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

John F. Hoffecker a,*, Vance T. Holliday b, M.V. Anikovich c, A.A. Sinitsyn c, V.V. Popov d, S.N. Lisitsyn c, G.M. Levkovskaya c, G.A. Pospelova e, Steven L. Forman f, Biagio Giaccio g

a Institute of Arctic and Alpine Research, University of Colorado at Boulder, 1560 30th Street, Boulder, CO 80309-0450, USA
b Departments of Anthropology and Geosciences, University of Arizona, PO Box 210030, Tucson, AZ 85721-0030, USA
c Institute of the History of Material Culture, Russian Academy of Sciences, Dvortsovaya nab., 18, 191186 St. Petersburg, Russia
d Kostenki Museum-Preserve, ul. Platonova, 8, 394006 Voronezh, Russia
e Institute of Earth Physics, Russian Academy of Sciences, Bol’shaya Gruzinskaya 10, 123955 Moscow, Russia
f Department of Earth and Environmental Sciences, University of Illinois, Chicago, IL 60607, USA
g Instituto di Geologia Ambiente e Geoingegneria, CNR, Rome 00133, Italy

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ABSTRACT

The Campanian Ignimbrite (CI) eruption, dated by 40Ar/39Ar 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-Borschchevo 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 Aurignacian 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; Groote 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
ornaments in the form of perforated marine shells (Bartolomei and 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, 1989: 697–705; 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 (Giacco 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; Giacco 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 climate-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 Neandertals 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., Streletskaia; 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; Giacco 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; Giacco et al., 2007). The source is the
Phlegranean Field located west of Naples in southern Italy. The CI eruption may have caused a caldera collapse of an estimated 230 km² 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 km² (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 km² (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 YS marine tephra [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 yr (Rozanski et al., 1995; Hillaire-Marcel et al., 1997). In some cases, it is represented by a maximum negative excursion in the office record (e.g., Brook et al., 1993). The Greenland Stadial (GS) 9 with an age of approximately 40,000 cal yr has been dated by 39Ar/39Ar dating on CI tephra at Temnata Cave in Bulgaria (Drobniewicz et al., 2000).

The ash plume of CI has been dated using many different methods, including 40Ar/39Ar dating on CI tephra from various locations within the area and on CI rocks from various locations within the area of the ash plume (De Vivo et al., 2001). It should be noted that 14C ages on the CI tephra consistently yield ages of about 32,000 14C 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) 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 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 of 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 (Grischenko, 1961: 64–65). Soil micromorphology analysis performed during the 2001–2004 project confirmed that in situ soil formation had occurred in these
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).

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 Phlegraean 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 tephra 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, Borschchevo 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 Borschchevo 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-Borschchevo sites

Identification of the CI tephra at Kostenki-Borschchevo 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-Borschchevo 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 dating

The most widely-applied dating method at the Kostenki-Borschchevo 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 14C BP (LE-1400) and 28,580 ± 420 14C 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 14C 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 2
Calibration of radiocarbon dates (on charcoal) from Kostenki according to Fairbanks et al. (2005) and Calpal (2005; S3, S4)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Cultural Layer I (Gmelin Soil)</td>
<td>22,330 ± 150</td>
<td>(Gm-17118)</td>
<td>26,808 ± 175</td>
<td>26,844 ± 471</td>
</tr>
<tr>
<td></td>
<td>23,600 ± 410</td>
<td>(Gm-5244)</td>
<td>28,149 ± 144</td>
<td>28,519 ± 564</td>
</tr>
<tr>
<td></td>
<td>24,030 ± 440</td>
<td>(Gm-5243)</td>
<td>28,619 ± 516</td>
<td>28,979 ± 556</td>
</tr>
<tr>
<td>Cultural Layer III (soil b2)</td>
<td>20,900 ± 1,600</td>
<td>(Gm-4848)</td>
<td>25,026 ± 1,949</td>
<td>25,128 ± 1,988</td>
</tr>
<tr>
<td></td>
<td>24,500 ± 1,300</td>
<td>(Gm-4850)</td>
<td>29,727 ± 1,540</td>
<td>29,113 ± 1,290</td>
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<tr>
<td></td>
<td>25,400 ± 400</td>
<td>(Gm-6248)</td>
<td>30,543 ± 513</td>
<td>30,291 ± 428</td>
</tr>
<tr>
<td></td>
<td>25,730 ± 1,800</td>
<td>(Le-3541)</td>
<td>30,599 ± 1,936</td>
<td>30,591 ± 2,035</td>
</tr>
<tr>
<td></td>
<td>25,900 ± 2,200</td>
<td>(Gm-4849)</td>
<td>30,744 ± 2,356</td>
<td>30,787 ± 2,500</td>
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<tr>
<td></td>
<td>25,820 ± 400</td>
<td>(Gm-2285)</td>
<td>30,965 ± 363</td>
<td>30,648 ± 304</td>
</tr>
<tr>
<td></td>
<td>26,200 ± 1,500</td>
<td>(Gm-4885)</td>
<td>31,124 ± 1,554</td>
<td>31,168 ± 1,725</td>
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<td></td>
<td>32,600 ± 400</td>
<td>(Gm-7117)</td>
<td>37,498 ± 634</td>
<td>37,950 ± 750</td>
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<tr>
<td></td>
<td>38,080 ± 5,460</td>
<td>(AA-5590)</td>
<td>(outside range)</td>
<td>42,233 ± 5,187</td>
</tr>
</tbody>
</table>

Y5 tephra (?)

| Cultural Layer V                |              |             |                         |               |
|                                | 30,170 ± 570 | (Le-3542)   | 35,194 ± 530           | 35,337 ± 597  |
|                                | 32,300 ± 220 | (Ga-5557)   | 37,073 ± 299           | 37,774 ± 809  |
|                                | 34,900 ± 350 | (Ga-5245)   | 40,380 ± 542           | 40,585 ± 803  |
|                                | 37,900 ± 2,800 | (Ga-5245) | (outside range)        | 42,106 ± 2,391 |

Kostenki 12

| Cultural Layer Ia (UHB)        | 28,500 ± 140 | (Ga-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-A-2158-14) | 36,734 ± 177     | 36,720 ± 279  |
|                                | 35,620 ± 230 | (Oxa-A-15482) | 41,263 ± 161         | 41,732 ± 190  |
|                                | 36,280 ± 360 | (Gr-5551)    | 41,535 ± 225         | 41,909 ± 218  |

Kostenki 14

| Cultural Layer IV               |              |             |                         |               |
|                                | 35,540 ± 260 | (Oxa-A-15555) | 41,079 ± 212     | 41,240 ± 550  |

CL in Ash

| Cultural Layer IVa              |              |             |                         |               |
|                                | 32,420 ± 440 | (Grn-18053) | 37,300 ± 600           | 37,355 ± 814  |

Y5 tephra

| Cultural Layer IVa              |              |             |                         |               |
|                                | 32,180 ± 450 | (Grn-1293)  | 37,062 ± 513           | 37,664 ± 890  |
|                                | 33,280 ± 650 | (Grn-22777) | 38,235 ± 887           | 38,760 ± 1,235 |
|                                | 33,200 ± 510 | (Grn-13001) | 38,125 ± 741           | 38,367 ± 861  |

Soil b4 below IVa

|                                | 34,550 ± 610 | (Grn-1297)  | 39,882 ± 877           | 40,355 ± 854  |

| Cultural Layer IVb              |              |             |                         |               |
|                                | 34,870 ± 630 | (Grn-1302)  | 40,566 ± 801           | 40,552 ± 875  |
|                                | 36,040 ± 250 | (Grn-15957) | 41,395 ± 166           | 41,824 ± 191  |
|                                | 36,540 ± 270 | (Grn-15961) | 41,689 ± 181           | 42,066 ± 203  |

Horizon of hearths

|                                | 35,330 ± 240 | (Grn-15958) | 40,917 ± 263           | 40,894 ± 777  |
|                                | 35,870 ± 250 | (Grn-15962) | 41,293 ± 170           | 41,752 ± 194  |
|                                | 36,010 ± 250 | (Grn-15965) | 41,377 ± 167           | 41,812 ± 191  |
|                                | 36,320 ± 270 | (Grn-15956) | 41,560 ± 174           | 41,927 ± 198  |
|                                | 37,240 ± 430 | (Ga-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 CL 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
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. The dates ranged between approximately 45,000 and 52,000 BP. Many of them exhibit methodological problems, underscore the comparatively limited precision of the stratigraphic reversals and all of them possess high standard errors, with one exception (UIC-749), OSL dates from sediment underlying the CI tephra level, and reported anomalous inclinations from deeper levels (units 14 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., Grischchenko, 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-Borschchevo 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; Borschchevo 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
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-Borschchevo 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. 3.** Stratigraphic profile of Kostenki 12 (east wall) showing OSL and calibrated radiocarbon dates on charcoal.

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

During this interval (which expands in calendar years with the calibration of the radiocarbon chronology from 32,000–27,000 14C 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-Borschchevo, 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-Borschchevo 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 (Streletskaia) that is recognized throughout the early Upper Paleolithic sequence at Kostenki-Borschchevo (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-Borschchevo 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 Streletskaia 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/CS 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-Borschchevo. In 2000–2001, however, artifacts were recovered from the ash at Kostenki 14, and from a layer overlying the ash at Borschchevo 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 assemblage contains 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 Borschchevo 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 117).

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

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

**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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