian and the combined Uluzzian industry underlie the CI tephra and are correlated with GI 11–9 in the Greenland ice record (43,000–40,000 BP_{GISP2}) in southern Italy (Giaccio et al., 2007). In Greece, isolated Upper Paleolithic artifacts underlie the CI tephra at Franchthi Cave (Farrand, 1988: 311), while carinated end-scrapers and Font-Yves points are buried below the CI tephra at Temnata Cave in Bulgaria (Drobniewicz et al., 2000).

The Kostenki-Borshchevo sites

Kostenki is located on the Middle Don River near the city of Voronezh in the Russian Federation at 51°40′N and 39°10′E. The village lies on the west bank of the river and the eastern margin of the Central Russian Upland at an elevation of approximately 125 meters above mean sea level. The village of Borshchevo is situated several kilometers southeast of Kostenki. The area is within the modern forest-steppe zone and experiences a continental climate with mean July and January temperatures of 19 °C and −8 °C, respectively. Precipitation averages 520 mm per year.

A total of 21 stratified Upper Paleolithic open-air sites have been investigated at Kostenki, and at least seven more sites have been discovered at Borshchevo. Although several sites are found in the main valley, most are situated at the mouths or in the upper courses of large side-valley ravines that are incised into the high west bank of the Don River (Fig. 1). Springs are active today in the ravines, and primary carbonate deposits in the sites indicate that they were active during Upper Paleolithic times as well (Holliday et al., 2007: 217–219). The sites are found primarily on the first (10–15 meters) and second (15–20 meters) terrace levels, although in isolated cases (e.g., Kostenki 18) they are located above the second terrace (Lazukov, 1957, 1982: 21–35).

Mammoth bones were known from Kostenki centuries ago and evidently account for the name of the village (kost' is the Russian word for bone), but archaeological remains were first discovered in 1879 (Klein, 1969: 29). Major excavations began in the 1920s and 1930s, and these were focused primarily on middle and late Upper Paleolithic occupations (especially the large Eastern Gravettian component in Layer I at Kostenki 1; Efimenko [1958]; Praslov [1982: 11–12]). Early Upper Paleolithic remains were investigated in the lower layers at Kostenki 1 and other localities prior to World War II (e.g., Kostenki 6), but most research on the early occupations was initiated by A. N. Rogachev (1957) in the late 1940s (Klein, 1969: 231–232). Sites containing early Upper Paleolithic layers (i.e., layers dating to the age equivalent of MIS 3) are confined to the second terrace.

Much of the research reported in this paper was undertaken for an international project conducted during 2001–2004 (Anikovich et al., 2007b; Holliday et al., 2007). A major focus of the project was the chronology of the early Upper Paleolithic at Kostenki, and especially the dating of occupation layers buried below the volcanic tephra horizon at sites located on the second terrace. As a result of the identification of this horizon as the CI tephra (Pyle et al., 2006) and research undertaken during 2001–2004, which included OSL dating, soil micromorphology, and paleomagnetic analyses (Pospelova, 2005; Holliday et al., 2007: 194), a new chronology was developed for the early Upper Paleolithic at Kostenki (Anikovich et al., 2007b).

Geology of the Kostenki-Borshchevo sites

The high west bank of the Don Valley, which represents the eastern margin of the Central Russian Upland, is composed on Cretaceous marl (chalk) and sand that unconformably overlie Upper Devonian clay (Lazukov, 1982: 15–17). Upper Paleolithic sites are buried in fill deposits of the first and second terraces of the Don River. The terraces are found in both the main valley and in portions of the large side-valley ravines—described above—incised into the west bank of the valley. The terraces are composed of alluvium, which unconformably overlies the pre-Quaternary units, capped with a complex sequence of eolian, slope, and spring deposits (Lazukov, 1982: 15–22; Holliday et al., 2007: 182–184).

The alluvium at the base of the second terrace (15–20 m above the Don River floodplain) is composed of coarse sand with gravels and cobbles that fine upward into medium and fine sand with chalk gravel. The uppermost alluvium is interstratified with coarse slope deposits derived from the Cretaceous bedrock (Velichko, 1961: 201–202; Lazukov, 1982: 21). Above these deposits lies a sequence of alternating thin lenses of silt, carbonate, chalk fragments, and organic-rich loam (Holliday et al., 2007: 184–186). At many localities, these lenses are subdivided by the volcanic tephra horizon. Traditionally, the lenses below and above the tephra have been termed the Lower Humic Bed and Upper Humic Bed, respectively (e.g., Velichko, 1961: 210). All early Upper Paleolithic occupation layers are found within the humic beds or their stratigraphic equivalent (see Fig. 2).

The origin of the humic beds has been the subject of debate for many years (e.g., Sinitsyn, 1996: 278–281). Although they often have been attributed to redeposition of soil from higher slopes, some geologists argued that the organic-rich lenses actually represent in situ soil horizons (Grishchenko, 1961: 64–65). Soil micromorphology analysis performed during the 2001–2004 project confirmed that in situ soil formation had occurred in these

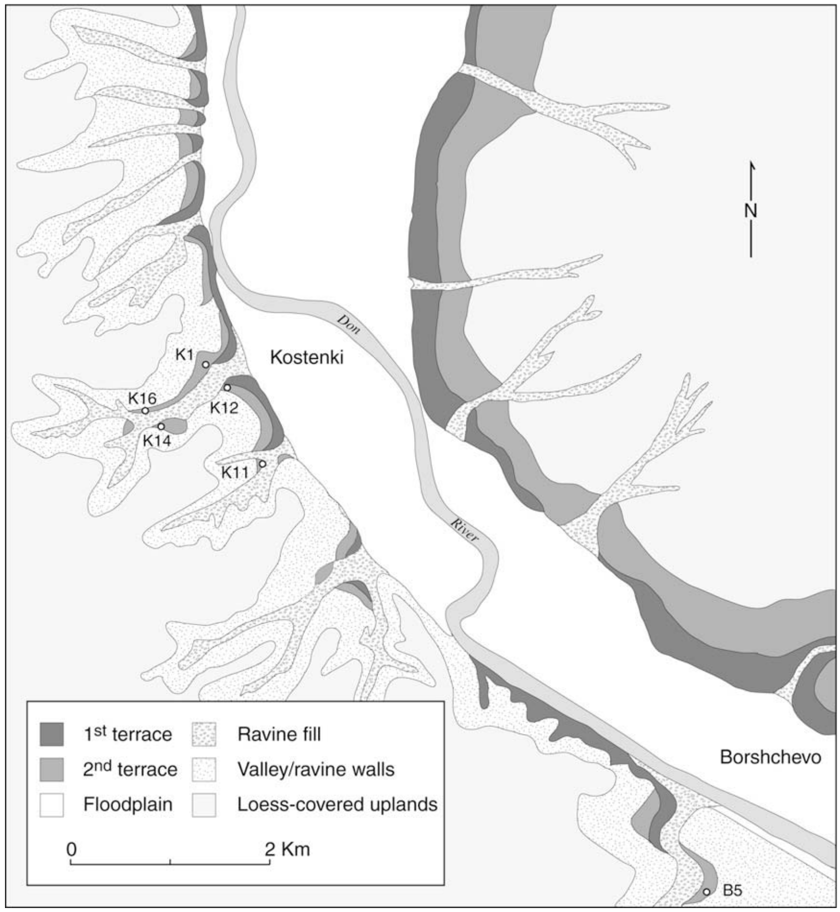

Fig. 1. Map of the Kostenki-Borshchevo area showing the location of sites investigated during 2001–2004.

lenses (Holliday et al., 2007: 190–192, their Table I). The carbonate bands formed as calcium carbonate precipitated (also in situ) from the discharge of springs and seeps that were active on the second terrace level at this time (Holliday et al., 2007: 217–218). The chalk fragments are derived from upslope exposures of eroding Cretaceous bedrock. The humic beds thus represent a complex interplay of colluviation, spring deposition, and soil formation.

At some sites, spring activity and/or other disturbances were absent, and normal soil profiles developed in place of the characteristic humic bed sequence. For example, three buried soils have been observed below the tephra horizon (i.e., stratigraphic equivalent of the Lower Humic Bed) at Kostenki 14 (Holliday et al., 2007: 202–203). At Kostenki 1, well-developed soil profiles are present in place of both humic beds (Holliday et al., 2007: 209). Like the humic beds, all of these soils were formed during the age equivalent of MIS 3 (prior to ca. 30,000 cal BP).

Fig. 2. The humic beds at Kostenki 12. Photograph by J.F. Hoffecker (2002).

At many Kostenki-Borshchevo sites, the upper portion of the humic beds (or their stratigraphic equivalent) is truncated by an erosional unconformity and a layer of coarse bedrock debris (Holliday et al., 2007: 219–220). The debris layer is capped with a weakly developed soil (Gmelin Soil), which dates to an early phase of the MIS 2 age equivalent (approximately 27,000–25,000 cal BP). Above the Gmelin Soil lies loess-like loam of Last Glacial Maximum age, which is capped with the modern chernozem (Lazukov, 1982; Holliday et al., 2007: 219).

The CI tephra at Kostenki-Borshchevo

The problem of the origin and age of the volcanic tephra horizon at Kostenki—first reported in 1928—has been researched for many decades (Klein, 1969: 38; Grishchenko, 1976: 190–198). During the 1980s, the source of the tephra was identified as the Phlegrean Field in southern Italy (Melekestsev et al., 1984; Sinitsyn et al., 1997: 27–28). Recently, on the basis of chemical analysis of samples collected in 2002, Pyle and colleagues (2006: 2717–2719) concluded that it was the CI Y5 tephra; this also was confirmed by Giaccio et al. (2006) on the basis of a sample from Borshchevo 5.

Occurrence of the tehpra in the Kostenki-Borshchevo area is highly variable, owing to local conditions and post-depositional disturbance. At Borshchevo 5, the tephra apparently was subject to minimum disturbance and is represented by a light yellowish brown (2.5Y 5.5/3) ash horizon varying 5–20 cm in thickness that occasionally thins to less than 1 cm (Pyle et al., 2006: 2715–2716;

Holliday et al., 2007: 213–214). At many Kostenki sites, the tephra layer has been eroded by wind and/or slope action and is thinner or invisible to the unaided eye. At Kostenki 14, it is typically less than 2 cm in thickness and exhibited some evidence of frost disturbance (Pyle et al., 2006: 2715).

In upslope portions of Kostenki 12 and at Kostenki 1, the tephra is not grossly visible, but its presence was established through microscopic analysis of sediment samples (Holliday et al., 2007: 200–209). Recent analysis of samples from Kostenki 1 indicates that magnetic sediment probably derived from the tephra is deposited in units below the level containing a high concentration of glass shards, suggesting that the stratigraphic position of the tephra may be lower than previously believed (i.e., the concentration of glass shards representing traces of tephra redeposited at a much later time). Ongoing research is designed to resolve this and other problems regarding the stratigraphy at Kostenki 1.

Tephra samples from Kostenki 14, Borshchevo 5, and other localities in the area comprise alkali trachytes typical of the Campanian province of Italy (Pyle et al., 2006: 2717). Pyle et al. (2006: 2719) note that the trachytic composition of the samples precludes an East European origin, such as the Caucasus Mountains. The chemical composition of the glass shards exhibits a close fit with samples of the CI tephra from Italy and the Y5 marine tephra (Pyle et al., 2006: 2717–2719). A sample from Borshchevo 5 comprises glasses from both the more and less evolved magma characterizing the CI magmatic system (low versus high K2O/Na2O-CaO-MgO; see Table 1).

The chronology of the Kostenki-Borshchevo sites

Identification of the CI tephra at Kostenki-Borshchevo provided a chrono-stratigraphic marker for the sites on the second terrace that contain early Upper Paleolithic occupation layers (Pyle et al., 2006: 2722–2723). Although the CI tephra represents the key marker, the Kostenki-Borshchevo chronology also is based on luminescence dating and paleomagnetic stratigraphy (Gernik and Gus'kova, 2002; Pospelova, 2005; Holliday et al., 2007: 194, their Table III), which suggest that the stratigraphic position of the tephra in the archaeological sites has not been significantly altered by post-depositional disturbance. Soil and pollen stratigraphy provide some additional support, and the latter may be especially helpful in correlation of layers containing the earliest Upper Paleolithic occupations with the Greenland and North Atlantic climate record (Levkovskaya et al., 2005: 113; Anikovich et al., 2007b: 224).

Radiocarbon dates yield significantly younger ages for the tephra and Lower Humic Bed (or its stratigraphic equivalents), and this pattern is consistent with that observed in Italy and other regions where the radiocarbon chronology can be evaluated against other dating methods for this time range (Giaccio et al., 2006; Sinitsyn and Hoffecker, 2006). Uncorrected radiocarbon dates associated with the CI tephra at the Kostenki-Borshchevo sites match those from the CI tephra in Italy (i.e., 33,000–31,000 ^{14}C BP; Fedele et al., 2003: 309).

Radiocarbon dating

The most widely-applied dating method at the Kostenki-Borshchevo sites is radiocarbon, and at least a few dates are available for most of the sites; at several sites (including Kostenki 1 and Kostenki 14) many dates have been obtained (Sinitsyn et al., 1997: 47–51; Haesaerts et al., 2004: 173; Sinitsyn and Hoffecker, 2006: 180). Samples have been prepared and dated by a variety of radiocarbon laboratories using both conventional and AMS methods. Radiocarbon dates are presented with corrected ages (based on two recently-developed calibration curves) for Kostenki 1, 12, 14, and 17 in Table 2.

The dates exhibit inconsistencies and often yield a wide age range for the same layer. Thus, for example, dates on bone of 19,300 ± 200 ^{14}C BP (LE-1400) and 28,580 ± 420 ^{14}C BP (OxA-4115) were obtained on Layer II at Kostenki 14 (Sinitsyn et al., 1997: 51). Much of the inconsistency presumably is due to contamination of younger carbon from percolating humic acids on samples of bone (Haesaerts et al., 2004: 172). Accordingly, only dates on charcoal (which can be effectively pretreated) are included in Table 2.

While application of the calibration curves improves the fit between the charcoal dates and other dating methods, the corrected dates still appear to underestimate the age of the tephra and Lower Humic Bed (or its stratigraphic equivalents) by more than 1,000 calendar years. The calibrated date for the CI tephra at Kostenki 14, for example, is 37,835 ± 814 cal BP (from an uncorrected date of 32,420 ± 440/420 ^{14}C BP [GrA-18053]), while the consensus date on the CI tephra is 39,300 cal BP (De Vivo et al., 2001; Pyle et al., 2006: 2722).

Luminescence dating

During the 2001–2004 project, 13 optically stimulated luminescence (OSL) dates were obtained on sediment samples collected

Table 1
Chemical composition of the glasses of the tephra from Borshchevo 5 (wt% on water-free bases) compared with representative analyses of the pumices and glasses of the CI fall (Signorelli et al., 1999) and flow units (Pappalardo et al., 2002)[a]

	Kostenki – Borshchevo 5				CI – Fall units					CI – Flows units		
	BOR 1	σ(20)	BOR 2	σ(4)	LFU			UFU		U I	U II	UIII
SiO2	61.41	*0.60*	61.57	*0.63*	61.22	61.55	61.20	61.71	60.10	61.64	61.14	60.10
TiO2	0.40	*0.04*	0.36	*0.07*	0.50	0.40	0.31	0.41	0.40	0.43	0.42	0.40
Al2O3	18.41	*0.16*	18.43	*0.20*	18.82	18.55	19.03	18.62	18.75	18.61	18.70	18.75
FeO	3.10	*0.12*	3.50	*0.18*	2.98	2.98	3.50	3.11	4.06	3.49	3.62	4.06
MnO	0.23	*0.07*	0.14	*0.02*	0.25	0.26	0.00	0.23	0.14	0.23	0.20	0.14
MgO	0.39	*0.11*	0.68	*0.08*	0.48	0.36	0.77	0.37	0.77	0.38	0.40	0.77
CaO	1.90	*0.20*	2.52	*0.14*	1.84	1.70	2.73	1.78	2.98	1.86	2.01	2.98
Na2O	5.76	*0.56*	3.39	*0.49*	5.34	6.10	3.09	5.75	4.11	6.11	5.77	4.11
K2O	7.40	*0.37*	8.86	*1.17*	7.65	7.22	8.74	7.06	8.52	7.17	7.75	8.52
F	0.26	*0.11*	0.04	*0.05*	0.26	0.00	0.12	0.00	0.15	0.09	0.09	0.15
Cl	0.67	*0.18*	0.40	*0.06*	0.52	0.79	0.33	0.84				
P2O5	0.06	*0.05*	0.11	*0.08*	0.06	0.05	0.15	0.03				
TOTAL	100		100		100	100	100	100	100	100	100	100
K2O/Na2O	1.30	0.18	2.69	*0.71*	1.43	1.18	2.82	1.23	2.07	1.17	1.34	2.07

[a] LFU = Lower Fall Unit; UFU = Upper Fall Unit; U I, II, III = Unit I, II, III. The Borshchevo tephra comprises glasses from both the more and less evolved magma characterizing the CI-zoned magmatic system (blue values with low K2O/Na2O-CaO-MgO and red values with high K2O/Na2O-CaO- MgO, respectively). These two magmas were tapped simultaneously or separately during the eruption.

Table 2
Calibration of radiocarbon dates (on charcoal) from Kostenki according to Fairbanks et al. (2005) and Calpal (2005; S3, S4)

Stratigraphy	^{14}C age	Lab no.	Fairbanks et al. (2005)	Calpal (2005)
		Kostenki 1		
Cultural Layer I (Gmelin Soil)	22,330 ± 150	(GrN-17118)	26,808 ± 175	26,844 ± 471
	23,600 ± 410	(GrA-5244)	28,149 ± 144	28,519 ± 564
	24,030 ± 440	(GrA-5243)	28,619 ± 516	28,979 ± 556
Cultural Layer III (soil b2)	20,900 ± 1,600	(GIN-4848)	25,026 ± 1,949	25,128 ± 1,988
	24,500 ± 1,300	(GIN-4850)	29,277 ± 1,540	29,113 ± 1,290
	25,400 ± 400	(GIN-6248)	30,543 ± 513	30,291 ± 428
	25,730 ± 1,800	(LE-3541)	30,599 ± 1,936	30,591 ± 2,035
	25,900 ± 2,200	(GIN-4849)	30,744 ± 2,356	30,787 ± 2,500
	25,820 ± 400	(GrN-22276)	30,965 ± 363	30,648 ± 304
	26,200 ± 1,500	(GIN-4885)	31,124 ± 1,554	31,168 ± 1,725
	32,600 ± 400	(GrN-17117)	37,498 ± 634	37,950 ± 750
	38,080 ± 5,460	(AA-5590)	(outside range)	42,233 ± 5,187
			Y5 tephra (?)	
Cultural Layer V	30,170 ± 570	(LE-3542)	35,194 ± 530	35,337 ± 597
	32,300 ± 220	(GrA-5557)	37,073 ± 299	37,774 ± 809
	34,900 ± 350	(GrA-5245)	40,380 ± 542	40,585 ± 803
	37,900 ± 2,800	(GrA-5245)	(outside range)	42,106 ± 2,391
		Kostenki 12		
Cultural Layer Ia (UHB)	28,500 ± 140	(GrA-5552)	33,136 ± 171	33,200 ± 666
	32,700 ± 700	(GrN-7758)	37,614 ± 843	38,019 ± 900
			Y5 tephra	
Cultural Layer III	31,760 ± 230	(OxA-X-2158-14)	36,734 ± 177	36,720 ± 279
	35,820 ± 230	(OxA-15482)	41,263 ± 161	41,732 ± 190
	36,280 ± 360	(GrA-5551)	41,535 ± 225	41,909 ± 218
Cultural Layer IV	35,540 ± 260	(OxA-15555)	41,079 ± 212	41,240 ± 550
		Kostenki 14		
Cultural Layer II (UHB)	26,700 ± 190	(GrA-10945)	31,683 ± 168	31,163 ± 128
	27,860 ± 270	(GrA-13292)	32,615 ± 229	32,370 ± 663
	29,240 ± 330	(GrA-13312)	34,278 ± 581	34,403 ± 541
	28,380 ± 220	(GrN-12598)	33,044 ± 240	32,979 ± 722
Cultural Layer III (UHB)	28,370 ± 140	(GrA-15960)	33,025 ± 139	32,956 ± 657
	29,320 ± 150	(GrA-15955)	34,420 ± 435	34,565 ± 401
	30,080 ± 590	(GrN-21802)	35,113 ± 564	35,217 ± 649
	31,760 ± 430	(GrA-13288)	36,700 ± 390	36,983 ± 661
CL in Ash	32,420 ± 440	(GrA-18053)	37,300 ± 600	37,835 ± 814
			Y5 tephra	
Cultural Layer IVa	32,180 ± 450	(GrA-13293)	37,062 ± 513	37,664 ± 890
	33,280 ± 650	(GrN-22277)	38,235 ± 887	38,760 ± 1,235
	33,200 ± 510	(GrA-13301)	38,125 ± 741	38,367 ± 861
Soil b4 below IVa	34,550 ± 610	(GrA-13297)	39,882 ± 877	40,355 ± 854
Cultural Layer IVb	34,940 ± 630	(GrA-13302)	40,366 ± 801	40,552 ± 875
	36,040 ± 250	(GrA-15957)	41,395 ± 166	41,824 ± 191
	36,540 ± 270	(GrA-15961)	41,689 ± 181	42,006 ± 203
Horizon of hearths	35,330 ± 240	(GrA-15958)	40,917 ± 263	40,894 ± 777
	35,870 ± 250	(GrA-15962)	41,293 ± 170	41,752 ± 194
	36,010 ± 250	(GrA-15965)	41,377 ± 167	41,812 ± 191
	36,320 ± 270	(GrA-15956)	41,560 ± 174	41,927 ± 198
	37,240 ± 430	(GrA-10948)	42,100 ± 263	42,317 ± 287
		Kostenki 17		
Cultural Layer I	26,750 ± 700	(GrN-10511)	31,721 ± 582	31,575 ± 793
			Y5 tephra	
Cultural Layer II	32,200 ± 2,000	(GrN-10512)	37,213 ± 2,126	37,724 ± 2,308
	36,780 ± 1,700	(GrN-12596)	41,735 ± 1,380	41,443 ± 1,558

from Kostenki 1, 12, and 14 (two dates also had been processed in 2000 prior to the start of the project). OSL dates were obtained on the fine-grained polymineral and quartz extracts under infrared stimulation (IRSL). The methods are described in Holliday et al. (2007: 225–228) and the dates are presented in Table 3.

At each site, samples were analyzed from the sediment overlying the CI tephra level in order to examine the results on deposits that were already dated by other means. The results were consistent with the calibrated radiocarbon dates for these units, although one of the OSL dates from Kostenki 1 (UIC-1523) and one from

Table 3
OSL dates from Kostenki (S. L. Forman)

Stratigraphy	OSL age	Lab no.	Provenience	
		Kostenki 1		
above b2 soil	30,670 ± 2,750	UIC-1522	Unit Ъ-80	185–195 cm below datum
below b2 soil	30,580 ± 2,740	UIC-1523	Unit Ъ-80	260–270 cm below datum
		Y5 tephra		
		Kostenki 12		
above Gmelin Soil	19,890 ± 1,730	UIC-1418	Unit Ы-73	110 cm below surface
below Gmelin Soil	25,770 ± 2,250	UIC-1419	Unit Ы-73	180 cm below surface
Upper Humic Bed	30,030 ± 2,210	UIC-916	Unit Ш-72	300 cm below surface
		Y5 tephra		
Lower Humic Bed	48,870 ± 3,620	UIC-915	Unit ц-90	255 cm below surface
Lower Humic Bed	47,390 ± 3,470	UIC-946	Unit ц-90	285 cm below surface
Lower Humic Bed	50,120 ± 3,630	UIC-947	Unit ц-90 315 cm below surface	
Lower Humic Bed	45,200 ± 3,260	UIC-945	Unit ц-90	345 cm below surface
Lower Humic Bed	52,440 ± 3,850	UIC-917	Unit ц-90	380 cm below surface
		Kostenki 14		
Upper Humic Bed	26,340 ± 1,920	UIC-1126	–	70–75 cm below 0 line
15 cm above tephra	32,230 ± 2,310	UIC-1127	Unit У-70	180 cm below 0 line
		Y5 tephra		
Cultural Layer IVb	47,780 ± 3,480	UIC-1128	Unit P-75	390 cm below 0 line
Horizon of hearths	34,170 ± 2,700	UIC-749	–	K14-99-337
Horizon of hearths	44,880 ± 3,580	UIC-748	–	K14-99-401

Kostenki 14 (UIC-1127) were somewhat younger than expected. Three OSL dates from above the CI tephra level at Kostenki 12 yielded estimates that conformed closely to the calibrated radiocarbon chronology (see Tables 2 and 3; Fig. 3).

With one exception (UIC-749), OSL dates from sediment underlying the CI tephra at Kostenki 12 and Kostenki 14 yielded ages greater than 40,000 BP_{OSL}. The dates ranged between approximately 45,000 and 52,000 BP_{OSL}. Many of them exhibit stratigraphic reversals and all of them possess high standard errors, which underscore the comparatively limited precision of the method. Nevertheless, the OSL dates from below the tephra level indicate that—despite evidence for redeposition of the tephra in many locations—the Upper Paleolithic occupations below the tephra probably were deposited prior to the CI eruption and may antedate this event by several thousand years.

Paleomagnetic stratigraphy

Paleomagnetic analyses of sediment have been performed at Kostenki 12 and 14 (Gernik and Gus'kova, 2002; Pospelova, 2005), and some earlier work apparently was conducted at Kostenki 17 (Sinitsyn and Hoffecker, 2006: 182–183). The methods employed and detailed discussions of the results are presented in Gernik and Gus'kova (2002) and Pospelova (2005).

At Kostenki 14, Gernik and Gus'kova (2002: 248) concluded that the Laschamp paleomagnetic excursion (known in Eastern Europe as the Kargopolovo excursion) could be identified ("with a high degree of probability") in sediment containing a buried soil 0.75 meters below the CI tephra (Pyle et al., 2006: 2714–2715; Holliday et al., 2007: 202–204). The Laschamp excursion is dated elsewhere to 41,700–40,300 cal BP (Voelker et al., 2000), and is closely associated with the CI tephra in Italy (Giaccio et al., 2006). More recently, however, Løvlie (2006: 135) found no evidence of geomagnetic excursions at Kostenki 14 (or at Kostenki 1).

At Kostenki 12, Pospelova (2005: 90) reported reversed magnetic polarity in samples from unit 12 (containing Cultural Layer III), which underlies the CI tephra level, and reported anomalous inclinations from deeper levels (units 13 and 15, which bracket Cultural Layer IV). Pospelova (2005: 90) tentatively identified the Laschamp excursion in Layer III—immediately below the CI tephra—but recommended additional analyses to confirm this observation.

At Kostenki 17, earlier paleomagnetic research results reportedly placed the Laschamp excursion in the Lower Humic Bed and in association with Cultural Layer II (Sinitsyn and Hoffecker, 2006: 182–183), which would put it in a similar stratigraphic position to Kostenki 12 (i.e., immediately below the CI tephra). These results have not been published, however.

Soil stratigraphy

Although some geologists suggested that intact soil profiles were observable in the humic beds (e.g., Grishchenko, 1961), normal in situ soil profiles were not reported in sites on the second terrace until the 1980s (Praslov, 1985). As a result, there is little history of soil stratigraphy at Kostenki. It is now apparent, however, that intact soils are present above and below the CI tephra, as well as in the loess-like loams that overlie the Upper Humic Bed and its stratigraphic equivalents. At least some of these buried soils can be correlated with dated soils in other regions, and thus contribute to the chronology of the Kostenki-Borshchevo sites.

The most widely-recognized buried soil—the Gmelin soil—lies at the base of the loess-like loam on the second terrace and is present on the first terrace as well (Lazukov, 1982: 33; Praslov and Ivanova, 1982: 199–200). On the second terrace, it caps the coarse debris layer that overlies the Upper Humic Bed. The Gmelin soil is typically represented by a weakly-developed A horizon and often exhibits the effects of frost action. Calibrated radiocarbon dates on charcoal and luminescence dates suggest that this soil is about 27,000–25,000 cal BP (Praslov and Ivanova, 1982: 209; Holliday et al., 2007: 220). At several sites, the Gmelin soil is associated with an Eastern Gravettian occupation (e.g., Kostenki 1, Layer I; Kostenki 14, layer I; Borshchevo 5, Layer I; Praslov and Rogachev [1982]; Holliday et al. [2007: 195, their Table IV]).

With respect to the chronology of the early Upper Paleolithic, the most important buried soil in the area may be the middle (or b2) soil at Kostenki 1, which overlies the CI tephra level (identified on the

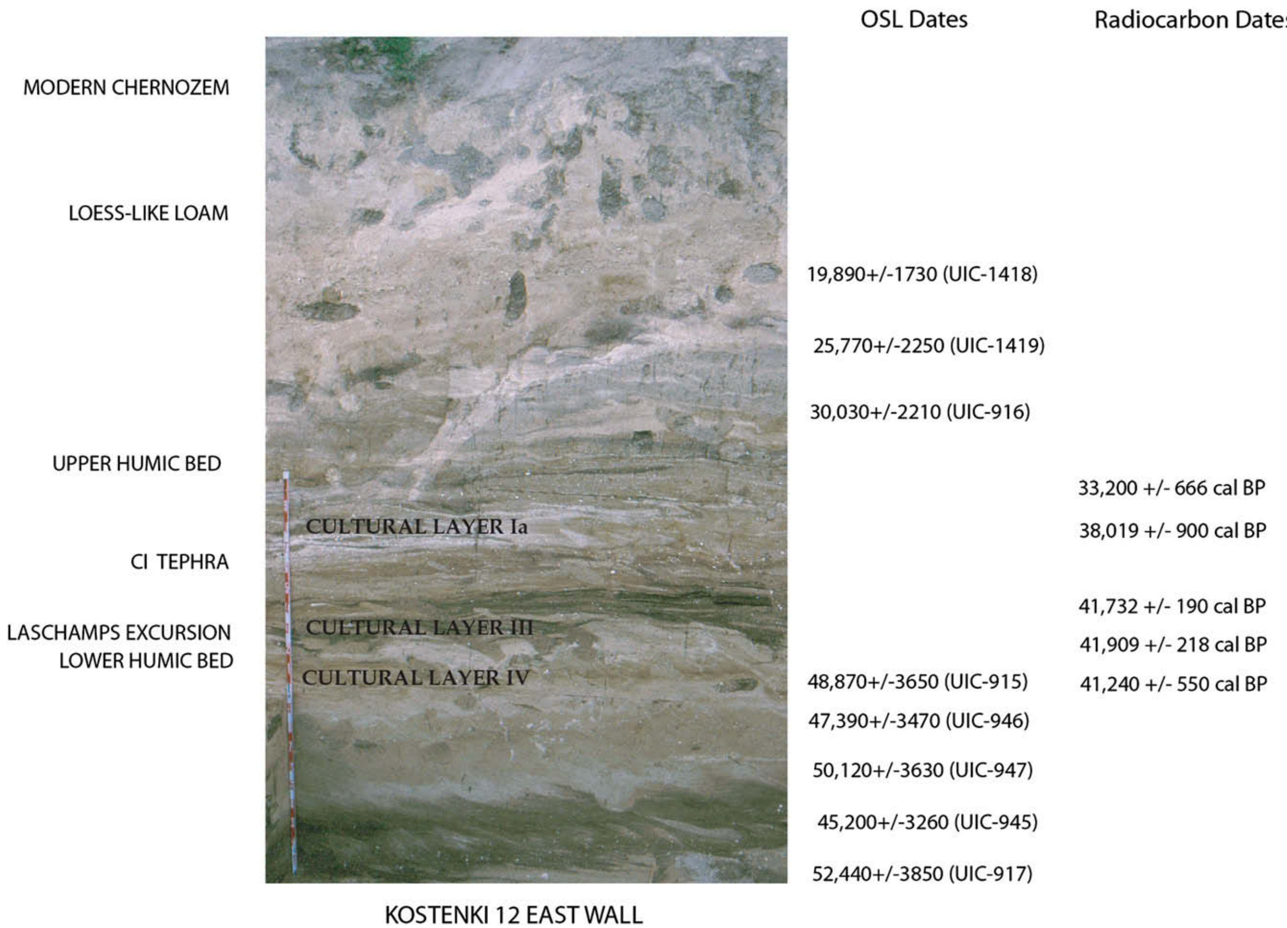

Fig. 3. Stratigraphic profile of Kostenki 12 (east wall) showing OSL and calibrated radiocarbon dates on charcoal.

basis of glass shards in sediment samples) and represents the stratigraphic equivalent of the Upper Humic Bed at this site (Holliday et al., 2007: 209–210). This is a moderately well-expressed soil with a highly irregular lower boundary in the form of tongues that penetrate into the underlying silt (Holliday et al., 2007: 198, their Fig. 6d; Fig. 4). Radiocarbon and luminescence dates suggest an age of > 30,000 cal BP, and it appears to represent the final warm phase of MIS 3. Both the chrono-stratigraphic position and character of this buried soil are similar to the widely-distributed frost-gley Bryansk Soil on the East European Plain (Velichko, 1990).

During the 2001–2004 project, one or more previously unrecognized buried soils were discovered in units below the CI tephra (i.e., stratigraphic equivalent of the Lower Humic Bed) at Kostenki 1, 12, and 14 (Holliday et al., 2007). At Kostenki 14, as many as three weakly developed soils were identified in this context (Sinitsyn, 2002: 234–235), and at Kostenki 12, several in situ soils also appear to be present (Holliday et al., 2007: 194–200). On the basis of their position below the CI tephra level—and above the second terrace alluvium—these soils apparently represent brief intervals of milder climate and/or local landscape stability during the earlier phases of MIS 3 (i.e., 60,000–40,000 cal BP), and may correlate with warm oscillations in the Greenland ice record between GI 12 and GI 9 (see Walker et al., 1999).

Pollen stratigraphy

Sediment samples have been analyzed for pollen and spores at several sites, including Kostenki 1, 12, 14, and 17 (Grichuk, 1969; Levkovskaya, 1977; Malyasova and Spiridonova, 1982; Spiridonova, 1991, 2002; Levkovskaya et al., 2005). As in the case of the buried soils, pollen stratigraphy by itself does not provide an effective chronometric tool, but in conjunction with other aspects of stratigraphy and dating methods, it helps build a more complete picture of the Kostenki-Borshchevo chronology. At Kostenki 12, Pospelova et al. (2005, 2007) found a correlation between variations in the magnetic characteristics of the sediment and pollen-spore samples.

Of particular interest are the pollen-spore records for the units that underlie the CI tephra. As noted above, these units are difficult to date because they lie beyond the effective range of radiocarbon dating and the OSL dates provide rough estimates of their age.

Fig. 4. The middle soil (b2) at Kostenki 1. Photograph by J.F. Hoffecker (2002).

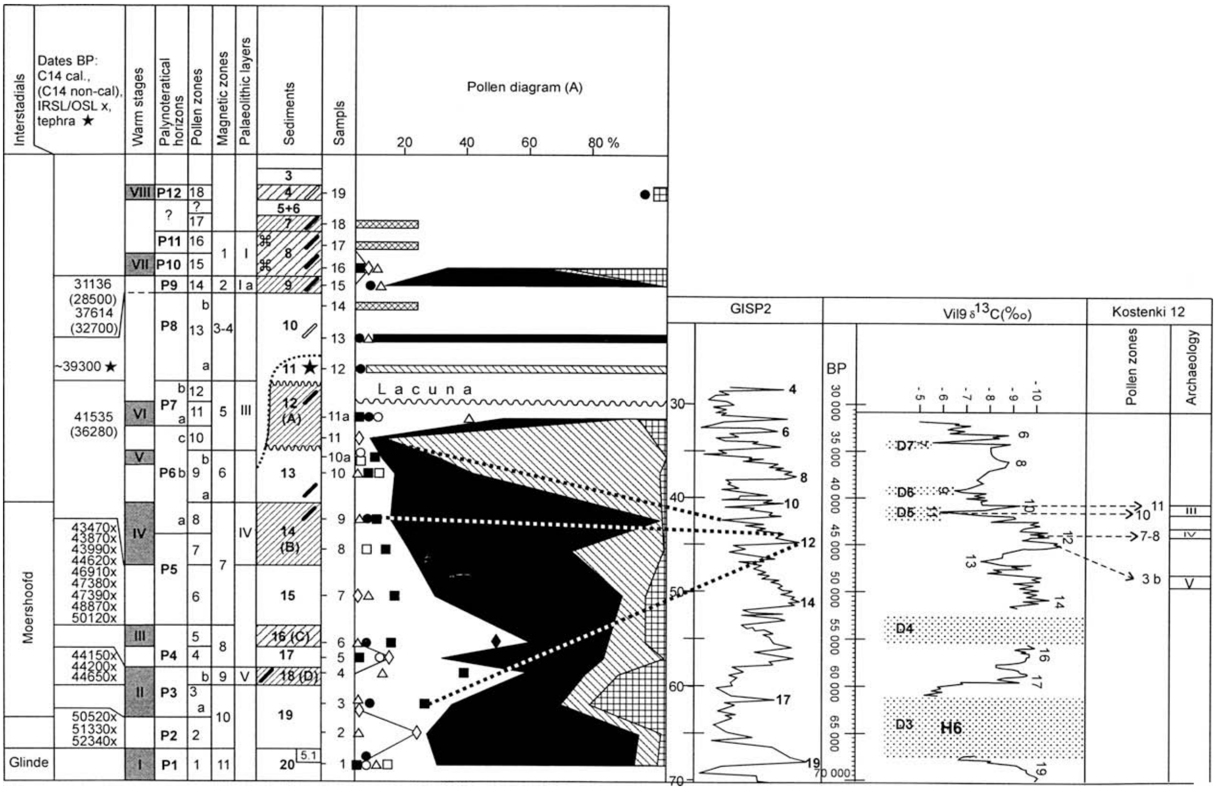

Fig. 5. Pollen record for Kostenki 12 (A), and suggested correlation with GISP2 ice core (adapted from Grootes et al. 1993) and σ[13]C isotope records from stalagmite data in southwest France (adapted from Genty et al., 2003: 834, their Fig. 2).

Variations in pollen-spore composition—combined with the buried soils described above—may permit correlation with dated events in the Greenland and North Atlantic climate records.

At Kostenki 14, Spiridonova (2002: 239) reported evidence for a relatively cold and wet climate interval in the oldest occupation (Cultural Layer IVb), followed by a very warm phase (AP includes isolated broadleaf taxa) associated with an archaeologically sterile layer (Sinitsyn, 2002: 226–227). A cold and dry phase (GS 10?) is associated with the overlying buried soil (Laschamp excursion) that contains isolated artifacts (Spiridonova, 2002: 239–240). The warm phase represented by the layer that overlies Layer IVb may be tentatively correlated with GI 11 or GI 10 with estimated ages of 42,000–41,000 BP_{GISP2} or possibly—given its magnitude—GI 12 with an age of about 45,000 BP_{GISP2} (e.g., Walker et al., 1999).

At Kostenki 12, Levkovskaya et al. (2005: 126–127, their Figs. 1 and 2) recorded a series of climate oscillations in the units below the CI tephra. A very warm phase (AP includes isolated broadleaf taxa) is associated with sediment immediately below Cultural Layer IV, and this has been tentatively correlated with GI 12 (estimated age of 45,000 BP_{GISP2}; Levkovskaya et al. [2005: 113]; Anikovich et al. [2007b: 224]; see Fig. 5). Cooler and drier conditions are associated with Cultural Layer III (GS 10?), which lies immediately below the CI tephra level and is tentatively correlated with the Laschamp excursion (Pospelova, 2005).

Kostenki-Borshchevo and the chronology of the Middle to Upper Paleolithic transition

Identification of the CI tephra, combined with the application of other non-radiocarbon chronometric techniques, has permitted integration of the sequence of early Upper Paleolithic occupation layers at Kostenki-Borshchevo with the MIS 3 climate stratigraphy for the northern hemisphere (e.g., GISP2) and the more reliably-dated regional frameworks for the period of the transition (e.g., Italy [Fedele et al., 2003; Giaccio et al., 2006]). The revised Kostenki-Borshchevo chronology provides new insights to the transition in Eastern Europe and relationship of events on the central plain to those in other parts of Europe (Anikovich et al., 2007a,b). The archaeological sequence reflects some similarities and probable links to events in Western and Central Europe, but also indicates some differences.

GI 8–GI 5: 38,000–32,000 BP_{GISP2}

During this interval (which expands in calendar years with the calibration of the radiocarbon chronology from 32,000–27,000 ^{14}C BP to roughly 40,000–30,000 cal BP ago), a cold event (HE4) was followed by several brief warm oscillations (GI 8–GI 5). In Western and Central Europe, Aurignacian assemblages are associated with HE4 deposits and the younger warm phases—spanning the entire interval (Laville et al., 1980; Svoboda et al., 1996: 114–118).

At Kostenki-Borshchevo, the interval is represented by the Upper Humic Bed and its stratigraphic equivalent (e.g., middle [b2] buried soil at Kostenki 1; Holliday et al. [2007: 209–210]). At Kostenki 1, Layer III contains an artifact assemblage widely classified as Aurignacian and comprising large blades with scalar retouch, carinate scrapers, backed bladelets, and other diagnostic items (Rogachev et al., 1982: 63–64; Anikovich et al., 2007a: 228–233). Associated human skeletal remains include fragments of the tibia, pelvis, and a tooth assigned to *H. sapiens* by I. I. Gokhman (Gerasimova et al., 2007: 83–85). The artifacts are found within and below the middle (b2) buried soil and may represent most of this interval. Alternatively, two occupation horizons may be present; during 2004–2005, a bifacial point fragment and other artifacts more characteristic of other Kostenki-Borshchevo industries (see below) were recovered from Layer III (Anikovich et al., 2006: 90).

At Kostenki 11 (Layer V) and Kostenki 12 (Layer Ia), the lower Upper Humic Bed contains assemblages with diagnostic triangular bifacial points, typical Middle Paleolithic artifact forms (points and side-scrapers), and also some end-scrapers and burins; non-stone artifacts are absent. Similar artifacts are found in the upper portion of the Upper Humic Bed at Kostenki 12 (Layer I). Traditionally, these assemblages have been assigned to a local combined industry (Streletskaya) that is recognized throughout the early Upper Paleolithic sequence at Kostenki-Borshchevo (Rogachev, 1957) and other sites on the East European Plain (e.g., Biryuch'ya balka; Bradley et al., 1995; Anikovich et al., 2007a: 236–248). Although a burial containing the partial skeleton of an infant (modern human) is found in Layer I at Kostenki 12, it is thought to be associated with a different artifact assemblage assigned to another industry (see below; Gerasimova et al., 2007: 92–94).

Another group of artifact assemblages dating to this interval at Kostenki-Borshchevo contain a high proportion of end-scrapers, as well as typical Middle Paleolithic forms (e.g., side-scrapers, points), and a varied assortment of bone artifacts. Among the bone artifacts are diagnostic "shovels" and the oldest known eyed needles (Rogachev and Anikovich, 1984: 183–185). These assemblages are found in the upper portion of the Upper Humic Bed at Kostenki 14 (Layer II) and the lower portion of the Upper Humic Bed at Kostenki 15. A similar assemblage is thought to be deposited with the Streletskaya assemblage in Layer I at Kostenki 12 (Rogachev et al., 1982: 134–137), and the assemblage in the lower part of the Upper Humic Bed at Kostenki 14 (Layer III) is sometimes considered part of this group (Sinitsyn, 1996: 284). Traditionally, these assemblages are assigned to the Gorodtsovskaya archaeological culture (Rogachev, 1957; Efimenko, 1958), which is recognized at several other East European sites (e.g., Mira) but unknown in Western and Central Europe (Anikovich et al., 2007a: 248–265).

Skeletal remains assigned to modern humans are associated with these assemblages at Kostenki 15, which yielded the partial skeleton of a child in a burial pit, and—as noted above—at Kostenki 12, Layer I (Yakimov, 1957; Gerasimova et al., 2007: 102–105). A complete modern human skeleton also was excavated from a burial pit in Layer III at Kostenki 14 (Rogachev, 1957), but has recently yielded radiocarbon dates of mid Holocene age (Haesaerts et al., 2004: 173, their Table 1); new dates are being obtained on bone from this skeleton.

Yet another industry is represented in the upper portion of the Upper Humic Bed at Kostenki 8 (Layer II). This assemblage is dominated by backed bladelets and points and is widely considered an early form of the Gravettian technocomplex—sites of which are common above the Upper Humic Bed and its stratigraphic equivalents in Eastern Europe (Anikovich et al., 2007a: 233–236). Associated human remains at Kostenki 8 include cranial fragments (Gerasimova et al., 2007: 90–91).

GI 9/GS 9: 41,000–39,000 BP_{GISP2} (CI eruption)

The CI tephra horizon is dated elsewhere to ca. 39,000 cal BP and underlies HE4 in the Greenland ice core record (Giaccio et al., 2007). Until recently, no artifacts or other traces of human occupation were known in close association with the tephra horizon at Kostenki-Borshchevo. In 2000–2001, however, artifacts were recovered from the ash at Kostenki 14, and from a layer overlying the ash at Borshchevo 5 (Sinitsyn, 2003: 10; Lisitsyn, 2006: 115).

The artifacts at Kostenki 14 are buried within and below the tephra deposit and apparently represent an occupation episode that preceded and was perhaps terminated by the CI eruption (Sinitsyn, 2003: 13). The lithic assemblage contains Dufour bladelets, retouched blades, and atypical scrapers, while non-stone artifacts include elongated bone beads (decorated with a spiral pattern) and perforated shells and fox teeth (Fig. 6). The sample of artifacts from Borshchevo 5 is small and contains only two retouched items (Lisitsyn, 2006: 117). To date, no human remains have been found associated with either assemblage.

Although broadly similar to the Aurignacian of Western and Central Europe, the assemblage from Kostenki 14 more closely corresponds to the Proto-Aurignacian of the Mediterranean zone (Kuhn and Bietti, 2000: 60–64; Mellars, 2006: 169–170). It appears to be in a similar stratigraphic position as the Proto-Aurignacian occupations in Italy (i.e., associated with the CI tephra and perhaps immediately below it [Fedele et al., 2003; Giaccio et al., 2007]), and underlies the more typical Aurignacian artifacts in Layer III at Kostenki 1 (described above).

GI 12–GI 10: 45,000–42,000 BP_{GISP2}

Below the CI tephra horizon—in the Lower Humic Bed and its stratigraphic equivalents—and associated with several warm intervals that preceded HE4, lie two assemblages that do not correspond closely to known industries in Western and Central Europe (Rogachev and Anikovich, 1984: 181; Anikovich et al., 2007a,b). In 1953–1955, Boriskovskii (1963) recovered one of them from Kostenki 17, Layer II (traditionally assigned to the Spitsyn culture). The artifacts, which were buried in humic deposits more than 1 meter below the CI tephra (Boriskovskii et al., 1982: 181–183), comprise numerous burins, large retouched blades, end-scrapers, and several microblades. Other items include bone awls, point fragments, and various ornaments, but no representational art. It is associated with palynological evidence for a very warm interval (Malyasova and Spiridonova, 1982: 237), which may correspond to one of the warmer interstadials in the Greenland record (GI 12 or GI 11?).

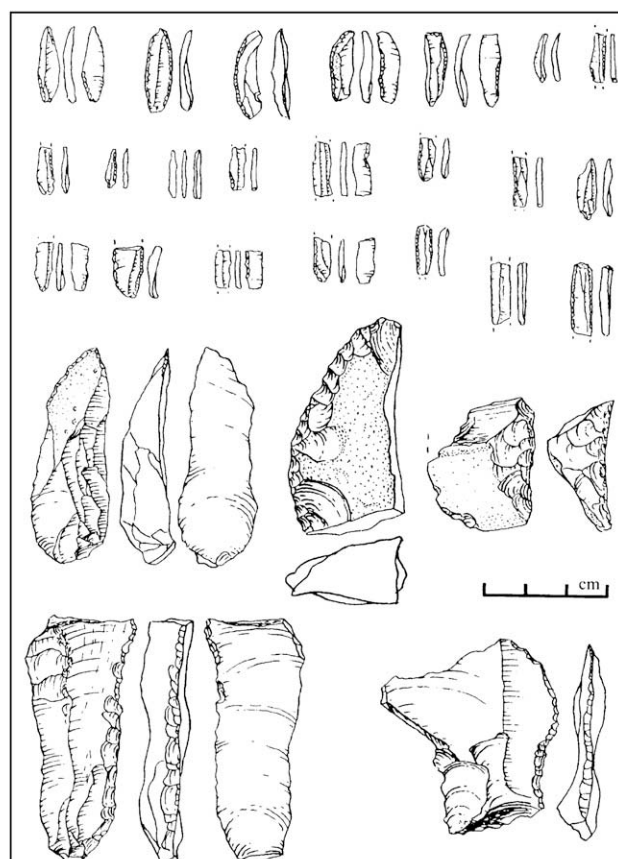

Fig. 6. Stone artifacts from the CI tephra horizon at Kostenki 14. From Sinitsyn (2003: 11, their Fig. 4).

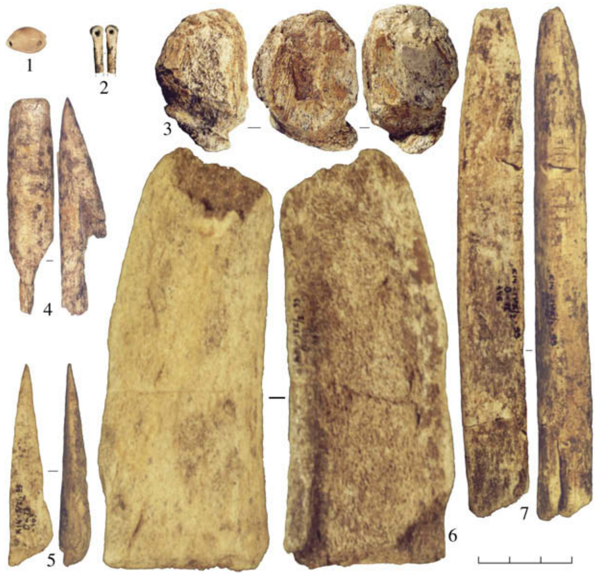

Fig. 7. Artifacts of bone, antler, ivory, and shell from Kostenki 14, Layer IVb. Photograph by A.A. Sinitsyn.

Another assemblage of particular interest from the units below the CI tephra was recovered from Kostenki 14, Layer IVb during 2001–2004. The stone artifacts comprise bladelets, burins, end-scrapers, and several bifaces, while non-stone artifacts include antler mattocks, bone points, perforated shells, and a carved ivory piece that may represent the head and neck of a (unfinished) human figurine (Sinitsyn, 2002: 227–230; Anikovich et al., 2007a,b: 221–224; Fig. 7). In contrast to Kostenki 17, Layer II, the Layer IVb assemblage is associated with a cold interval that precedes a much warmer phase (described above) and might be older than the Kostenki 17 occupation.

Human skeletal remains in these layers are confined to isolated teeth: 1) a third molar from Kostenki 17, Layer II; and 2) the worn crown of a deciduous tooth from Kostenki 14, Layer IVb (Boriskovskii, 1963: 85; Sinitsyn, 2002: 230). They have been assigned to *H. sapiens* by Y. P. Yakimov and I. I. Gokhman, respectively.

The units below the CI tephra also contain assemblages similar to those recovered from the Upper Humic Bed containing end-scrapers and Middle Paleolithic flake tool types, such as side-scrapers, small bifaces, and triangular points; non-stone tools, ornaments, and art are totally absent (Rogachev and Anikovich, 1984: 179–181; Anikovich, 1992; Bradley et al., 1995). These assemblages have been found in Kostenki 6 and Kostenki 12, Layer III; a similar assemblage is reported from Kostenki 1, Layer V, but may be younger and post-date the CI tephra (Anikovich et al., 2006: 91–92). Traditionally, these assemblages are assigned to an early phase of the Streletskaya industry (Anikovich et al., 2007a: 236–240). No human skeletal remains have been found in these occupation layers.

Summary

Identification of the CI tephra at Kostenki-Borshchevo presents an opportunity for better integration of the early Upper Paleolithic record for the central plain of Eastern Europe with that of Western and Central Europe (see Fig. 8). The CI tephra provides a key chrono-stratigraphic marker in a temporal zone beyond the effective range of radiocarbon dating. Luminescence dating, calibrated radiocarbon dates, paleomagnetism, and soil and pollen stratigraphy offer additional support for the Kostenki-Borshchevo chronology. The latter indicates that Upper Paleolithic occupation of the central plain began at least as early as in Western and Central Europe—during the series of brief interstadials (GI 12–9) that preceded the CI eruption and HE4 (ca. 45,000–40,000 cal BP). Artifact assemblages from Kostenki 14 and 17 exhibit a generic Upper Paleolithic character (including non-lithic implements and possibly figurative art), but do not correspond closely with industries in Western and Central Europe dating to this time period. Assemblages containing a combination of typical Middle and Upper Paleolithic artifacts also are known from below the CI tephra at Kostenki, but these also do not closely resemble combined industries from other parts of Europe (e.g., Uluzzian, Szeletian). On the other hand, an assemblage comprising many Dufour bladelets associated with the tephra horizon at Kostenki 14 is similar to the Proto-Aurignacian industry of the Mediterranean zone, which also dates broadly to this time period (ca. 40,000 cal BP). Above the tephra—in layers that date to HE4 and subsequent interstadials

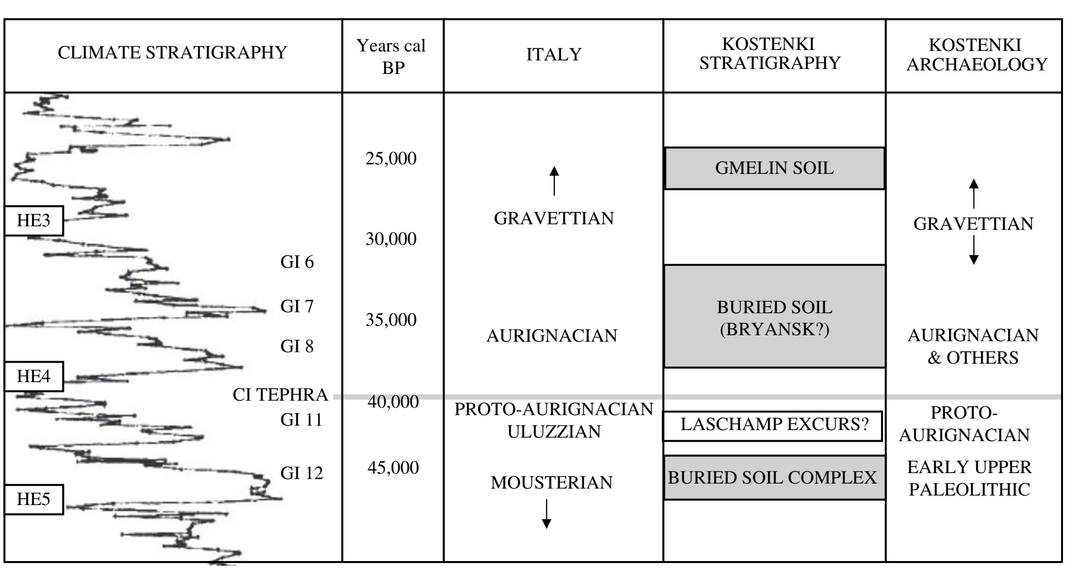

Fig. 8. Proposed correlation of Kostenki-Borshchevo stratigraphy and archaeological units with Italy and the climate stratigraphy for the North Atlantic (adapted from Bond et al., 1993: 144, their Fig. 2).

during the final millennia of MIS 3 (39,000–30,000 cal BP)—lies an assemblage at Kostenki 1 that contains many diagnostic elements of the early Aurignacian of Western and Central Europe. The skeletal remains of anatomically modern humans are associated with this assemblage, as well as other assemblages in the same stratigraphic unit at Kostenki.

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