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Early Upper Paleolithic Tubular Beads from the Main Chamber of Denisova Cave

The authors present the results of a technological and functional analysis of bone tubular beads from the Upper Paleolithic layer 11 in the Main Chamber of Denisova Cave, northwestern Altai. Tubular beads are among the most widespread categories of Early Upper Paleolithic ornaments from the cave. The technological sequence of operations has been reconstructed. It included several stages: selection of blank, planing, manufacture of preform by truncating the epiphyses, ornamenting the preform, marking preforms for fracturing into short tubes, sawing or cutting, fragmentation by cuts, removal of cancellous bone, and smoothing the fracture surfaces. Prepared blanks and diagnostic production waste were not noted in the technological context of the complex; this indicates that the tubular beads were probably manufactured outside the excavated area of the Main Chamber. The analyses revealed traces of wear caused by contact with clothing or human skin and by threading on a string or thin strap. Tubular beads were used by the Upper Paleolithic inhabitants of the cave as elements of clothing, necklaces, and probably bracelets. The closest but still considerably distant parallels to the tubular beads from the Altai are Aurignacian ornaments of a similar age from Western, Central, and Eastern Europe.

Keywords: *Altai Mountains, Denisova Cave, Early Upper Paleolithic, tubular beads, traceological and technological analysis.*

Introduction

Beads in the form of hollow items of elongated cylindrical shape, usually made from the diaphyses of tubular bones of mammals and birds, less often from mammoth ivory, sea-mollusk shells, or semi-precious stones, constitute one of the most noticeable groups of Upper Paleolithic non-utilitarian products (Abramova, 1962; Averbouh, 1993; Vanhaeren, d'Errico, 2006; Wright et al., 2014). These items are often called "cylindrical beads", "threaded beads", and in English and French publications, "tubular beads" and "perles tubulaires" (Vanhaeren, d'Errico, 2011; Rigaud et al., 2014). Tubular beads differ from other hollow items made of bone (such as needle cases or handles, which had a utilitarian purpose) primarily in size—their lengths rarely exceed 40 mm (Averbouh, 1993). Bone tubular beads often bear ornaments and traces of intense contact with soft organic material, which allows for their interpretation as personal ornaments (Gerasimov, 1941), buttons (Khlopachev, 2011), or musical instruments (Lbova, Kozhevnikova, 2016). Owing to their specific appearance, ornamented cylindrical beads are often considered as specific cultural elements and chronological markers of various Upper Paleolithic complexes of Eurasia (Vanhaeren, d'Errico, 2006; Rybin, 2014).

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In Northern Asia, bone tubular beads were widespread over vast regions already in the early stages of the Upper Paleolithic—from the Altai in the west to Transbaikalia in the east, from the Yana-Indigirka lowland in the north to Central China in the south (Abramova, 1962, 1979; Lbova, 2000; Derevianko, Shunkov, 2004; Pitulko, Pavlova, Ivanova, 2014; d'Errico et al., 2021). In the Upper Paleolithic assemblages from this vast area, they usually occur as solitary pieces or small series. The exception is the collection from the Yana site, which contains the largest set in Siberia of cylindrical beads made of tubular bones, approx. 300 specimens (Pitulko, Pavlova, Ivanova, 2014). The second largest and one of the most ancient sets of bone cylindrical beads, including more than 50 specimens, comes from Upper Paleolithic assemblages of Denisova Cave in the Altai Mountains (Fig. 1) (Derevianko, Shunkov, Kozlikin, 2020; Shunkov et al., 2020).

Cylindrical bone beads have been recovered from the Upper Paleolithic layers in all main sections of Denisova Cave. Currently, the beads from the East (Shunkov et al., 2020) and South (Shunkov, Fedorchenko, Kozlikin, 2019) Chambers of the cave have been most comprehensively studied. Previously published works provide the data on the tubular beads from the Main Chamber (excavations of 1984, 1993–1995, 1997, and 2016) (Shunkov, Krivoshapkin, Anoikin, 1995; Prirodnaya sreda…, 2003; Derevianko, Shunkov, 2004; Shunkov et al., 2016). Information about cylindrical beads from Denisova Cave is presented in review papers addressing the emergence of symbolic behavior and the spread of ancient personal ornaments in Eurasia (Sinitsyn, 2005; d'Errico, Vanhaeren, 2009; Wright et al., 2014). However, most of the Upper Paleolithic tubular beads from Denisova Cave remain outside the focus of special research addressing the production technology and methods of use, while the previously presented reconstructions were based on small samples and require verification (Shunkov et al., 2016; Shunkov, Fedorchenko, Kozlikin, 2017; Shunkov et al., 2020).

Layer 11 in the Main Chamber of the cave yielded the most representative collection of the Early Upper Paleolithic tubular beads in Siberia.

Here, we present the results of a detailed analysis of the entire collection of bone tubular beads from the Main Chamber. The excellent state of preservation and considerable quantity of the recovered beads make it possible to consider these items as the basis for reconstruction of the production technologies and use patterns of ancient Siberian tubular beads.

Materials and study methods

The Early Upper Paleolithic collection of artifacts from the Main Chamber of Denisova Cave comprises 28 specimens related to the manufacture of bone tubular beads (see *Table*): 27 specimens are finished beads of two types—with (*n*=19; Fig. 2, *3*) and without ornaments, or simple (*n*=8; Fig. 4); and one item is a longitudinally split fragment of a preform (Fig. 5, *1*). Among these, 16 beads were intact, seven artifacts show signs of longitudinal fracture, and four beads show traces of transverse and longitudinal fragmentation.

All the tubular beads were found in 1984–2018, in the excavation with an area of 21 m^2. Most of the beads (*n*=21) concentrated in sq. Д–Ж/6–8, in layers 11.2, 11.4, and 11.5 (see *Table*). Six items were recovered

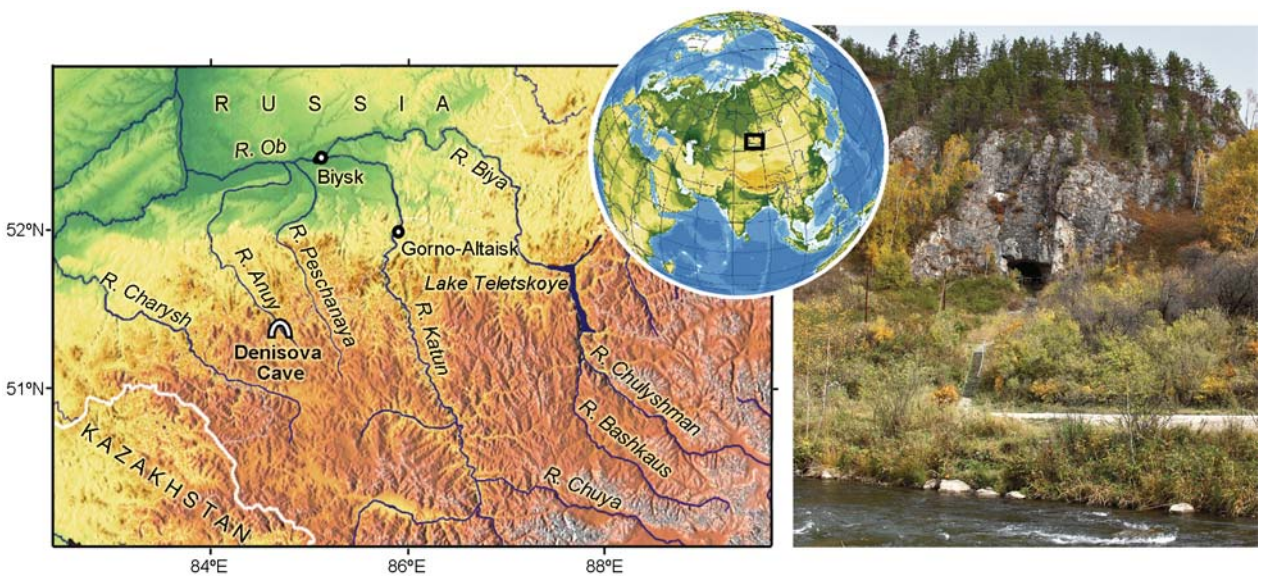


Fig. 1. Location of Denisova Cave.

from sq. Ж/7–8 and Е–8, lithological unit 11.2. Another six beads were found in the filling of two artificial depressions/pits noted in the 1984 excavation area in sq. Д/6–7 and stratigraphically related to the upper part of layer 11 (Prirodnaya sreda…, 2003: 132). Eight beads were recovered from the low part of layer 11: six items in sq. Е–Ж/6, Ж–7, and Е–Ж/8, layer 11.4, two items in sq. Е–Ж/7, layer 11.5. Eight beads were identified during the sorting of the faunal collection and wet-sieving of the sediments of layer 11 collapsed from the excavation's walls.

The available biostratigraphy data and absolute dates indicate that the deposits of layer 11 in the Main Chamber accumulated during the period corresponding to the

Bone tubular beads of the Initial Upper Paleolithic from the Main Chamber of Denisova Cave

No.	Year	Layer	Sq.	Type	Fragmentation	Length, mm	Width, mm	Thickness, mm	Fig.
1	1995	11.2	Е-8	Ornamented	Longitudinal and transversal	7.53	4.84	1.57	2, *1*
2	1997	11.2	Ж-7	"	None	17.72	8.75	6.25	2, *6*
3	1997	11.2	Ж-8	"	Longitudinal	31.03	6.02	1.88	3, *9*
4	2016	11.2	Ж-8	"	None	22.71	10.22	8.55	2, *9*
5	2016	11.2	Ж-8	Unornamented	"	22.43	4.36	3.67	4, *2*
6	2019	11.2	Ж-8	Ornamented	"	4.62	4.01	3.57	2, *5*
7	1984	11 pit	Д-7	"	"	34.33	13.70	12.56	3, *8*
8	1984	11 pit	Д-7	"	"	14.46	7.11	5.99	2, *10*
9	1984	11 pit	Д-6	Unornamented	"	36.05	4.70	4.09	4, *1*
10	1984	11 pit	Д-7	"	"	17.39	4.18	3.81	4, *3*
11	1984	11 pit	Д-7	Ornamented	Longitudinal	10.98	4.59	2.10	2, *4*
12	1984	11 pit	Д-6	Unornamented	None	23.69	13.95	12.56	4, *7*
13	1995	11.4	–	Ornamented	"	29.97	5.86	3.86	3, *4*
14	1995	11.4	Е-6	"	"	21.54	5.75	4.76	3, *1*
15	1995	11.4	Е-8	"	Longitudinal and transversal	21.12	6.66	2.00	3, *5*
16	1997	11.4	Ж-8	"	"	24.47	7.30	3.22	3, *7*
17	1997	11.4	Ж-7	"	Longitudinal	29.62	5.22	1.92	3, *6*
18	2016	11.4	Ж-6	Unornamented	None	18.49	11.83	11.31	4, *8*
19	1994	11.5	Е-7	Ornamented	Longitudinal	23.60	8.19	3.65	3, *3*
20	1997	11.5	Ж-7	"	None	20.16	4.26	3.48	3, *2*
21	1984	11	Д-8	Unornamented	"	9.62	9.30	6.99	4, *6*
22	1992	11	Г-5	Ornamented	Longitudinal and transversal	8.54	5.29	2.40	2, *2*
23	1992	11	Д-5	Preform	Longitudinal	34.89	11.93	5.83	5, *1*
24	1993	11	В/Д-5	Ornamented	"	10.30	8.58	5.34	2, *3*
25	1993	11	В-5	Unornamented	"	30.77	9.39	4.48	4, *4*
26	1994	11	Е-6	"	None	17.41	12.16	12.05	4, *5*
27	1994	11	Б-8	Ornamented	Longitudinal	13.21	7.69	2.74	2, *8*
28	2018	11	Б-8/9	"	None	16.49	8.75	7.26	2, *7*

Fig. 2. Ornamented tubular beads from layer 11 in the Main Chamber of Denisova Cave.

Fig. 3. Ornamented tubular beads from layer 11 in the Main Chamber of Denisova Cave.

first half of MIS 3 (Ibid.). The earliest radiocarbon dates for lithological unit 11.4 were established through direct dating of two artifacts—a bone point and an awl: 39,300 ± 1200 (OxA-34877) and 41,200 ± 1400 (Ox-A30271) / 42,900 ± ± 2000 BP (OxA-29872) (Douka et al., 2019). A younger age was determined by AMS-dating of bone remains with traces of butchering and a piece of charcoal—in the range from 32,150 ± 450 (OxA-34725) to 34,990 ± 340 BP (OxA-34722); similar data were generated for layer 11.2—from 33,900 ± 380 (OxA-X-2696-40) to 34,600 ± 600 BP (OxA-34919). These radiocarbon determinations correspond to calendar dates in the range of 38,000–40,000 BP, which is consistent with OSL-dating results (Jacobs et al., 2019).

The processes of bone working were reconstructed through the analysis of technological context, morphology of artifacts, and production sequence (Crémades, 1994; Teyssandier, Liolios, 2003; Laroulandie, d'Errico, 2004). Published experimental data were used in verification of the derived results (Buc, 2011; Buc, Acosta, Mucciolo, 2014; Orłowska, Ćwiek, Osipowicz, 2022). The ways of using the ornaments were determined by experimental and traceological analysis (Álvarez, Mansur, Pal, 2014; Bradfield, 2015; Osipowicz

Fig. 4. Unornamented tubular beads from layer 11 in the Main Chamber of Denisova Cave.

et al., 2020). The primary examination of artifacts was carried out at ×7.5–×45 magnification, using an Altami CM0745-T microscope; microscopic examination (×100–×500) was carried out using an Olympus VNM microscope. Photographic recording of the use-wear traces was made with a Canon EOS 5D Mark IV camera, EF 100mm f/2.8 Macro USM and MP-E 65mm F2.8 1-5X Macro lenses, and a tripod, with manual focusing. The images of use-wear traces with focusing over the entire area of one frame were obtained with the aid of Helicon Focus software.

Identification of the species of animals whose bones were selected for making the ornaments was based on determinations of the dimensions (length, diameter, and thickness) of the artifacts' walls. Faunal identifications were made by A.K. Agadjanian (Palaeontological Institute, Russian Academy of Sciences) and S.K. Vasiliev (Institute of Archaeology and Ethnography, Siberian Branch, Russian Academy of Sciences).

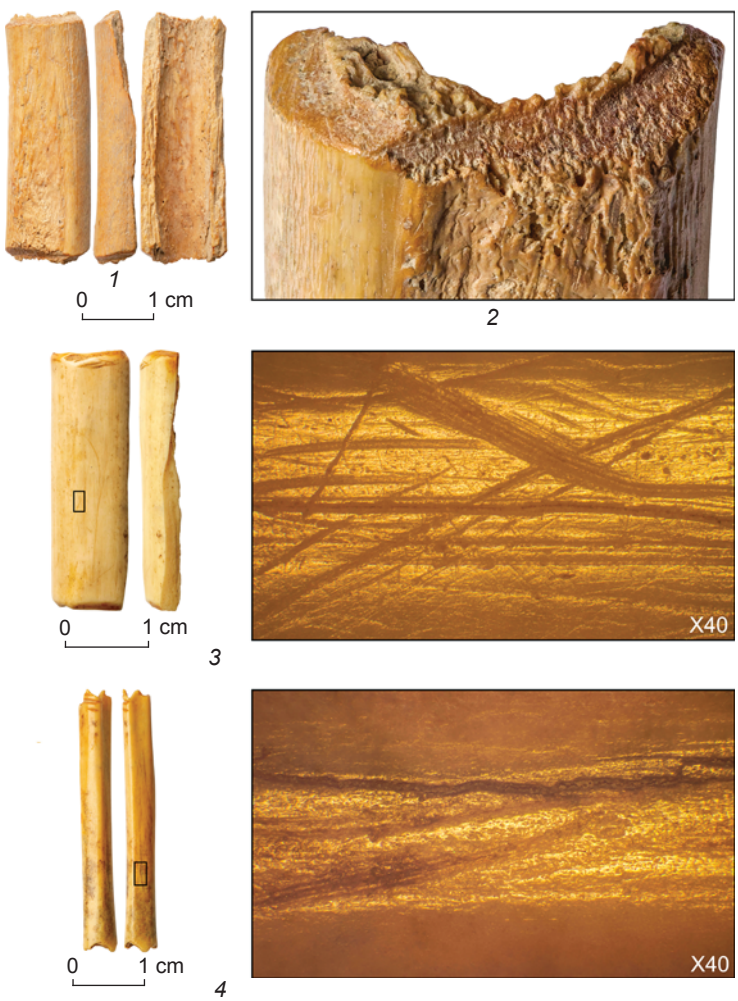


Fig. 5. Fragment of a preform of unornamented beads (*1*); fragment bearing traces of sawing off the diaphysis (*2*); fragments of ready-made beads bearing traces of planing (*3*, *4*) from layer 11 in the Main Chamber of Denisova Cave.

Study results

Technological context. Our results have shown that the technological context of the production of bone tubular beads in layer 11 of the Main Chamber was incomplete. Analysis of the archaeological and faunal collections led to one artifact being interpreted as a preform; however, no blanks or diagnostic technological waste were found. The absence of the latter suggests that the ornaments were made either in the unexplored areas of the cave, or beyond the site. Traces of wear on all the beads from the Main Chamber may indicate that these were delivered to the site as finished products. Refitting analysis did not show any correspondence between the finished products and/or the bead fragments.

Blank selection. The initial stage of the manufacture of tubular beads was the selection of blanks. The Upper Paleolithic inhabitants of the cave used tubular bones from mammals and birds of various sizes to make cylindrical beads. The blanks were dominated by ulna and humerus bones from birds of the size of a black grouse *Tetrao tetrix* or wood grouse *Tetrao urogallus* (*n*=12), and also from representatives of smaller species of the size of a thrush *Turdus philomelos/ruficlollis* or jackdaw *Corvus monedula* (*n*=7). Less common were the bones of the limbs of large mammals of the size of a roe deer *Capreolus pygargus* or red wolf *Cuon alpinus* (*n*=5), and smaller animals of the size of a marmot *Marmota* sp. or hare *Lepus* sp. (*n*=4). The incompleteness of the technological context, together with considerable modification and wear of finished products, make it impossible, in most cases, to identify accurately the animal species whose bones were used as raw material.

Preform preparation. The next stage in the technological sequence was processing of blanks by planing, followed by the removal of one or both epiphyses to obtain the required preforms. Five tubular beads show extended linear marks in certain parts of the surfaces; the marks are located parallel or subparallel to the long axis of the blank, and run over the entire lengths of the products (Fig. 5, *3*, *4*). The planing marks are partially covered by subsequent polishing during wear. The least deformed linear marks are observed on the preform. Most of the finished beads have no visible planing marks. The beads were probably planed situationally to flatten or smooth the surface of the blanks. The main shaping technique in the manufacture of preforms was the truncation of one or both epiphyses of the bone by cutting or sawing (Fig. 5, *2*), which was performed by reciprocal movements of a stone tool with a straight blade all around the blank (Buc et al., 2014).

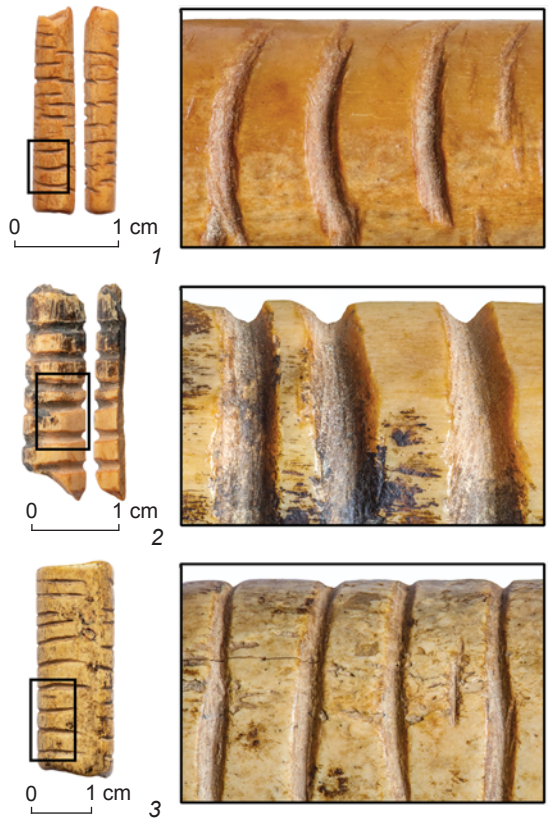
Ornamentation. Marks of shape-forming cutting or sawing at the ends of most finished ornamented beads overlap the traces of notching, suggesting that the stage of decorating the surfaces of artifacts with ornamentation preceded the segmentation of preforms*. This chaîne opératoire probably ensured the convenience and ease of ornamentation of a larger item, which was the preform, as compared to small, sometimes miniature, ready-made beads. The peculiarities of the technique of decorating preforms were reconstructed based on of the analysis of finished beads. Engraving of the artifacts was executed with a stone tool with a thin V-shaped blade by means of reciprocating movements (Fig. 6). In almost all cases, the notches on the products were located across the long axis. On one longitudinally fragmented bead, the notches slant at an angle of 70°.

Finishing stage. The preforms, starting from the ends freed from the epiphyses, were marked out for the subsequent division into segments. Ten beads from the collection show single, less often grouped, short and thin notches on their surfaces, close to the cut-off ends (Fig. 7, *1*, *2*), which might be interpreted as traces of preliminary marking. The subsequent division of the preform into short tubes was carried out by the technique of circular sawing or cutting with the above-mentioned stone tool (Laroulandie, d'Errico, 2004). Judging by the number and position of the grooves at the end zones of the beads (Fig. 7, *2*), the preform was successively rotated 3–5 times during the sawing process (see Fig. 5, *2*). The sawn grooves were mostly uneven, but closed down; only one third of the products show the grooves forming a relatively regular circle at their ends. In almost half of the finished beads, the cut does not run perpendicular to the long axis of the product. Only a quarter of all the beads were cut off from the preform at a right angle. For the fragmented items, making up 1/3 of the collection, it was impossible to determine the position of the tool during sawing.

The next stage of processing was the fragmentation of products along cuts by breaking; this is confirmed by the impressive traces of transverse fracture at one or two ends of the vast majority of intact tubular beads (see Fig. 7, *3*, *4*). One of the techniques used at the finishing stage of manufacturing beads was the removal of cancellous tissue. This operation was carried out to form and widen the hole in the bead by a tool with a thin and sharp cutting edge. Traces of the use of this technique were recorded on three tubular beads that were cut from epiphyseal fragments of long bone (see Fig. 2, *3*, *5*, *8*). After the hollow sections had been obtained, fragmentation zones were additionally processed, probably by planing or grinding, to remove or

*The finished preforms of cylindrical beads with notches resembled an ornamented product, with deep circular cuts and an unseparated epiphysis, from cultural layer II at Kostenki-14 (Sinitsyn, 2016: 322–323, fig. 10, *10*). Materials from the East Chamber of Denisova Cave contain a piece interpreted as a preform of ornamented tubular beads (Shunkov et al., 2020: Fig. 7, *1*).

Fig. 6. Ornaments on bone tubular beads from layer 11 in the Main Chamber of Denisova Cave.



smooth out the protrusions (Orłowska, Ćwiek, Osipowicz, 2022). The cut ends of half of the items show traces of deliberate smoothing (see Fig. 7, *5*, *6*).

Finished tubular beads are short or slightly longer straight tubes, with or without ornamentation. The length of the intact beads (n=16) varies from 4.6 to 36.5 mm, with a median of 19.3 mm (see *Table*). Enlarging the sample to include the longitudinally fragmented beads (n=7) doesn't change the extreme length values and doesn't significantly affect the median value, which is 20.2 mm in this case. The maximum diameter of intact tubular beads ranges from 4 to 14 mm, with a median of 11 mm.

The original feature of the finished beads is the ornamentation in the form of straight short notches or elongated lines. The incisions on intact beads are usually short (90 %); their length does not exceed 10 mm. The other incised lines reach 10–25 mm. The depth of the cuts varies from 0.2 to 1.4 mm, the width is from 0.2 to 1.6 mm. The intact beads show notches and lines grouped into three (n=5), two (n=3), or six (n=1) blocks. A total of 27 blocks were identified, including from 1 to 16 notches: 37 % of the examined blocks consisted of 1–5 lines, 37 %

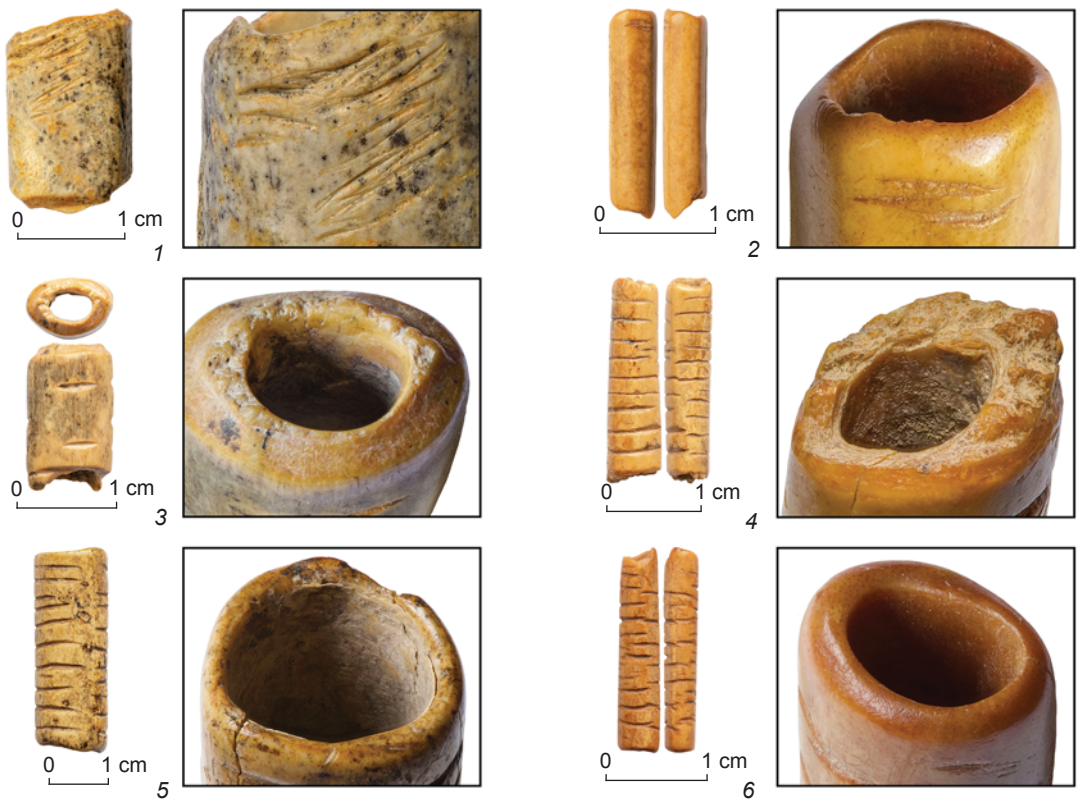


Fig. 7. Test incisions (*1*, *2*); traces of deliberate breaking at the ends of tubular beads (*3*, *4*); traces of deliberate leveling of surface at the ends of tubular beads (*5*, *6*) from layer 11 in the Main Chamber of Denisova Cave.

of 6–10 lines, 22 % of 11–15 lines, and 4 % of more than 15 lines. The number of notches grouped in blocks on each bead is rarely the same.

The noted morphometric parameters, the number and features of the arrangement of notches on intact and fragmented beads (*n*=19) reveal several ornamental patterns differing in the degree of concentration on the beads' surfaces. Variant 1 includes beads (one intact and five fragments) with relatively sparse, short, mostly narrow and shallow notches. Each block shows from two to four notches on average, which are usually not connected with one another. Variant 2 includes two intact beads with more regular (from 7 to 15 per block) short cut marks similar in size and morphology. On the surfaces of these beads, the notches in adjacent blocks often overlap and intersect one another. Variant 3 comprises beads (three intact ones and two fragments) bearing elongated, thin, and shallow lines. Each block contains from six to nine lines, which are rarely interconnected. Variant 4 includes ornaments (two intact beads and three fragments) with elongated, wide, and deep lines often connecting one another.

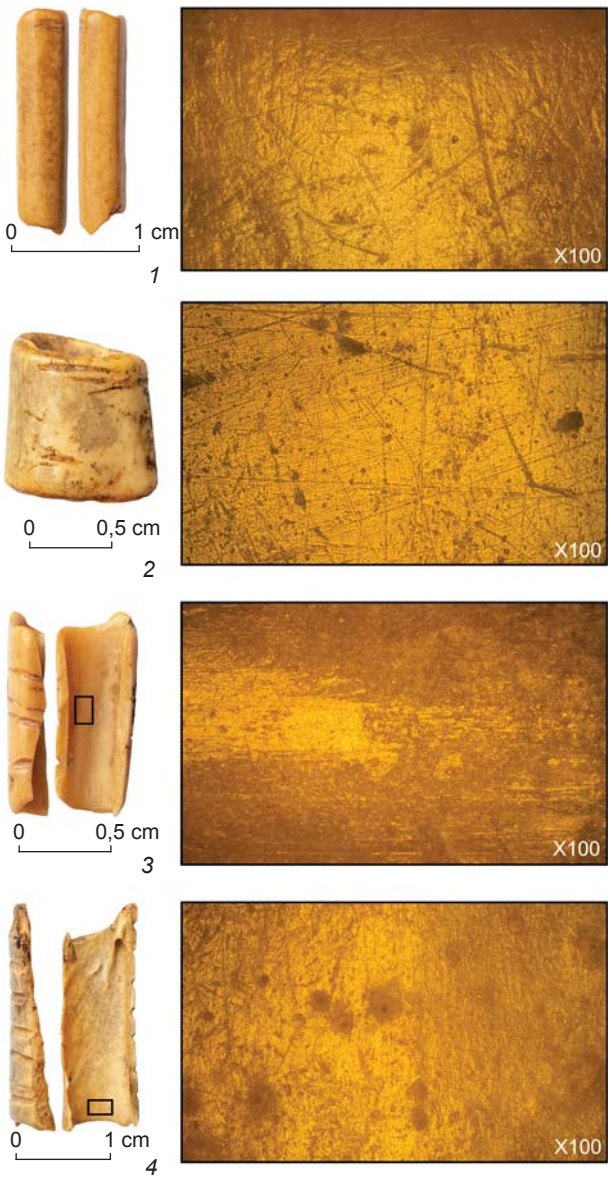


Fig. 8. Use-wear traces on the surfaces of tubular beads from layer 11 in the Main Chamber of Denisova Cave.

Use of tubular beads. The traceological analysis of all the ready-made beads revealed various types of wear traces, representing the features of human use of the products. At ×40 to ×200 magnification, thin elongated or short multidirectional incisions and larger rectangular dents were identified on the beads' surfaces, covered with glossy polishing (Fig. 8, *1*, *2*). This type of wear suggests the intense contact between the bone and a soft organic material (Buc, 2011; Bradfield, 2015; Osipowicz et al., 2020). The cut surfaces resulting from sawing and cutting at the ends of the beads are smoothed, rounded, and polished (see Fig. 7, *2*, *5*, *6*), most likely due to contacts with clothing and human skin. On the interior surface of longitudinally fragmented items (*n*=11), there are extended areas of dull and matte polishing, stretched parallel to the long axis of the item (see Fig. 8, *3*, *4*). Such wear traces occur on bone ornaments as a result of friction during prolonged wear on a thread or thin strap (Shunkov et al., 2020).

Discussion

At present, in the Altai, cylindrical beads made of tubular bone have been found only in Denisova Cave. The closest parallels to these artifacts have been recorded thousands of kilometers away from this site. In North Asia, outside the Altai region, the oldest ornamented tubular beads have been reported from the Early Upper Paleolithic collection from Kamenka in Transbaikalia (44.9–41.4 ka cal BP) (Lbova, 2000; Zwyns, Lbova, 2019). The collection from this site contains three small beads with traces of circular cutting at the ends, decorated with single and paired cut marks. Two large bird bone beads were made using similar technique: one item shows two rows of notches, the other, three blocks of three or four short lines. All the artifacts were polished during use (Lbova, Kozhevnikova, 2016). The other closest parallel to the beads from the Main Chamber of Denisova Cave are the ornaments from the Upper Zhoukoudian Cave in Central China (35.1–33.5 ka cal BP) (d'Errico et al., 2021). Here, four cylindrical beads made of tubular bone, decorated with blocks of one, two, or three short notches, were discovered. Unfortunately, the state of preservation of these beads makes it impossible to reconstruct reliably the technology of their manufacture.

The largest collection of Upper Paleolithic tubular beads in Northern Eurasia has been found at the site of

Yana, located in eastern Yakutia (33.2–31.0 ka cal BP) (Pitulko, Pavlova, Ivanova, 2014). More than 300 small cylindrical beads were discovered at this site; the beads were made from the bones of hare limbs through the technique of sequential truncation of diaphysis. Most of the beads show continuous or partially closed circular incisions in the medial part. Despite some differences in the morphology of the ready-made beads, the technology of their manufacture generally corresponds to that of the tubular beads from Denisova Cave.

A few beads in the form of elongated hollow cylinders from the tubular bones of birds and arctic foxes, as well as blanks and waste products, have been reported from the Middle Upper Paleolithic assemblage from the site of Malta in the Angara region (Gerasimov, 1941). Small series of bone tubular beads were noted in the Late Upper Paleolithic assemblages from Kokorevo II, Afontova Gora II and III on the Yenisei (Abramova, 1979; Astakhov, 1999), as well as from Krasny Yar in the Angara region (Abramova, 1962). The majority of these beads do not show any ornamentation; some pieces has one or two circular incisions in the medial part. The Upper Paleolithic tubular beads from the sites of the Angara region and the Yenisei valley have close parallels among typologically and technologically similar artifacts from the Yana collection.

The Upper Paleolithic tubular beads of Western Europe are traditionally associated with the spread of the Aurignacian technocomplex about 41–35 ka cal BP (Teyssandier, Liolios, 2003; Vanhaeren, d'Errico, 2006). The most expressive personal ornaments of this type were found at the cave sites of Le Côte and Isturitz in southwestern France (Rigaud et al., 2014; White, Normand, 2015), Spy in Belgium (Khlopachev, 2011), Geißenklösterle and Hohle Fels in southern Germany (Bolus, 2015; Dutkiewicz, Wolf, Conard, 2018), and Bombrini in Italy (Arrighi et al., 2020). Numerous short and elongated cylindrical beads from Aurignacian sites were made by dividing the tubular bones of mammals and birds or carved from mammoth ivory. Aurignacian beads show a variety of ornamentation—zigzags and oblique lines, transverse circular carving, short longitudinal and transverse notches, and lines twisted in spirals over the beads' axes. In Aurignacian assemblages, small tubular beads are often found in association with elongated "tubes", often ornamented in the same way as other bone items (Tartar, 2015).

In Central Europe, the technology of making ornamented bone beads was used since the Aurignacian period. In Pod Hradem Cave in the Czech Republic (41.7–39.2 ka cal BP), a cylindrical bead made from a small carnivore bone by planing and subsequent truncation of epiphyses was found; the bead was ornamented with three groups of seven, five, and four short and deep cuts (Wright et al., 2014). Later, cylindrical beads made of bone and tusk became widespread in the Gravettian complexes—Dolní Věstonice I, Klimăutsi II, and others (31.0–23.8 ka cal BP) (Cârciumaru, 2019; Láznicková-Galetová, 2021). The cylindrical beads from these sites are characterized by an ornament that combines transverse circular cuts, rounded dots, and short longitudinal lines, or a simpler motif in the form of rows of short notches similar to that on the ornaments from Denisova Cave.

In contrast to the beads from Western and Central Europe, the oldest Upper Paleolithic bone beads from the Russian Plain are very diverse. One of the earliest finds comes from cultural layer II of Kostenki-17, dated to 41–40 ka cal BP, which industry is considered to be a local variant of the Proto-Aurignacian (Stepanova et al., 2022). Made of mammoth ivory, this cylindrical item has no ornamentation. Its manufacturing technique is similar to a more recent technology reconstructed from the ornaments of Dolní Věstonice I. Expressive tubular beads, similar to the items from Denisova Cave, occur in non-contemporaneous complexes at Kostenki-14 (Sinitsyn, 2015). The oldest of these were discovered in the Aurignacian industry from the volcanic ash horizon, dated to 40.1 ka cal BP. The beads are made from arctic-fox bone using the technique of sequential separation of the epiphyses; the beads bear elongated, often interconnected notches, sometimes twisted into spirals. Younger, unornamented elongated beads come from layer III at Kostenki-17, dated to 35.2–33.8 ka cal BP.

Elongated-narrow and short-wide hollow cylinders, similar in age and technology, have been reported from the Sungir collection, most likely associated with the Streletskaya culture (34.6–33.7 ka cal BP) (Bader, 1973; Sinitsyn, 2016). A number of cylindrical beads of the Gorodtsov culture were recovered from layer II at Kostenki-14 (34.0–33.0 ka cal BP). These items were cut from rodent bones and decorated with two or three rows of transverse, short, and parallel notches. Elongated beads ornamented with rows of short notches located parallel or obliquely to the long axis of each bead were discovered in the younger Early Gravettian complex of cultural layer II at Kostenki-8 (Sinitsyn, 2016).

In general, the tubular beads from the Upper Paleolithic complexes of Eurasia are similar to the ornaments from layer 11 in the Main Chamber of Denisova Cave in shape, manufacturing technology, ornamentation techniques, and probable use patterns. In this case, the ornamented items offer the greatest potential for comparison. The Eurasian context provides a great variety of geographical and chronological affiliations of short and long cylindrical beads decorated with rows of parallel notches. The Altai tubular beads demonstrate the greatest similarity to Aurignacian items from the chronologically close, but geographically distant complexes of Western, Central, and Eastern Europe. Notably, the assemblages of Eastern European and especially North Asian sites with

the oldest artifacts of this type often do not show direct similarities with each other, in contrast to the probably monocultural Aurignacian earliest tubular beads from the sites in Western Europe.

Conclusions

The analytical data obtained of the artifact collection from layer 11 of the Main Chamber of Denisova Cave suggest that the production of tubular beads followed a standardized technological sequence: selection of blanks of the required configuration—tubular bones of birds, small and medium-sized mammals; leveling and smoothing of blank surfaces by planing; shaping of preforms by truncation of one or both epiphyses; ornamentation of the preform with short notches or lines grouped in separate rows or closed in a ring; marking of preforms into short tubes; dividing of preforms by sawing or cutting, fragmentation by cuts; removal of cancellous tissue and smoothing of fragmentation surfaces. The absence of blanks and production waste suggests that tubular beads were most likely made outside the excavated area of the Main Chamber of Denisova Cave.

The analysis of the chaîne opératoire showed that the ornamentation by groups of short or long notches of the surface was carried out at the stage of preparing preforms, rather than at the very end; when ornamentation was ready, the preform was cut into smaller fragments. The diverse morphometric characteristics and arrangement of lines indicate that the ornamentation did not have any "utilitarian" purpose, but was likely of certain cultural or symbolic character. Ornamentation with short notches and lines has been recorded not only on beads, but also on other products of the Early Upper Paleolithic from Denisova Cave—tools and non-utilitarian items made of bone, tusk, and horn: on points, needle cases, awls, buttons, plaques, and unique zoomorphic figurine.

Complete tubular beads from the Main Chamber demonstrate considerable variations in metric characteristics and proportions, suggesting their division into several size classes. This variability may be due to preferences in the choice of initial blanks, as well as to cultural norms determining the look of non-utilitarian products. Tubular beads are one of the most widespread categories of personal adornment in the Denisova Cave collections. Together with perforated pendants of mammalian teeth and flat beads of soft stone, bone, ivory, and shell, tubular beads were widely used by the Upper Paleolithic cave inhabitants as elements of clothing decoration, personal necklaces, and probably bracelets.

Bone tubular beads are a specific category of personal ornament broadly distributed over Eurasia since the Early Upper Paleolithic. Their manufacturing technique was relatively simple, as the raw materials used were the most accessible tubular bones of mammals and birds. At the same time, the choice of ornamentation techniques did not seem to be really strict; ornamentation determined the symbolic content of personal ornaments in accordance with existing cultural canons. According to the results of the analysis of the chronology and geography of cylindrical beads in Eurasia, products with identical ornaments and morphometric characteristics, close in age and similar in manufacturing technology, differed in cultural affiliation and were often found in regions hundreds and thousands of kilometers apart. The spread of ornamented tubular beads in Eurasia during the Early Upper Paleolithic was probably due to the transfer of their production technology in a ready-made form during migrations or intercultural contacts. The possibility of the convergent emergence, extinction, and reappearance of this technology in different parts of Eurasia at various stages of the Upper Paleolithic cannot be ruled out either. These processes were most likely facilitated by the special demand for these ornaments, the availability of raw materials, and the relative ease of their manufacture.

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