



Early Upper Paleolithic in Eastern Europe and Implications for the Dispersal of Modern Humans

M. V. Anikovich, *et al.*
Science **315**, 223 (2007);
DOI: 10.1126/science.1133376

The following resources related to this article are available online at www.sciencemag.org (this information is current as of August 23, 2007):

Updated information and services, including high-resolution figures, can be found in the online version of this article at:

<http://www.sciencemag.org/cgi/content/full/315/5809/223>

Supporting Online Material can be found at:

<http://www.sciencemag.org/cgi/content/full/315/5809/223/DC1>

A list of selected additional articles on the Science Web sites **related to this article** can be found at:

<http://www.sciencemag.org/cgi/content/full/315/5809/223#related-content>

This article has been **cited by** 2 article(s) on the ISI Web of Science.

This article appears in the following **subject collections**:

Anthropology

<http://www.sciencemag.org/cgi/collection/anthro>

Information about obtaining **reprints** of this article or about obtaining **permission to reproduce this article** in whole or in part can be found at:

<http://www.sciencemag.org/about/permissions.dtl>

Early Upper Paleolithic in Eastern Europe and Implications for the Dispersal of Modern Humans

M. V. Anikovich,¹ A. A. Sinitsyn,¹ John F. Hoffecker,^{2*} Vance T. Holliday,³ V. V. Popov,⁴ S. N. Lisitsyn,¹ Steven L. Forman,⁵ G. M. Levkovskaya,¹ G. A. Pospelova,⁶ I. E. Kuz'mina,⁷ N. D. Burova,¹ Paul Goldberg,⁸ Richard I. Macphail,⁹ Biagio Giaccio,¹⁰ N. D. Praslov¹

Radiocarbon and optically stimulated luminescence dating and magnetic stratigraphy indicate Upper Paleolithic occupation—probably representing modern humans—at archaeological sites on the Don River in Russia 45,000 to 42,000 years ago. The oldest levels at Kostenki underlie a volcanic ash horizon identified as the Campanian Ignimbrite Y5 tephra that is dated elsewhere to about 40,000 years ago. The occupation layers contain bone and ivory artifacts, including possible figurative art, and fossil shells imported more than 500 kilometers. Thus, modern humans appeared on the central plain of Eastern Europe as early as anywhere else in northern Eurasia.

Modern humans and their Upper Paleolithic industry (Aurignacian) spread rapidly across western and central Europe roughly 42,000 to 40,000 years ago; there is evidence for a slightly earlier influx in south central Europe (1). The early Aurignacian sites appear to represent the dispersal of modern humans from Africa into Europe [although their skeletal remains more than 30,000 years old are scarce in northern Eurasia (2)]. The initial spread of the Upper Paleolithic is difficult to date because this event lies near the limit of effective ¹⁴C dating and a major radiocarbon plateau (3). A volcanic ash deposited about 40,000 years ago (the CI tephra) provides a stratigraphic marker in parts of southern and eastern Europe (4). On the Don River in Russia, Aurignacian artifacts are buried within and beneath the CI tephra at Kostenki (5, 6). Below the tephra lie traces of a local Upper Paleolithic industry that appears to date as early as 45,000 to 42,000 years ago (7) and contains typical Upper Paleolithic tool forms, personal ornaments, carved ivory (possible figurative art), and raw materials imported from distant sources (8, 9). The artifacts probably were made by modern humans, although skeletal remains are confined to isolated teeth. The Kostenki discovery indicates the presence of a fully developed Upper Paleolithic industry on the central

East European Plain as early as anywhere in northern Eurasia, and it has implications for both the timing and routes of modern human dispersal.

Kostenki is located ~400 km south of Moscow on the west bank of the Don River, which is deeply incised by ravines (Fig. 1). Most

of the Paleolithic sites are found on low terraces near the mouths or the upper reaches of these ravines (10, 11), all of which contain active springs. A total of 21 sites—most of them comprising several occupation levels—are known at Kostenki. An additional seven sites now are recorded near Borshchevo, several kilometers to the southeast (11–13) (Fig. 2).

The west bank of the Don Valley is composed of Cretaceous marl and sand that unconformably overlie Devonian clay (14–16). Although several Upper Paleolithic sites (e.g., Kostenki 18) are located on the third terrace (30 to 40 m) in late Pleistocene loams that directly overlie Cretaceous sand, most sites are found on the second (15 to 20 m) or first (10 m) terrace (10–12). Sites that contain Upper Paleolithic artifacts dating to the interstadial that correlates with Marine Isotope Stage 3 (60,000 to 30,000 years ago) are confined to the second terrace. Alluvium of this terrace was deposited by the Don River earlier than 50,000 years ago and rests unconformably on the Devonian clay (17). Above the alluvium is a sequence of interbedded lenses of silt, carbonate, chalk fragments, and organic-rich loam (“humic beds”) that date to ~50,000 to 30,000 years ago

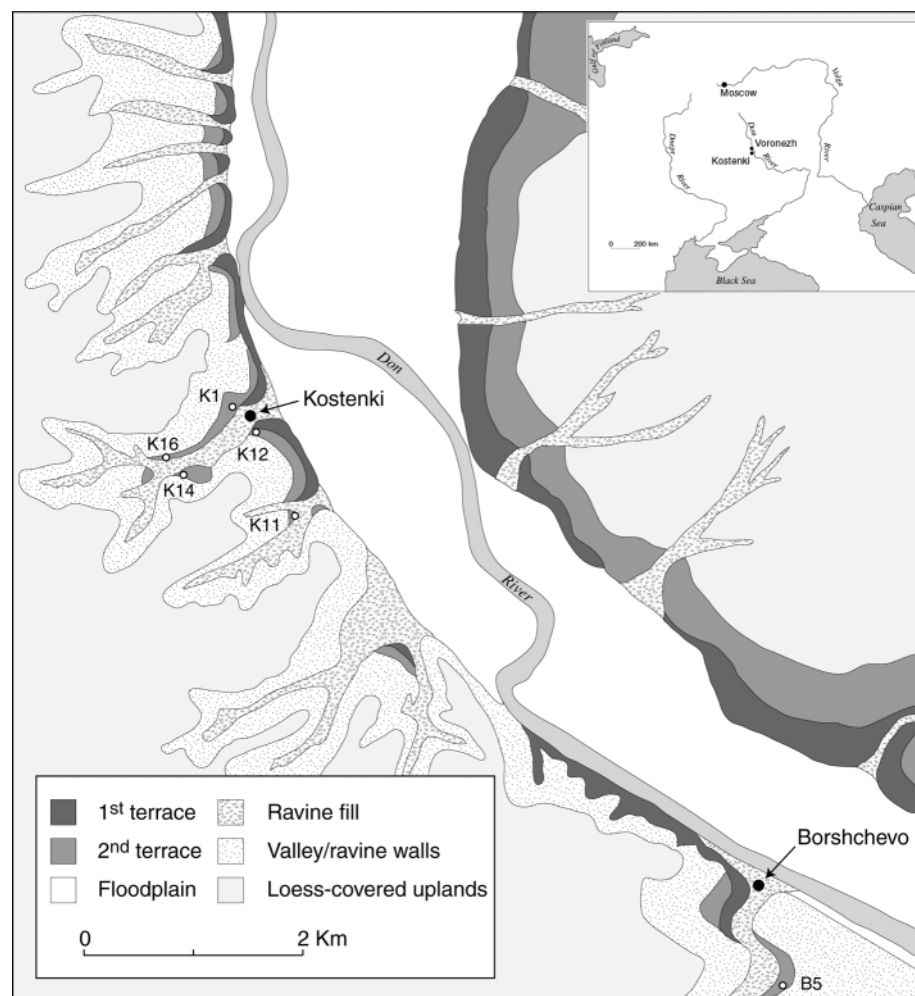


Fig. 1. Map of the Kostenki-Borshchevo area (14, 17), showing the location of Upper Paleolithic sites investigated during 2001–2004. Inset: location of Kostenki.

¹Institute of the History of Material Culture, Russian Academy of Sciences, 191186 St. Petersburg, Russia. ²Institute of Arctic and Alpine Research, University of Colorado, Boulder, CO 80309, USA. ³Departments of Anthropology and Geosciences, University of Arizona, Tucson, AZ 85721, USA. ⁴Kostenki Museum-Preserve, 396355 Kostenki, Voronezh region, Voronezh, Russia. ⁵Luminescence Dating Research Laboratory, Department of Earth and Environmental Sciences, University of Illinois, Chicago, IL 60607, USA. ⁶Institute of Earth Physics, Russian Academy of Sciences, 123995 Moscow, Russia. ⁷Zoological Institute, Russian Academy of Sciences, 199034 St. Petersburg, Russia. ⁸Department of Archaeology, Boston University, Boston, MA 02215, USA. ⁹Institute of Archaeology, University College London, London WC1H 0PY, UK. ¹⁰Istituto di Geologia Ambientale e Geoingegneria-CNR, Consiglio Nazionale delle Ricerche, 00133 Rome, Italy.

*To whom correspondence should be addressed. E-mail: john.hoffecker@colorado.edu

(18) (tables S1 and S2). Micromorphology analysis indicates that the carbonate is primary and probably derived from local springs and seeps, whereas the chalk fragments represent eroded Cretaceous marl washed and soliflucted from higher slopes (Fig. 3) (table S3).

The humic beds are subdivided by the Campanian Ignimbrite (CI) Y5 tephra (5, 19). The CI tephra has an $^{40}\text{Ar}/^{39}\text{Ar}$ date of 41,000 to 38,500 years ago and is stratigraphically correlated with the onset of Heinrich Event 4, as well as with Laschamps geomagnetic excursion and a related cosmogenic nuclide peak (4, 20). At Kostenki 12, sediment below the level of the ash horizon yielded optically stimulated luminescence (OSL) dates of between $52,440 \pm 3850$ and $45,200 \pm 3260$ years (table S4). Paleomagnetic measurements show that this

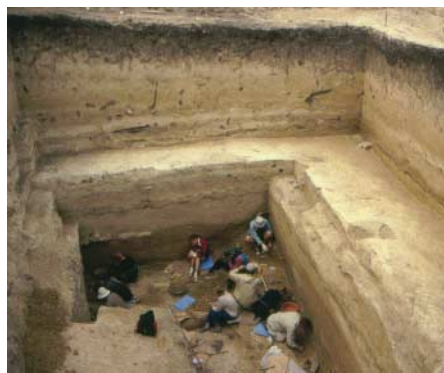
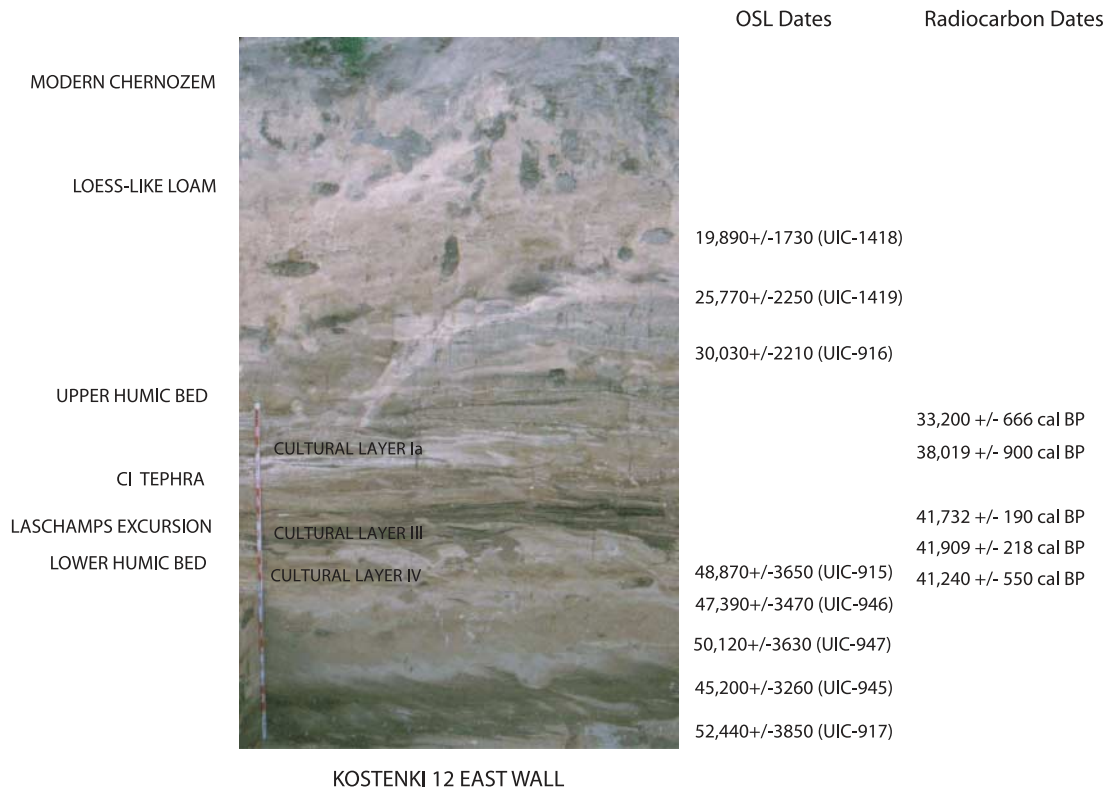


Fig. 2. Excavations at Kostenki 14 in 2002, showing the north and east walls.

Fig. 3. Stratigraphic profile of Kostenki 12 (east wall) showing the position of the humic beds, CI tephra horizon, Laschamps excursion, and Upper Paleolithic cultural layers, as well as OSL dates and calibrated radiocarbon dates on charcoal.



sediment contains the Laschamps excursion, which has been dated elsewhere to 45,000 to 39,000 years ago (21, 22). Calibration of conventional and AMS radiocarbon dates obtained on charcoal (23) with two long curves (24, 25) yields a similar chronology, although calibrated dates above and below the CI tephra are roughly 2000 years younger than ages determined by other methods (table S5).

Artifacts assigned to the Upper Paleolithic have been recovered from all levels of the humic beds (including the tephra horizon at Kostenki 14) and indicate substantive occupation of the Kostenki area before 40,000 years ago. Human skeletal remains found below the tephra are confined to two isolated teeth, which are tentatively assigned to modern humans (*Homo sapiens*) (8, 9). More complete skeletal remains that can be firmly attributed to modern humans have been recovered from the humic layers (and a buried soil at Kostenki 1) above the CI tephra and dated to $\geq 30,000$ years ago (23).

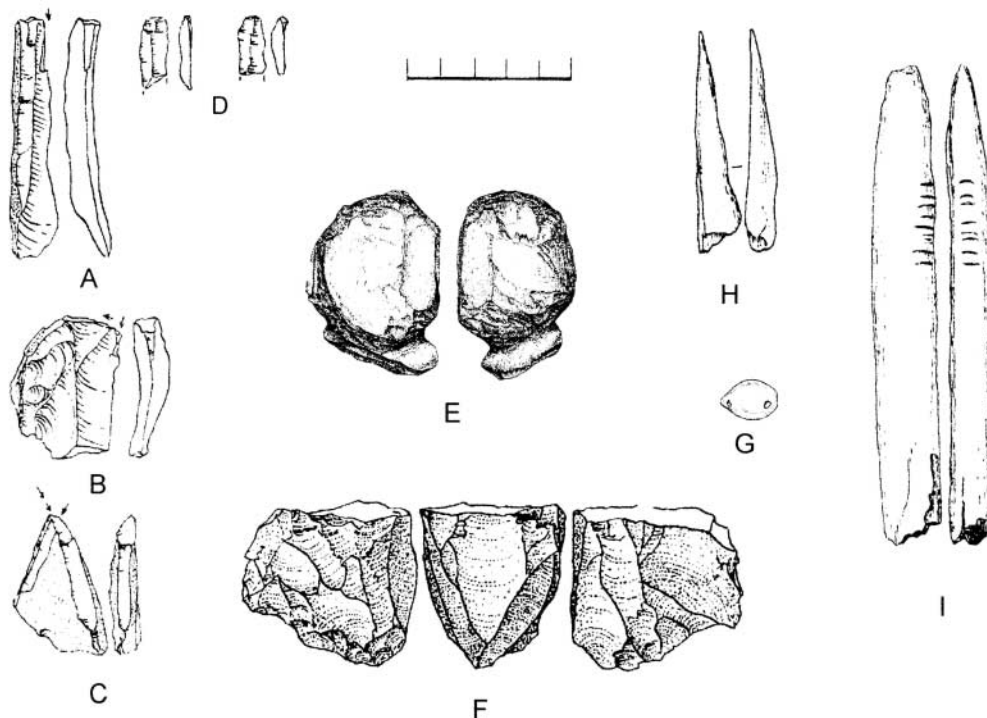
Although generally rare in eastern Europe, assemblages that may be assigned to the Aurignacian industry are present at Kostenki (26). An early Aurignacian assemblage containing end-scrapers, *lamelles Dufour*, and ornaments of shell and bone was recovered from the CI tephra at Kostenki 14 (i.e., $\sim 40,000$ years ago) (6). Younger Aurignacian artifacts are associated with the buried soil above the tephra at Kostenki 1 and date to $\sim 30,000$ years ago (7, 12).

Occupation layers buried below the CI tephra at Kostenki 1, 12, 14, and 17 contain Upper Paleolithic assemblages that precede the local

Aurignacian. Pollen stratigraphy at Kostenki 12 (which exhibits good agreement with the magnetic characteristics of the sediment) indicates that the interbedded silts and organic loams containing these assemblages accumulated during a series of warm and cold oscillations during MIS 3 before the CI eruption (27, 28). The period of maximum warmth corresponds to the lowest artifact-bearing units and—on the basis of stratigraphic position and OSL dates—is correlated with GIS 12 in the Greenland ice record (with an estimated age of 45,000 years in GISP2) (29), which appears to represent a lower limiting date for Upper Paleolithic occupation at Kostenki.

At least two types of assemblages are found below the CI tephra. At Kostenki 14, the lowermost occupation level (Layer IVb) contains prismatic blade cores, bladelets, end-scrapers, burins, *pièces esquillées*, and small bifaces. Nonstone artifacts include bone points, antler mattocks, worked ivory, and perforated shell ornaments (Fig. 4). One carved piece of ivory appears to represent the head of an (unfinished) human figurine (Fig. 4E) (8). At Kostenki 17, Layer II yielded large prismatic blades, numerous burins, end-scrapers, and some *pièces esquillées*. Ornaments of stone were perforated with a hand-operated rotary drill (9). Nonstone items include bone points and awls and some worked ivory. These assemblages are associated with large numbers of small and medium mammal remains—especially hare (*Lepus tanaiticus*), arctic fox (*Alopex lagopus*), and wolf (*Canis lupus*)—and some bird remains. The bones and teeth of large mammals, including horse (*Equus latipes*) and

Fig. 4. Stone, ivory, and bone artifacts from the lowest Upper Paleolithic horizon at Kostenki (Kostenki 14, Layer IVb): (A to C) burins; (D) small bade fragments; (E) carved ivory fragment possibly representing the head of an unfinished human figurine; (F) blade core; (G) perforated fossil shell; (H) bone awl; (I) bone point. Scale bar = 5 cm.



reindeer (*Rangifer tarandus*), are present but less common (30).

The artifact assemblages below the CI tephra do not represent an Upper Paleolithic industry that is “transitional” from the local Middle Paleolithic, but rather an abrupt departure from the latter. Prismatic blade technology is predominant and Middle Paleolithic artifact types are rare. Most of the stone used for artifact production was imported 100 to 150 km from its sources (9), and the perforated shells (Columbellidae) in the lowermost level at Kostenki 14 (Fig. 4G) apparently are derived from a source no closer than the Black Sea (i.e., transported >500 km) (8). Other raw materials include bone, antler, and ivory. Most noteworthy is the carved ivory piece that may represent an example of figurative art. Novel technologies include the rotary drill and—by implication—devices for harvesting small game (26). Although taxonomic assignment of the associated human teeth is tentative, the contents of this Upper Paleolithic industry suggest that it was probably manufactured by modern humans.

Deposits below the CI tephra at Kostenki also yielded several artifact assemblages that primarily contain typical Middle Paleolithic tool forms (e.g., side-scrapers, bifaces) manufactured on flakes (7). They lack imported raw materials, bone-antler-ivory artifacts, and art. The faunal remains are confined to large mammals (30). These assemblages, which are assigned to the local Strelets culture, are analogous to the “transitional” Upper Paleolithic industries of western and central Europe (especially the Szeletian), at least some of which apparently were produced by local

Neandertals (1, 26). The Strelets artifacts are not associated with any human skeletal remains and their makers are unknown. They may represent an activity variant of the other Kostenki industry (i.e., probably produced by modern humans) related to the butchering of large mammals. Younger Strelets assemblages are found above the CI tephra (7, 12).

The developed (i.e., nontransitional) Upper Paleolithic industry in the lowest occupation levels of Kostenki 14 and 17 appears to represent an intrusion of modern humans onto the central East European Plain several thousand years before their spread across western and eastern Europe. It is not clear whether Neandertals also occupied the central East European Plain at this time (although they were present in other parts of eastern Europe) (26), and both climate and the presence of human competitors might have played a role in the early appearance of modern humans on the middle Don River. Also unclear is the relationship between the Kostenki industry and the earliest dated Upper Paleolithic remains in south central Europe, which appear to be of comparable age (1, 4). Although broadly similar, the early Upper Paleolithic assemblages of each region may represent separate routes of dispersal for modern humans entering Europe.

References and Notes

- P. Mellars, *Nature* **439**, 931 (2006).
- N. J. Conard, P. M. Grootes, F. H. Smith, *Nature* **430**, 198 (2004).
- K. Hughen *et al.*, *Science* **303**, 202 (2004).
- F. G. Fedele, B. Giaccio, R. Isaia, G. Orsi, *Geophys. Monogr.* **139**, 301 (2003).
- D. M. Pyle *et al.*, *XVI INQUA Congress Program with Abstracts* (Desert Research Institute, Reno, NV, 2003), p. 147.
- A. A. Sinityn, *Antiquity* **77**, 9 (2003).
- M. V. Anikovich, *Archaeol. Ethnol. Anthropol. Eurasia* **2**, 15 (2003).
- A. A. Sinityn, in *Kostenki v kontekste paleolita Evrazii*, A. A. Sinityn, V. Ya. Sergin, J. F. Hoffecker, Eds. (IIMK, St. Petersburg, 2002), pp. 190–195.
- P. I. Boriskovskii, *Mater. Issled. Arkheol. SSSR* **121** (1963).
- A. N. Rogachev, *Mater. Issled. Arkheol. SSSR* **59**, 9 (1957).
- R. G. Klein, *Man and Culture in the Late Pleistocene: A Case Study* (Chandler, San Francisco, 1969).
- N. D. Praslov, A. N. Rogachev, Eds., *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu 1879–1979* (Nauka, Leningrad, 1982).
- P. P. Efimenko, *Kostenki I* (USSR Academy of Sciences, Moscow, 1958).
- G. I. Lazukov, *Mater. Issled. Arkheol. SSSR* **59**, 135 (1957).
- M. I. Grishchenko, *Tr. Kom. Izuch. Chetvertich. Perioda* **17**, 62 (1961).
- A. A. Velichko, *Geologicheskii vozrast verkhnego paleolita tsentral'nykh raionov Russkoi ravniny* (USSR Academy of Sciences, Moscow, 1961).
- G. I. Lazukov, in *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu 1879–1979*, N. D. Praslov, A. N. Rogachev, Eds. (Nauka, Leningrad, 1982), pp. 13–37.
- G. V. Kholmovoi, E. V. Nesterova, *Pleistotsenovye otlozheniya Kostenkovsko-Borshchevskogo paleoliticheskogo raiona* (Voronezh State Univ., Voronezh, 2001).
- I. V. Melekestsev, V. Yu. Kirianov, N. D. Praslov, *Vulkanol. Seismol.* **3**, 35 (1984).
- T. Ton-That, B. Singer, M. Paterne, *Earth Planet. Sci. Lett.* **184**, 645 (2001).
- G. A. Pospelova, in *Problemy rannei pory verkhnego paleolita Kostenkovsko-Borshchevskogo raiona i sopredel'nykh territorii*, M. V. Anikovich, Ed. (Russian Academy of Sciences, St. Petersburg, 2005), pp. 87–92.
- G. A. Pospelova, G. N. Petrova, Z. V. Sharonova, *Fiz. Zemli* **5**, 65 (1998).

23. A. A. Sinitsyn, N. D. Praslov, Yu. S. Svezhentsev, L. D. Sulerzhitskii, in *Radiouglerodnaya khronologiya paleolita Vostochnoi Evropy i Severnoi Azii. Problemy i perspektivy*, A. A. Sinitsyn, N. D. Praslov, Eds. (Russian Academy of Sciences, St. Petersburg, 1997), pp. 21–66.
24. R. G. Fairbanks *et al.*, *Quat. Sci. Rev.* **24**, 1781 (2005).
25. CalPal Online (www.calpal-online.de).
26. J. F. Hoffecker, *Desolate Landscapes: Ice-Age Settlement in Eastern Europe* (Rutgers Univ. Press, New Brunswick, NJ, 2002).
27. G. M. Levkovskaya, in *Paleoekologiya drevnego cheloveka*, I. K. Ivanova, N. D. Praslov, Eds. (Nauka, Moscow, 1977), pp. 74–83.
28. E. A. Spiridonova, *Evolutsiya rastitel'nogo pokrova basseina Dona v verkhnem pleistotsene-golotsene* (Nauka, Moscow, 1991).
29. N. J. Shackleton, R. G. Fairbanks, T.-C. Chiu, F. Parrenin, *Quat. Sci. Rev.* **23**, 1513 (2004).
30. N. K. Vereshchagin, I. E. Kuz'mina, in *Paleolit Kostenkovsko-Borshchevskogo raiona na Donu 1879–1979*, N. D. Praslov, A. N. Rogachev, Eds. (Nauka, Leningrad, 1982), pp. 223–232.
31. We thank D. M. Pyle and B. J. Carter for analyses of volcanic ash samples, J. Pierson and J. Gomez for assistance with OSL dating, Ya. I. Starobogatova for the identification of fossil shells from Kostenki 14, and S. L. Kuhn for review of an earlier draft. Figure 1 was

prepared by the University of Wisconsin Cartography Lab. Supported by NSF grants BCS-0132553 and BCS-0442164, Leakey Foundation 2001 and 2004 general grants, and Russian Foundation for Basic Research grant N05-06-80329a. The Leakey Foundation grants were administered by the Illinois State Museum.

Supporting Online Material

www.sciencemag.org/cgi/content/full/315/5809/223/DC1
Tables S1 to S5

References

2 August 2006; accepted 13 November 2006
10.1126/science.1133376

Late Pleistocene Human Skull from Hofmeyr, South Africa, and Modern Human Origins

F. E. Grine,^{1*} R. M. Bailey,² K. Harvati,³ R. P. Nathan,⁴ A. G. Morris,⁵ G. M. Henderson,⁶ I. Ribot,⁷ A. W. G. Pike⁸

The lack of Late Pleistocene human fossils from sub-Saharan Africa has limited paleontological testing of competing models of recent human evolution. We have dated a skull from Hofmeyr, South Africa, to 36.2 ± 3.3 thousand years ago through a combination of optically stimulated luminescence and uranium-series dating methods. The skull is morphologically modern overall but displays some archaic features. Its strongest morphometric affinities are with Upper Paleolithic (UP) Eurasians rather than recent, geographically proximate people. The Hofmeyr cranium is consistent with the hypothesis that UP Eurasians descended from a population that emigrated from sub-Saharan Africa in the Late Pleistocene.

Most genetic studies indicate that all contemporary humans owe their ancestry to a sub-Saharan African population, extant between 100 and 200 thousand years ago (ka) (1–3). A number of genetic studies further suggest that modern humans left sub-Saharan Africa in the Late Pleistocene, between 65 and 25 ka (1–6). The middle of this range (~45 to 35 ka) corresponds not only with the appearance of Later Stone Age (LSA) industries in sub-Saharan Africa (7) but also with the earliest Upper Paleolithic (UP) industries and human skeletons in Eurasia (8). However, other genetic data appear to suggest substantial non-African contributions to the genomes of modern human populations, and

these data have been interpreted as being inconsistent with any population bottleneck associated with a recent African exodus (9, 10).

The human palaeontological record might be used to test predictions from these hypotheses. Craniometric data tend to differentiate recent human populations in accord with their geographic distributions and genetic relationships (11–15). Eurasian UP crania do not particularly resemble those of earlier Eurasian Neandertals (16), nor are they especially similar to recent human crania from sub-Saharan Africa (12). Thus, we should not expect to see any special similarity between the UP Eurasians and contemporaneous sub-Saharan Africans in the absence of a Late Pleistocene exodus from sub-Saharan Africa.

Although there are several variably complete crania from North Africa that date to between about 40 and 20 ka (from Dar es Soltan, Morocco; and Nazlet Khater and Wadi Kubbania, Egypt), the only sub-Saharan specimen in LSA context that has been claimed to pre-date 20 ka is an infant mandible from Origstad Shelter, South Africa, and it may be substantially younger (17). The lack of Late Pleistocene human remains from sub-Saharan Africa has resulted in an inability to test competing models of human evolution (18).

We report on a nearly complete human cranium from Hofmeyr, South Africa, and its dating to 36.2 ± 3.3 ka. The skull was discovered in 1952 in a dry channel bed of the Vlekpoot River ($25^{\circ}58'E$, $31^{\circ}34'S$) near the town of

Hofmeyr, Eastern Cape Province, South Africa. The endocranial cavity, orbits, nasal cavity, and palate were filled with an indurated carbonate-sand matrix. No other bones or archaeological artefacts were reportedly found in the vicinity at the time of the skull's discovery, and within a decade, the channel had become filled by silt, after the construction of an anti-erosion weir downstream. This precludes any possibility of locating the original position of the specimen or of directly dating the surrounding sediments.

In the 1960s, a substantial portion of the left parietal bone was removed, presumably in an attempt to obtain a radiocarbon date, although no date has ever been published. Another, smaller bone sample was submitted by us to the University of Oxford Radiocarbon Accelerator Unit to assess its amenability to accelerator mass spectrometry (AMS) ^{14}C dating, but it lacked sufficient collagen for an accurate age determination (19). Instead, we estimated the burial age of the skull by dating the residence time of the matrix filling the endocranial cavity, using a combination of optically stimulated luminescence and uranium-series dating methods, coupled through a radiation-field model. The length of time between death and incorporation of the sediment within the skull is expected to be short, because the loss of organic material after death would be rapid (days to months). Furthermore, the skull's relatively good state of preservation suggests that it had neither been uncovered long before nor transported any substantial distance before its discovery (the force required to scour the innermost sediments would certainly have resulted in substantial damage). Additional evidence for a single infilling episode comes from the consistency of the dates determined from the samples of endocranial matrix.

The signals measured in luminescence dating are a consequence of the absorption by mineral grains of ionizing radiation from low concentrations of radionuclides that are naturally present in the sediment and from cosmic rays (20). Luminescence dating methods provide estimates of the total ionizing radiation dose [D_e , in units of grays (Gy)] absorbed by sediment (in this case quartz) grains since their burial. Estimation of burial age is possible if the radiation dose rate (D' , in units of Gy/ka) is known. In the simplest case, where D' is constant in time, $\text{age} = D_e/D'$. Three samples of endocranial sediment were extracted

¹Departments of Anthropology and Anatomical Sciences, Stony Brook University, Stony Brook, NY 11794-4364, USA.

²School of Geography and the Environment, University of Oxford, South Parks Road, Oxford, OX1 3QY, UK. ³Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, 04103 Leipzig, Germany. ⁴Research Laboratory for Archaeology and the History of Art, University of Oxford, South Parks Road, Oxford, OX1 3QY, UK. ⁵Department of Human Biology, University of Cape Town, Observatory 7925, Cape Town, South Africa. ⁶Department of Earth Sciences, University of Oxford, South Parks Road, Oxford, OX1 3PR, UK. ⁷Département d'Anthropologie, Université de Montréal, CP 6128, Succursale Centre-Ville, Montréal, Québec H3C 3J7, Canada. ⁸Department of Archaeology and Anthropology, University of Bristol, 43 Woodland Road, Bristol, BS8 1UU, UK.

*To whom correspondence should be addressed. E-mail: fgrine@notes.cc.sunysb.edu