Quaternary International xxx (2016) 1–15

Contents lists available at ScienceDirect

Quaternary International

journal homepage: www.elsevier.com/locate/quaint

Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces

Mikhail Zhilin

Institute of Archaeology, Russian Academy of Sciences, Moscow, Russia

ARTICLE INFO

Article history:
Available online xxx

Keywords:
Mesolithic
Bone arrowheads
Technology
Manufacture
Use-wear traces
Central Russia

ABSTRACT

A multilayer peat bog site Ivanovskoye 7 is situated in Central Russia, 120 km to the north from Moscow. Early, middle and late Mesolithic cultural layers with rich bone industry were excavated. Various arrowheads were discovered in Mesolithic layers. Most of them were made from elk long bones. All arrowheads including fragments preforms and blanks were studied with the help of a stereomicroscope with magnifications from 3.6 to 119 times. The following chain of operations was established in the manufacture of bone arrowheads from Mesolithic layers of Ivanovskoye 7 site. Elk long bones were soaked in water for softening, after it long narrow splinters were removed with the use of the "groove and splinter" technique. Then splinters were turned into preforms with the help of crude scraping or whittling. Fine whittling and scraping was used for shaping the preform into arrowhead. At this stage various details such as barbs, grooves, slots for inserts were made with the help of grooving, sawing, carving, whittling and scraping. Some arrowheads were decorated with engraved ornamentation. Final treatment included grinding with fine grained abrasive slabs and bright polishing with hide. Slots of composite arrowheads were filled with glue and heated. When the glue became soft, inserts were put inside these slots. Of special interest is the final treatment of one long needle shaped arrowhead with the help of the turning lathe. Use-wear traces include rounding or smashing of the tip of the point and polishing running from the point gradually disappearing accompanied by fine linear traces running from the tip along the axis of the arrowhead or at acute angles to it, indicating hitting rather soft slightly dirty material. Coarse linear traces in the shape of grooves running from the point, resembling traces on soil digging tools indicate hitting the ground when the arrow missed the target. This research showed the skill of Mesolithic inhabitants of Ivanoskoye 7 site in the manufacture of bone arrowheads, which they used for hunting various animals. Numerous bones of the latter from Mesolithic layers confirm this.

1. Introduction

Bow and arrows were the main hunting weapon during the Mesolithic in many parts of Northern Eurasia, and Central Russia is one of them. More than 500 Mesolithic sites are known nowadays in the region, and about a hundred of them were excavated, but most of these sites are situated on dry land where organic remains are not preserved. Field surveys and excavations, carried out by the author in 1988–2000, revealed about 60 wetland sites with good preservation of organic remains, reliable stratification and perfect opportunities for the application of scientific methods. Twelve of them were excavated, with a very good sequence of cultural layers from the very beginning until the very end of the Mesolithic. The lower layer of Stanovoye 4 is dated to the transition from the Younger Dryas to the Preboreal period by pollen and about 10060–9800 BP (uncal.) by ^{14}C; bottom layers of Ivanovskoye 7 and Sakhtysh 14 – to the first half of the Preboreal period by pollen and about 9700–9500 BP; layer III in cut 3 of Stanovoye 4 and layer III of Sakhtysh 14 – to the second half of Preboreal by pollen and about 9400–8900 BP; lower layer of Ozerki 17 and 16 sites – to the first quarter of the Boreal period by pollen and about 8900–8800 BP; layer III in cut 2 of Stanovoye 4, bottom layer of Nushpoli 11 and layer III of Ivanovskoye 7 – to the first half of the Boreal period by pollen and about 8700–8500 BP; layer II of Saktysh 14 – to the second half of the Boreal period by pollen and about 8400–8200 BP; the bottom layer of Okajomovo 5 – to the end of the Boreal by pollen and about 8000–7800 BP; layer IIa of Ivanovskoye 7, bottom layers of Okayomovo 4, 18a and Ozerki 5 – to early Atlantic period by pollen and about 7400–7000 BP (Zhilin,

E-mail address: mizhilin@yandex.ru.

http://dx.doi.org/10.1016/j.quaint.2015.09.095
1040-6182/

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

2003a, 2003b, 2006a, 2007, 2009; Hartz et al., 2010). These sites produced extensive series of bone arrowheads, which are usually several times more numerous and various than lithic ones from the same sites. Good preservation of bone arrowheads and presence of blanks, preforms and unfinished arrowheads abandoned at different stages of their production gives good opportunity for the study of their manufacture (Zhilin, 1998) and use. Ivanovskoye 7 is one such site. Typological analysis of arrowheads from this site was carried out and results were published (Zhilin, 2001; Zhilin et al., 2002), but results of technological and use-wear analyses with the exception of one arrowhead (Skakun et al., 2014) are not published yet.

2. Materials and methods

2.1. Excavations and finds

Ivanovskoje peat bog is situated about 150 km north-east of Moscow, in the middle flow of river Nerl, which ran through a large lake during the Stone Age, connecting it with the Klyazma River, the left tributary of the Oka (Fig. 1). Ten sites were discovered there. Ivanovskoje 7 is the most interesting because it produced cultural layers of early, middle and late Mesolithic with good preservation of various organic materials including various bone artifacts in good stratigraphic sequence divided by sterile peat and gyttja. 106 square meters were excavated there by D.A. Krainov in 1974–1975, and 332 square meters by M.G. Zhilin in 1992–1997 (Zhilin et al., 2002). The site has 3 Mesolithic and 2 Neolithic cultural layers. Mesolithic settlements occupied a low promontory during lake regressions, which was submerged during transgressions.

The lower, early Mesolithic (IV) layer is dated by ^{14}C to 9650 ± 110 BP (GIN-9520) and 9640 ± 60 BP (GIN-9516). It is dated by pollen to the first half of the Pre-boreal period, before its optimum. During the middle Pre-boreal transgression, the site was submerged. Specialists in scientific methods consider that the phases of water level changes in Central Russia were caused by climatic changes in the early Holocene of Northern Eurasia (Velichko (ed.) 1994). About 300 bone and antler artefacts were found. 24 arrowheads including fragments were found in this layer. Long needle-shaped are the most recurrent (Fig. 2: 2–4, 11–12), some with slots for insets (Fig. 2: 7–8); one with a relief belt near the tang (Fig. 2: 5). A preform of a long needle-shaped arrowhead was found (Fig. 2: 1). Other types include long with regular biconical ornamented head (Fig. 2: 6); narrow tanged slotted with microblades preserved in slots at both sides, fixed by a sort of glue (a composite resin which is discussed in more detail in Section 3.3) (Fig. 2: 14); asymmetric one-winged with a slot for insets opposing the wing (Fig. 2: 9–10), and a small barbed unilateral arrowhead (Fig. 2: 13).

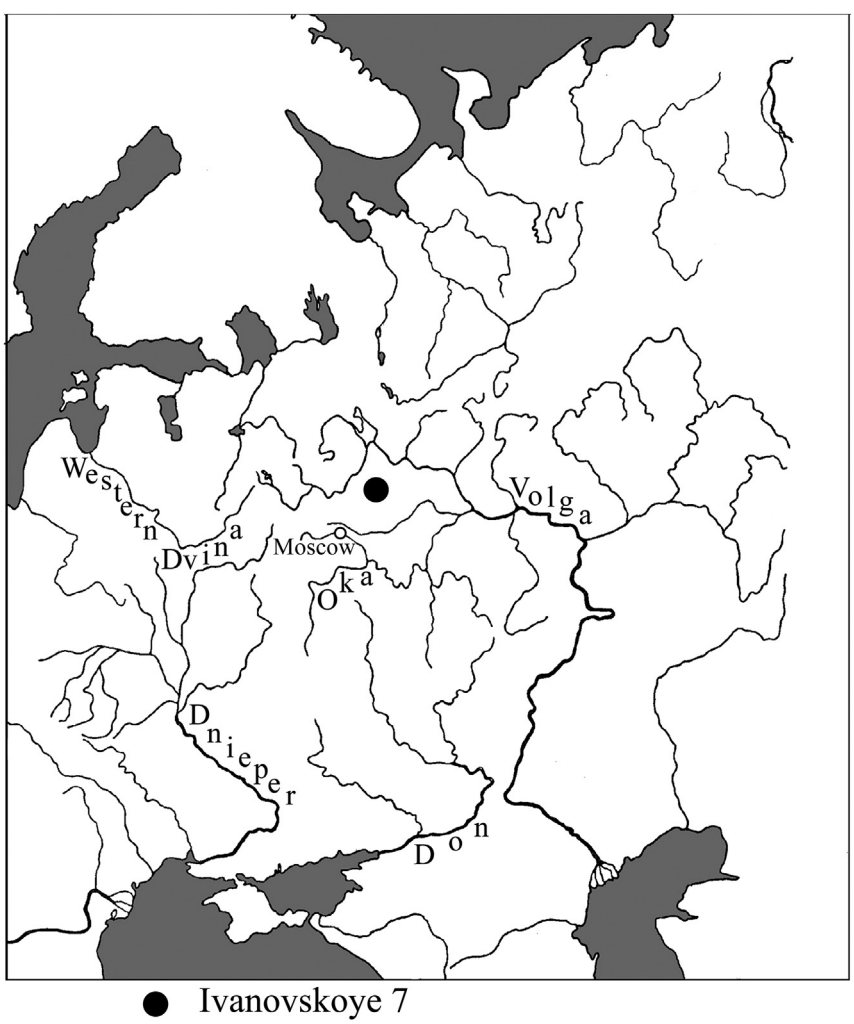

Fig. 1. Situation of Ivanovskoye 7 site.

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

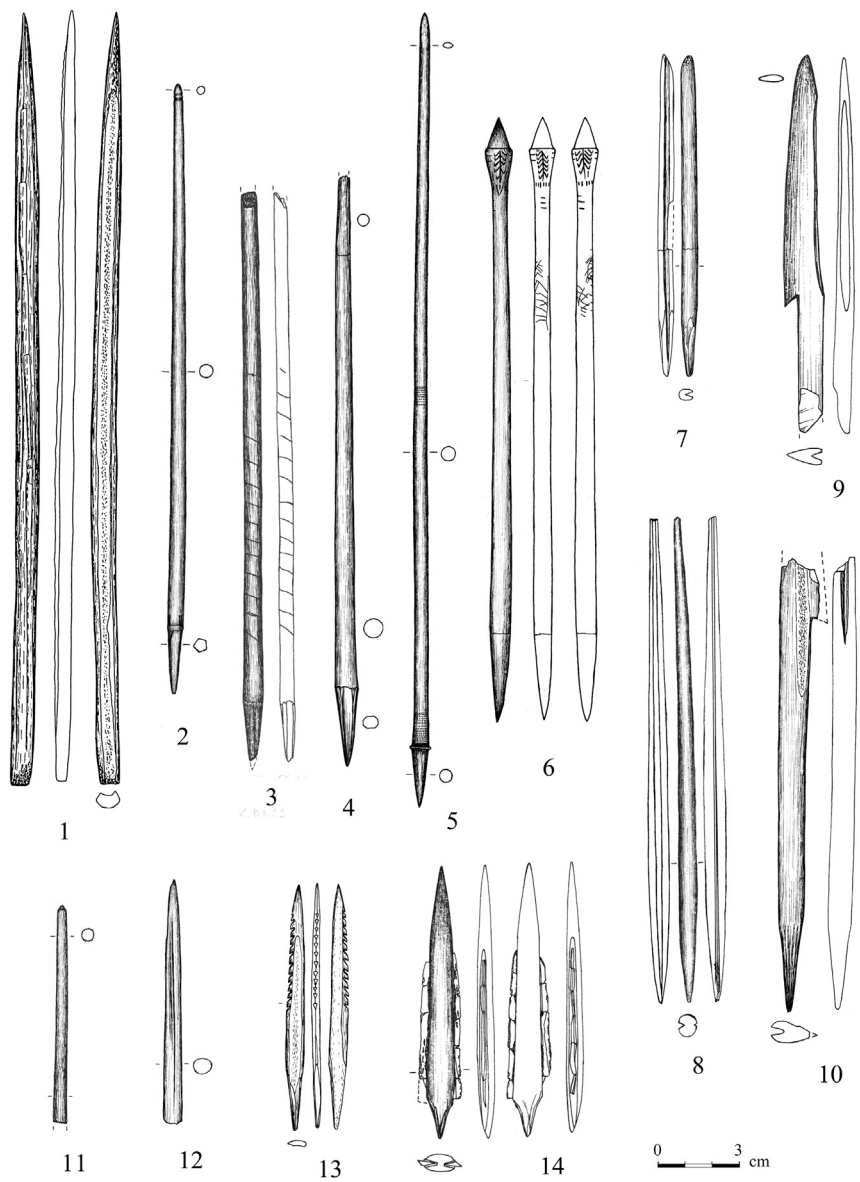

Fig. 2. Bone arrowheads from the early Mesolithic layer IV.

The next occupation, which left the middle Mesolithic (III) cultural layer, is dated to the second quarter of the Boreal period by pollen. ^{14}C dates of this layer are: 8780 ± 120 BP (GIN-9383), 8550 ± 100 BP (GIN-9366), 8530 ± 50 BP (GIN-9373 II), 8290 ± 160 (GIN-9372). About 8500 BP this settlement was submerged again. Bone artefacts include arrowheads – with thickened head resembling biconical (Fig. 3: 2–4), narrow flat one (Fig. 3: 1) and long arrowheads with a barb near the point (Fig. 3: 5–6).

The terminal Mesolithic settlement (layer IIa) emerged at this site during the next regression during early Atlantic period as defined by pollen analysis. Peat with cultural remains is dated by ^{14}C to 7530 ± 150 BP (GIN-9361 I), 7520 ± 60 BP (GIN-9361 II), 7490 ± 120 BP (LE-1260), 7375 ± 170 BP (LE-1261), 7320 ± 190 BP (GIN-9369 I). Bone and antler artefacts include arrowheads: short and long needle-shaped (Fig. 4: 1–3), one with a short slot, filled with glue with an imprint of a micro-blade (Fig. 4: 4); long with a leaf-shaped blade with a barb at one side and a slot with glue on the other (Fig. 4: 5); symmetrical two-winged with a hollow for a flint point at the end (Fig. 4: 6) and two massive blunt arrowheads for fur hunting (Fig. 7: 7).

2.2. Traceological analysis

All arrowheads including fragments, preforms and blanks were studied with a help of a stereomicroscope MBS-10 with magnifications from 3,6x to 119x. Most traces from manufacture and use were clearly visible under magnifications from 6x to 40x. Stronger magnifications were useful for investigation of details of use-wear traces, for example, very fine linear traces embedded inside broader ones, or for studies of the surface inside linear traces. A camera-ocular DCM 800 was used for taking photos just through the microscope.

2.3. Experiments

A series of experiments was carried out. Their aim was the research of technological process of arrowheads production, and

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

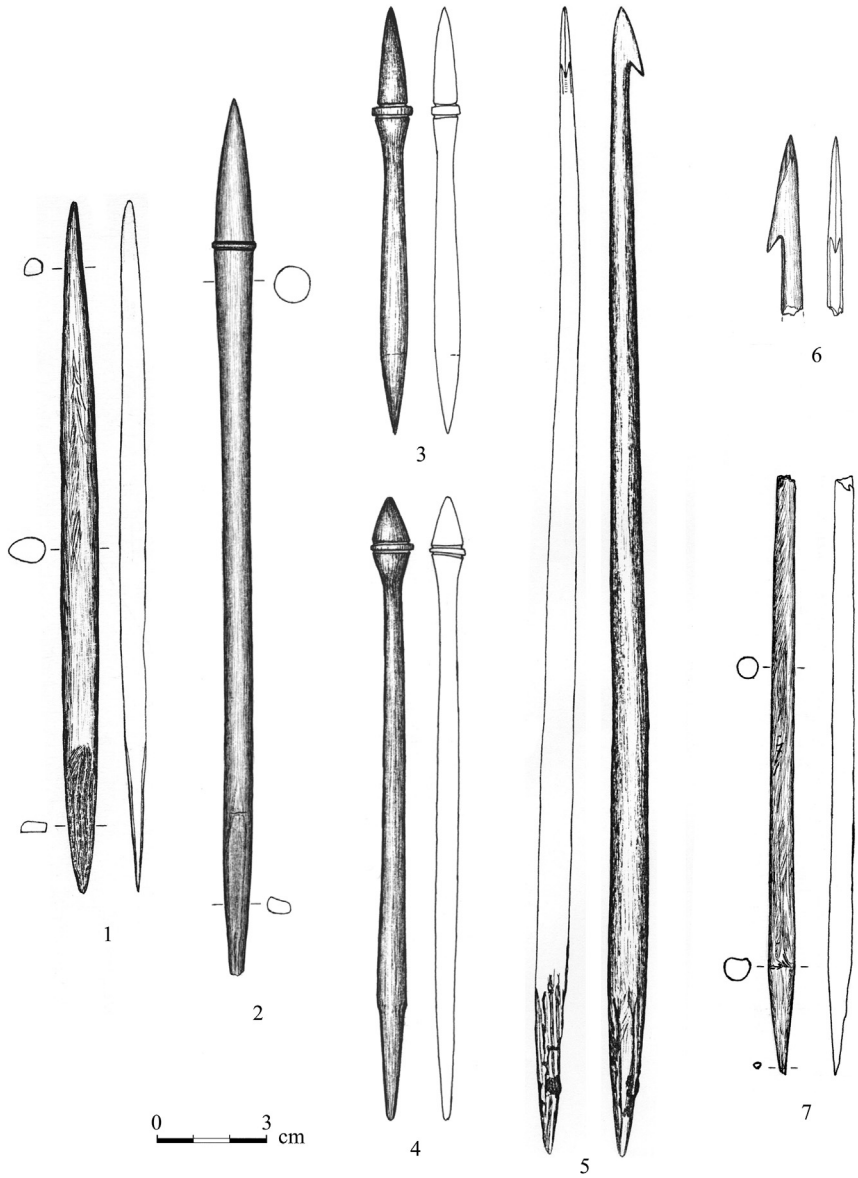

Fig. 3. Bone arrowheads from the middle Mesolithic layer III.

the study of these artefacts used as arrowheads shafted in arrows shot from bows. Several arrowheads of the types found in Mesolithic layers of Ivanovskoye 7 site (needle-shaped; similar with a slot with microblades-inserts fixed with glue; and with thickened biconical head) were made by the author and Svetlana Savchenko from elk long bones with the help of replicas of flint tools. The latter were made by the author from flint and siliceous rocks, represented among finds from the site. Their shape and size was similar to original tools from the site Ivanovskoye 7, used for processing bone (Skakun et al., 2011, 2014). Arrowheads were hafted into shafts made from pine wood and willow branches and shot from a bow of the Holmegaard type. Bows of this type were widespread in the forest zone from Denmark to Trans-Urals during the Mesolithic, and most probably could have been used by Mesolithic inhabitants of Ivanovskoye 7. After several shots, experimental arrowheads were studied with the help of the same stereomicroscope. Use-wear traces similar to observed on studied arrowheads from Ivanovskoye 7 were found on our experimental arrowheads. They included smashing and rounding of the tip, polishing and striations, running from the tip along the axis of the arrowhead and at acute angle to it.

3. Results

3.1. Technology of the manufacture of bone arrowheads in Mesolithic layers of Ivanovskoye 7

Traces of various operations, preceding final treatment, overlapping each other were found at several places of some artifacts. Such “technological stratigraphy” and various blanks, preforms and waste made possible to establish with sufficient certainty the sequence of operations and reconstruct stages of production of arrowheads. The following operation sequence (chaîne opératoire) was established in the manufacture of bone arrowheads from Mesolithic layers of Ivanovskoye 7 site. Elk long bones were soaked in water for softening, as indicated by a cache find of three elk long bones, which were put inside a pit, dug in the bottom layer of the site. It was sunk below the ancient water level, and bones placed

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

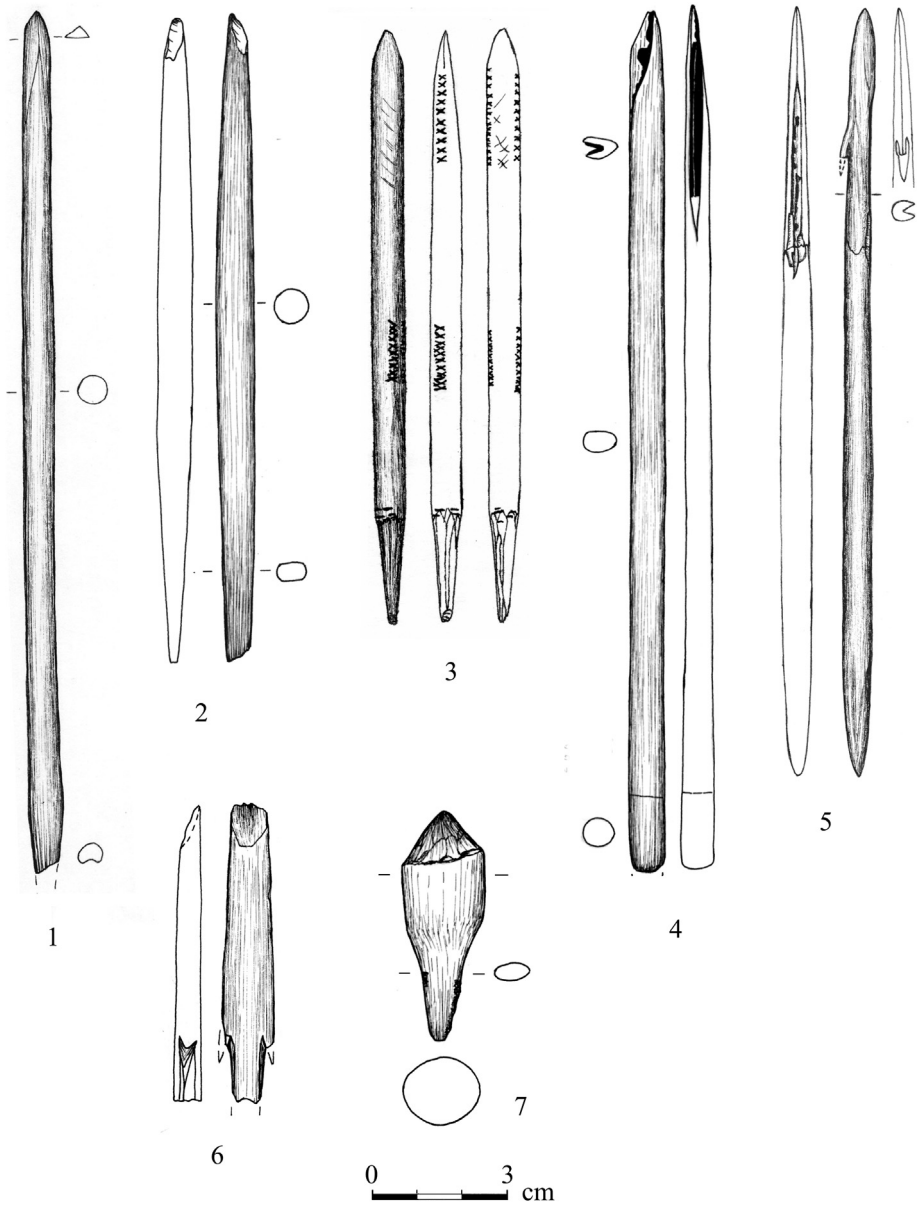

Fig. 4. Bone arrowheads from the late Mesolithic layer IIa.

there were resting in the sand with water. One of these bones had shallow longitudinal straight lines along both sides made with a sharp burin at places of future grooves (Zhilin et al., 2002). When bones softened, shallow transverse grooves running across the perimeter of bone were made near one or both epiphyses, which were broken off along this groove. Such a groove was usually made with the help of a chisel or an adze with unpolished cutting edge, which left characteristic pitting like traces on bone surface (Fig. 5: 1). A series of 13 removed epiphyses with similar traces and a breakage scar was found (Zhilin et al., 2002). After it bone diathesis was first cut into halves (Fig. 5: 1), and then long narrow splinters were removed with the use of the "groove and splinter" technique. In some cases, long bones were cut into halves with preserved epiphyses, or the latter were longitudinally smoothed with an adze, and part of the joint surface is visible at the end of a preform. Thirteen fragments of splinters without epiphyses and four similar fragments with partly preserved epiphyses were found. The groove was usually cut at a depth of 2/3 to 5/6 of the thickness of a wall of the bone. Long parallel traces were left by a burin along sides of the groove (Fig. 5: 2). Such traces are sometimes visible on some parts of finished arrowheads (Fig. 2: 12), indicating the use of this technology of blank production. When the splinter was too wide, it was narrowed with the help of percussion with a hammerstone. This operation left characteristic scars like facets on lithic tools (Fig. 5: 2). Then splinters were turned into preforms with the help of crude scraping or whittling. The experiments showed that percussion technique gives good results with dry bone, but wet bone is much easier worked by scraping, carving and whittling (Savchenko, 2010). When proportions of a splinter were most suitable, secondary treatment started with sharpening the point of the future arrowhead with longitudinal whittling and shaping its surface in the same manner. The preform of a long needle-shaped arrowhead left at this stage (Fig. 2: 1) shows both long linear traces left by a burin on its side, which preserved the surface of groove, and long flat longitudinal facets with typical longitudinal linear traces left by a whittling knife on its dorsal (convex) surface. Typical cross section

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

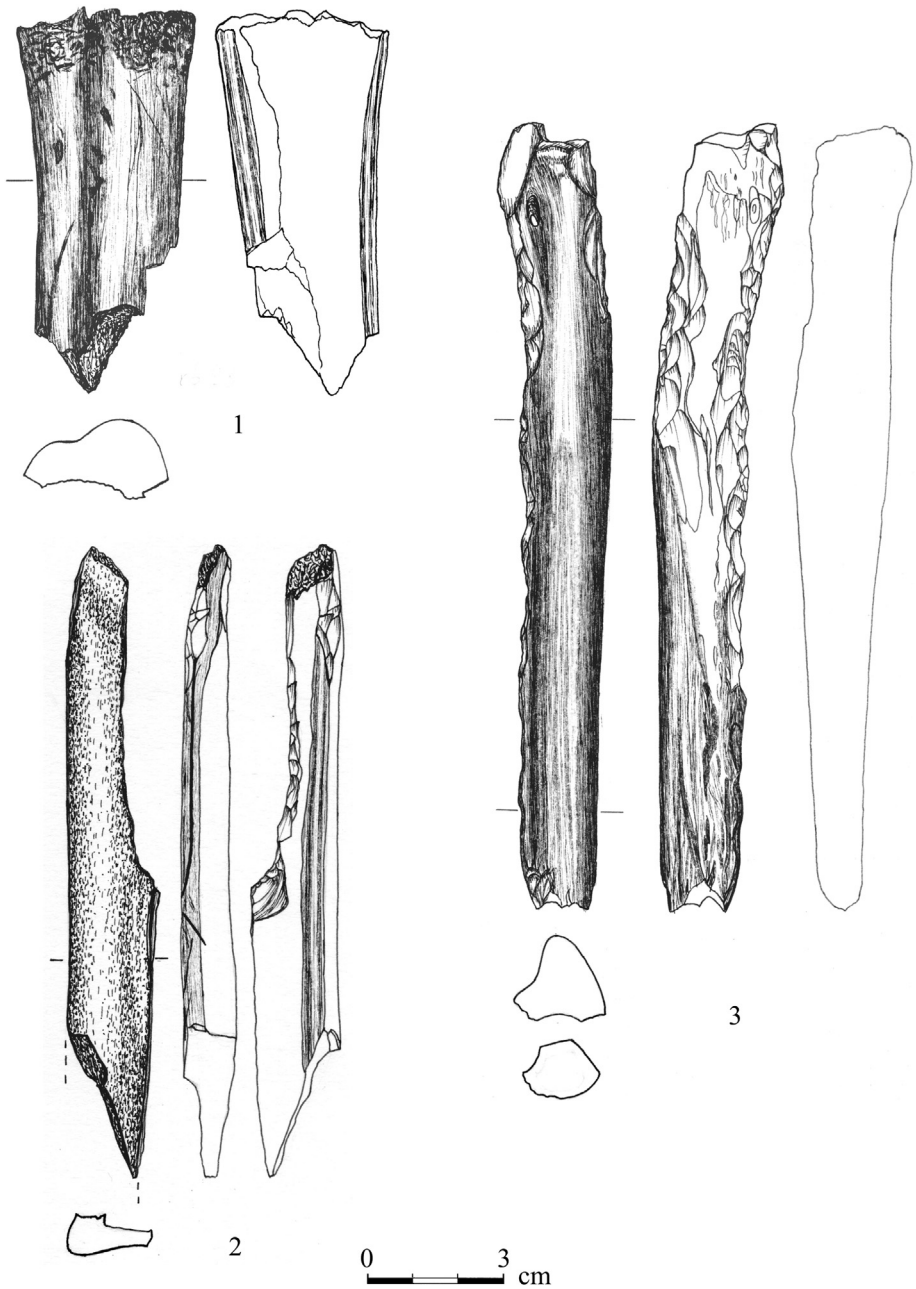

Fig. 5. Bone blanks and preforms: 1, 2 – layer IV; 3 – layer III.

and preserved outer (convex) and inner (concave) bone surfaces indicate that it was made from a long bone. The other technique was aimed in splitting long bones into pieces with a hammerstone and further modification of a piece into necessary shape by percussion with a hammerstone (Fig. 5: 3). The massive preform illustrated here is most probably a preform of an arrowhead with a thickened biconical head. Such arrowheads are most numerous in the middle Mesolithic layer of the site (Fig. 3: 2–4), where this preform was found. After percussion, this preform was shaped by longitudinal scraping and whittling, which left characteristic traces, removing percussion facets in its bottom part. This preform was abandoned in the beginning of this stage. Further whittling and scraping was used for shaping preforms into arrowheads. At this stage, various details such as barbs, grooves, slots for inserts were formed with the help of carving, grooving, sawing, fine whittling and scraping. Many arrowheads were finished at this stage and used, as indicated by traces of glue at their bases and use-wear at their points. Some arrowheads were decorated with engraved ornamentation (Fig. 2: 3, 6; 4: 3) which was carried out with a burin with a very sharp edge. Our experiments showed that a broken flint blade is most suitable for this. Final treatment included grinding with fine grained abrasive slabs and bright polishing with hide or other organic polishers. Grinding was scarcely used in Ivanovskoye 7, and bright polishing was carried out just after fine whittling or fine scraping of the surface. Tangs and bevels of arrowheads were not polished. Ornamentation was executed after fine treatment of the surface by whittling or scraping, but before polishing.

Slots for inserts in composite arrowheads were grooved after fine scraping or whittling, but before polishing. A flat shelf about 2–3 mm wide was made by whittling with a knife along the edge of

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

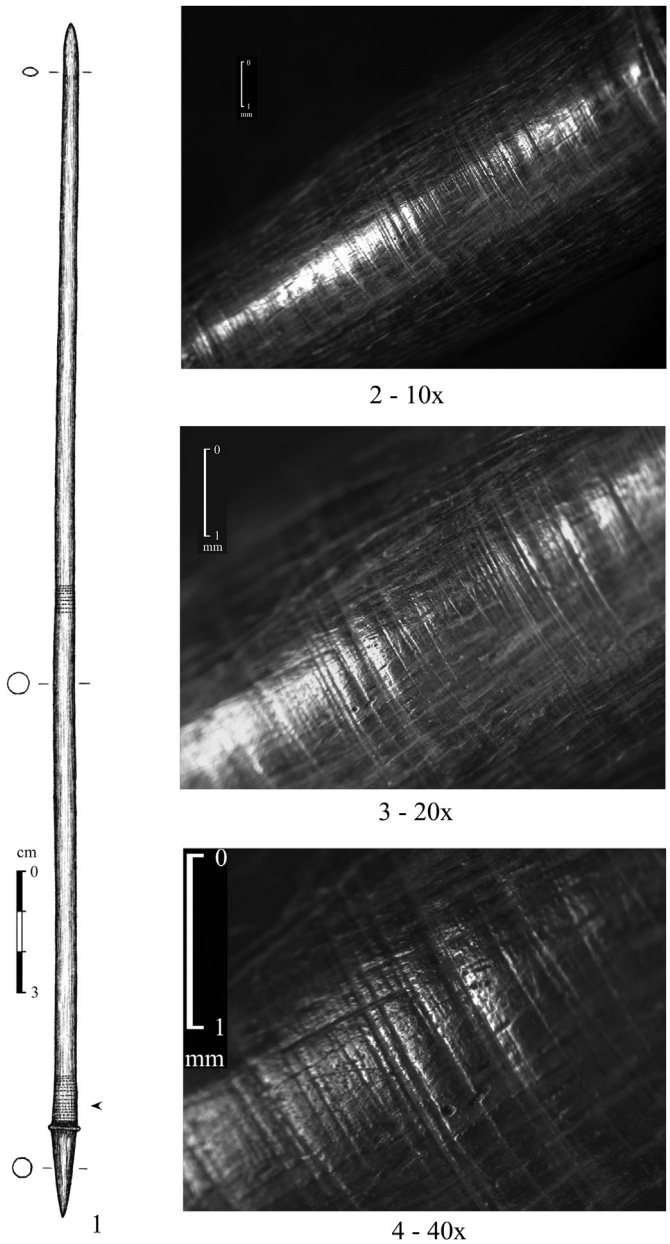

Fig. 6. A needle-shaped arrowhead, layer IV.

an arrowhead. Fragments of broken flint blades served as burins with a very sharp working edge for cutting slots with V-shaped cross section (Fig. 2: 7–8). Other arrowheads have trapeze-like cross section of slots (Fig. 2: 14), which indicates that the cutting edge of a burin was formed by a very narrow burin scar. Our experiments showed that such burin scars often appear as a result of work, and not intentional treatment of a burin. After about half an hour of grooving the working edge of a broken blade becomes dull, and more effort is needed for work. Application of greater effort often results in removal of a very narrow burin spall from the working edge and formation of a burin scar. When it happens, the burin works much better, but the shape of a cross section of the groove changes from V-shaped into trapezoidal. When slots were finished, the shelf was removed by fine longitudinal whittling, and only small remaining parts of the shelf could be observed under a microscope. Afterwards, some slotted arrowheads were polished, and inserts were mounted into the slot.

The detailed study of the edges of inserts preserved in slots of a narrow flat arrowhead (Fig. 2: 14) and experimental data indicate that the grooves were first filled with glue then the artifact was heated over hot charcoal or a very small fire until the glue became soft. Then, inserts were put into each slot resulting in extra glue pressing off from it. The latter covered the sides of the inserts and was removed by longitudinal movement, which produced long striations on the remains of the glue, covering the side surfaces of inserts (Fig. 11: 6). Tiny drops of glue, which set and were preserved on some facets of retouch, proved that the trimming of these inserts was done before they were mounted into the slot. When the glue became hard, the arrowhead was ready. Special attention was paid to the firm placement of inserts for obtaining a straight even cutting edge. The row of inserts for each side of an arrowhead was composed in advance. If needed, intact microblades were broken into parts, documented by glue covering the breakage between the fragments of one microblade (Skakun et al., 2014). Inserts were placed in such position, that all of them along one side were mounted with their dorsal face up, while at the opposite side all of them were mounted with their dorsal face down (Fig. 2: 14; 11: 1–2). Similar way of mounting inserts was also observed by S.V. Oshibkina at Veretje 1 site (Oshibkina, 1989, 1999) and the author in Stanovoye 4 (Zhilin, 1998, 2001). It had no practical sense, but because it was repeatedly used it had some meaning for Mesolithic hunters who made such arrowheads.

Treatment of several artifacts is of special interest and should be described separately. One long needle shaped arrowhead from the lower layer (Fig. 2: 5) is supplied with a relief belt situated at the border between the stem and tang of the arrowhead. This belt was first marked with circular grooves which were removed by further whittling, and only their deepest parts are visible under the microscope. Ornamentation in the shape of a very dense fine spiral running over the stem was carved with a burin with a very sharp working edge in the middle of the stem and at its bottom near the relief belt. It is clearly seen under the microscope that traces of the burin are mostly parallel to each other, but some are crossing at very acute angles (Fig. 6). It is also worth noting that elevations of micro relief of the artifact surface are altered with this treatment, while micro depressions are not affected. Such traces are characteristic for various round artifacts worked with the help of a turning lathe, when the worked item was rotating, while the burin was slowly moving along it. Crossing of some traces indicates that the burin was not firmly fixed as in modern turning lathes, but most probably held in the hand of a worker. After ornamentation the arrowhead was brightly polished, most probably with hide or other organic polisher.

A narrow flat arrowhead from the middle Mesolithic layer (Fig. 3: 1) has a wedge-like bevel, very carefully treated with longitudinal whittling, which left very accurate parallel traces on a very flat and smooth surface on both sides of the bevel (Fig. 7: 4–5). Our experiments showed that such an accurate very flat surface with similar traces is achieved as a result of whittling wet preform with a side of a burin scar when the burin is firmly mounted in a handle.

A two-winged arrowhead with barbs from the upper Mesolithic layer (Fig. 4: 6) has a hollow instead of a point, carefully modeled by longitudinal scraping. This hollow was used for mounting of a flint point, which is confirmed by finds of similar arrowheads with flint and quartz points in the late Mesolithic Oleneostrovskiy cemetery in Karelia (Gurina, 1956).

3.2. Use-wear traces on bone arrowheads

All studied arrowheads and their fragments with preserved point displayed more or less pronounced use-wear under the

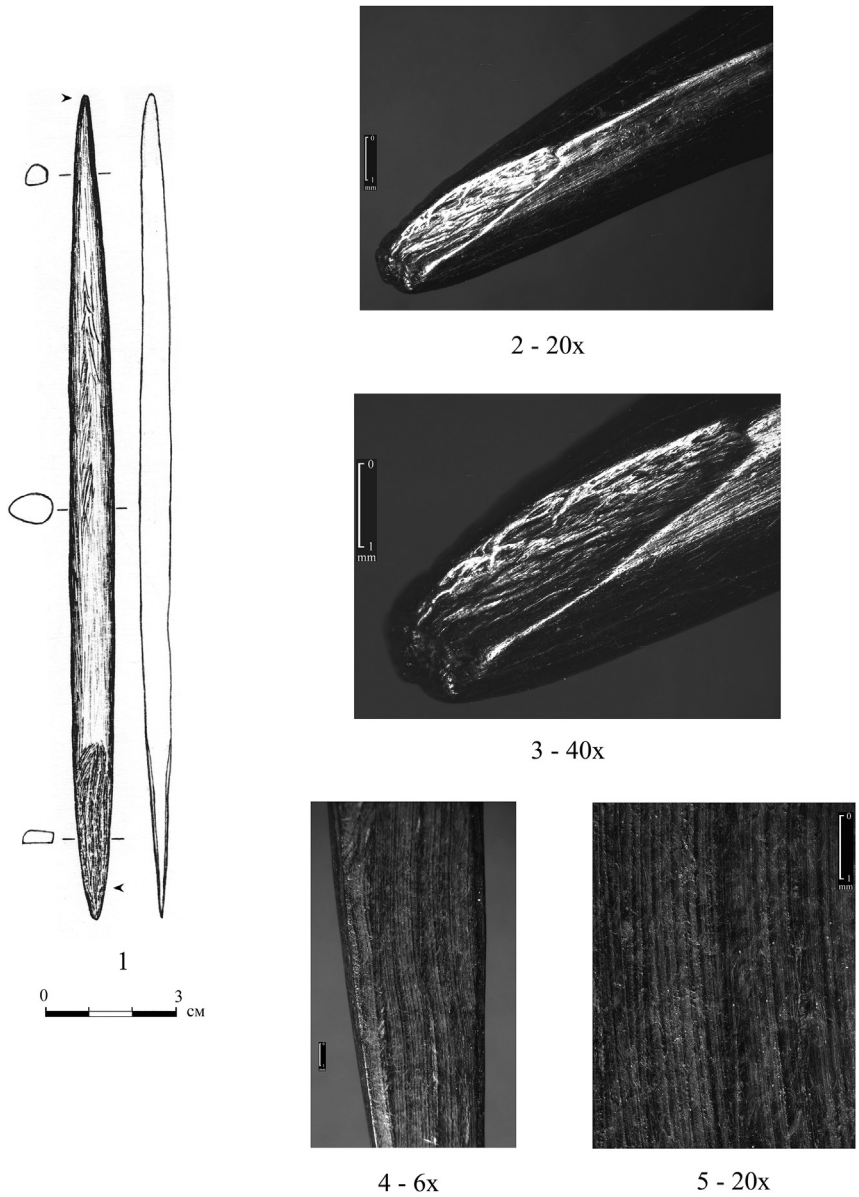

Fig. 7. A narrow flat arrowhead, layer III.

microscope. On the majority of artifacts it included rounding, smashing or chipping of the tip; small or larger flat or semi-flat facets running from the tip along one or two, sometimes more sides of the point; "hide" polishing, running from the tip, gradually disappearing; fine and sometimes also coarse striations, running from the tip along the axis of an arrowhead or/and at acute angles to it. Similar traces were also observed on the points of our experimental arrowheads after hitting the target made of peat and covered with fresh wild boar skin. Rounding and smashing of tips of experimental arrowheads were rather well pronounced. "Hide" polishing was very gentle, and only several scarce striations were observed after several shots, resembling Fig. 8. At most studied arrowheads from Ivanovskoye 7, use-wear was not well developed (Fig. 8), indicating rather short use, but some of them displayed very good use-wear patterns.

One narrow flat arrowhead from layer III (Fig. 3: 1) displays a facet about 5 mm long running at an acute angle from a smashed tip along the axis of the artifact (Fig. 7: 2–3). On the other side of the point of this arrowhead, smaller flat facets are observed. Such macrowear is typical for hitting some hard material and was observed on many arrowheads which hit rocky cave walls from Mesolithic cave sanctuaries in the Urals (Chairkin and Zhilin, 2005; Serikov, 2009), and on some experimental projectile heads (Cattelain, 1997; Petillon and Plisson, 2006; Petillon and Langlaix, 2011). One of our experimental arrowheads was broken when it hit a stone in the target. Flat scars similar to those described were observed on the tip of its broken point. The tip is rounded, and bright polishing runs from the tip, covering the surface of described facets indicating that the arrowhead was used after damage of its tip. Inside this polish, long and short fine striations run from the tip at a very acute angle to the axis of the arrowhead, indicating multiple hits on soft medium dirty material.

The point of a fragment of a long needle-shaped arrowhead from layer IV (Fig. 2: 11: 9: 1) was supplied with a gentle step. It is rounded and smoothed, and bright polishing runs from the tip, gradually dulling. Inside this polishing, fine striations and coarse grooves running from the tip at acute angle to the artifact axis are clearly visible (Fig. 9: 2–3). Fine striations resulted from multiple

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

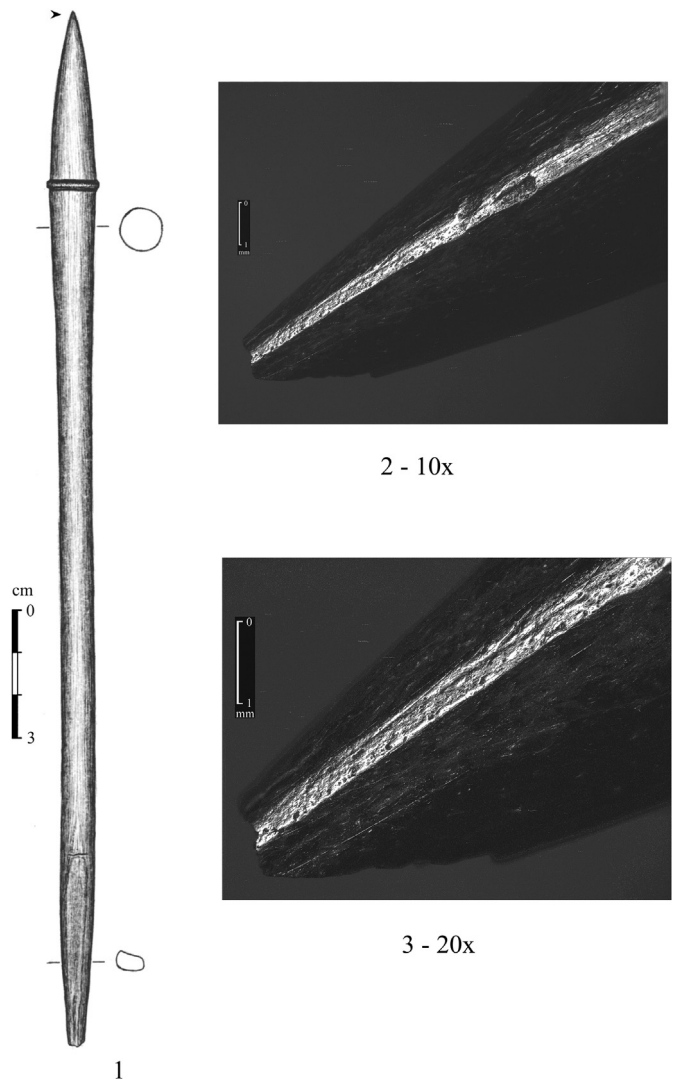

Fig. 8. An arrowhead with thickened head, layer III.

hits on soft medium dirty materials, while grooves indicate hitting the ground during long use of this arrowhead.

The point of a slotted needle-shaped arrowhead from layer IV (Fig. 2: 7; 10) was smashed as a result of hitting some hard material, and flat facets running from the tip are observed at one side of the artifact point. An oblique breakage scar accompanied by chipping facets, polishing, grooves and fine striations running from the tip along the axis of the arrowhead are seen at its other side (Fig. 10). This arrowhead was also used for a long time, hitting hunted animals and the ground when missed the target. Traces of repair (or several repairs?) partly removed the slot at both its point and bevel. Finally, it was broken in two pieces which were found at a distance of several meters from each other.

The point of an arrowhead with a barb from layer III (Fig. 3: 6; 9: 4) was broken and resharpened with a burin, which left characteristic traces in the shape of longitudinal groves, running towards the tip with clear parallel striations on their bottom (Fig. 3: 5–6). The surface of the point of the artifact is smoothed, the tip rounded, and bright polishing runs from the tip, gradually disappearing. Within the polishing, long and short fine striations running from the tip along the axis of the arrowhead are observed. While burin traces are preserved at the bottom of grooves, left by the instrument, use-wear striations occupy elevations on the surface of the artifact as well as slopes of elevations and depressions (Fig. 9: 6).

A small barbed point (Fig. 2: 13) was found in layer IV stuck in the lake bottom near the ancient shoreline at an angle about 70°. The small tang of this artifact is identical to tangs of other small arrowheads and indicates similar hafting and use of this point as an arrowhead. This position supposes shooting into the water from a very short distance. The tip of the artefact's point is rounded, and dull matt polishing runs from it gradually disappearing. Inside this polishing, multiple long fine striations with illegible sides run from the tip (Fig. 9: 8–10) up to the first barb and some even further. Observed use-wear traces and the position of this arrowhead stuck in the lake bottom near the shore most probably indicate that it was used for shooting pike, but missed the target. Pike dominates among fish remains from this layer of Ivanovskoye 7, which was inhabited during warm seasons as indicated by numerous remains of migrating waterfowl, hazelnut shells and bones of some juvenile mammals taken (Zhilin and Karhu, 2002; Zhilin et al., 2002). During warm weather, pike likes to warm itself in shallow water near the surface, and that is the best time for shooting it.

Rounding, chipping and small pits are observed at the tip of the point of a slotted narrow flat arrowhead with flint inserts from layer IV (Fig. 2: 14). Dull polishing runs from the tip, gradually disappearing covers the point of the arrowhead. Furthermore, inside this polishing two types of linear traces are observed (Fig. 11: 3–5). The first is represented by straight thin striations and scarce grooves running from the tip along the axis of the arrowhead. Other linear traces are thin short striations running from the tip in a screw-like pattern at an acute angle to the axis of the artifact. Some of the latter overlap straight striations of the first group. Traces on the point of the arrowhead indicate multiple penetration into soft medium dirty material and also some hits into the ground at a small depth. The latter is indicated by grooves at the tip and nearby and the absence of such grooves less than 2 cm from the tip and further. Besides these, various deformations caused by its long use and by natural damage in the cultural layer are observed on its surface. The microscopic study of inserts shows that their edges are rounded and smoothed and that they bear traces of abrasion (Fig. 11: 6–7). Such features are probably connected with keeping this arrow in the quiver together with other arrows when arrowheads were in contact with each other. Besides this, inserts display utilization chipping on their edges, and some also display micro scars, resembling burin scars on their angles. Scarce thin strips of oriented polishing running from the point of the arrowhead at an acute angle to the edge of an insert, sometimes almost parallel to it, were observed at some inserts, especially at the second insert from the left (Fig. 11: 8) and the third insert from the right side. Scarce thin scratches running in the same direction were also discovered there. Such traces probably emerged from multiple sliding contacts with bones, sinew, cartilage and dirty skin of animals when the arrowhead hit the target. As a result of such contact, chipping of edges of inserts took place, and this tiny flint chips were sliding across the surface of other inserts and could also leave the observed linear traces (Skakun et al., 2014).

3.3. Traces of glue

Two types of glue were recognized in slots and on bevels of bone arrowheads from Ivanovskoye 7. The first one was observed in the slot of a one-winged arrowhead from layer IV (Fig. 2: 9). It is brown, looking like resin, semi-transparent and shining on breakage with characteristic wavy surface of a facet like on glass or flint. Imprints of three microblades were observed in this glue, the first and the second were unretouched, while the last one opposite to the barb on the other side of the arrowhead preserved traces of several

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

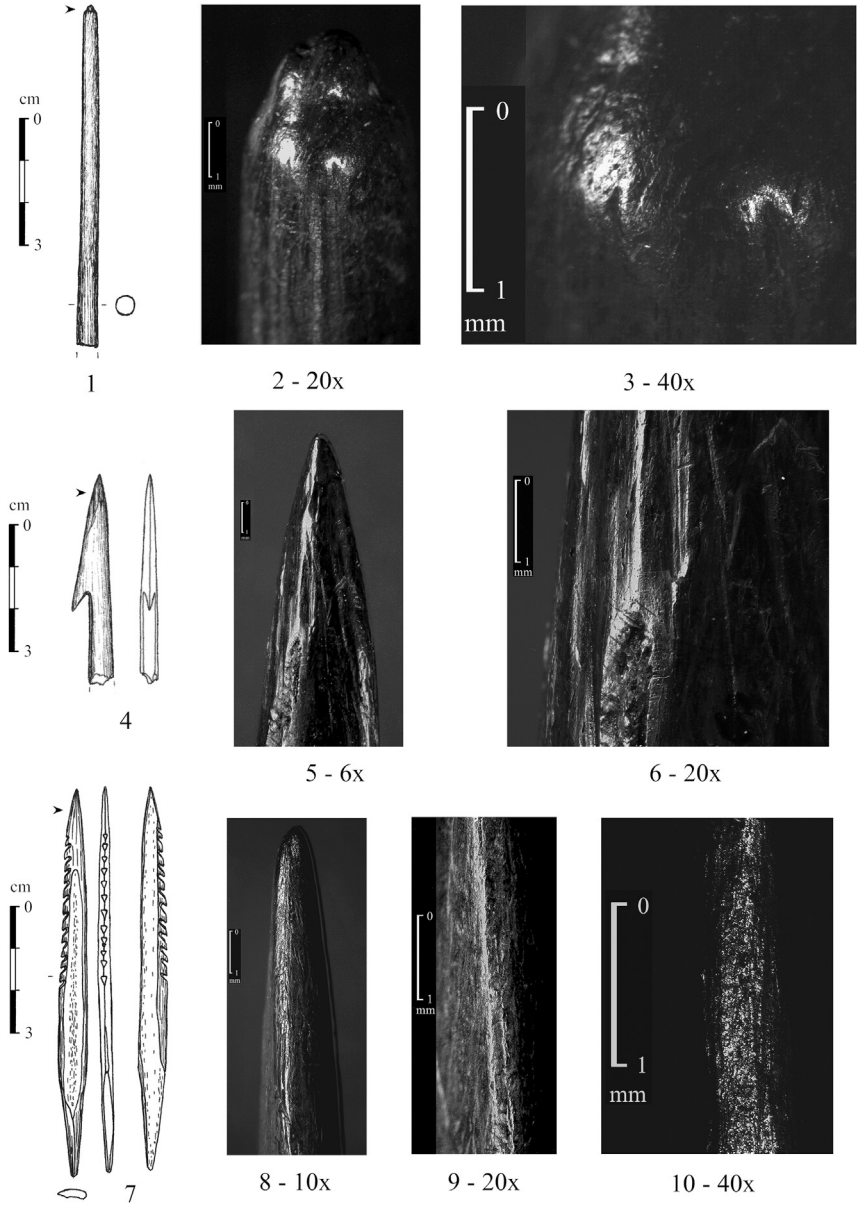

Fig. 9. 1–3 – A needle-shaped arrowhead, layer IV; 4–6 – an arrowhead with a single barb, layer III; 7–10 – a unilateral barbed arrowhead, layer IV.

facets of steep retouch forming obliquely truncated end of this insert. Similar glue was produced in experiments by melting pure pine and spruce pitch without any admixtures. It was rather fragile and not strong enough, but still able to fix inserts.

The other type of glue was observed in both slots of a narrow flat arrowhead from the lower layer (Fig. 2: 14). Under the microscope this glue looks like grayish-brown, matt micro granular substance at breakage with a lot of tiny charcoal particles. In experiments, such glue was made as a mixture of coniferous (pine or spruce) pitch, beeswax and charcoal dust. It was very good for fixing projectile inserts. Similar looking glue was also made by melting pine pitch on one of stones, encircling the camp fire and adding ash from the hearth until the glue became not liquid, but not solid. This glue was put into the slot of an arrowhead and microblades were mounted into it. The extra portion of glue which was pressed out from the slot was removed by a longitudinal movement, as in Ivanovskoye 7. This glue was also very good when hardened, and inserts remained in their position in the slot after several shots and hitting the target. Remains of similar glue were observed on bevels of two arrowheads from the middle Mesolithic layer: one with a thickened head (Fig. 3: 2), another with a single barb (Fig. 3: 5). A needle-shaped arrowhead with a short slot from the upper Mesolithic layer (Fig. 4: 4) preserved similar glue with an imprint of an unretouched microblade insert in the slot, and also traces of the same glue on its bevel. Similar glue, also with an imprint of an unretouched microblade insert, was preserved in the slot of another arrowhead from the same layer (Fig. 4: 5). Samples of glue from Ivanovskoye 7 site are in process of chemical analysis at Tartu University in Estonia.

4. Discussion

4.1. Pretreatment of bone

As indicated above, bone is much easier worked by scraping, grooving, carving, whittling, sawing, drilling after softening. Based

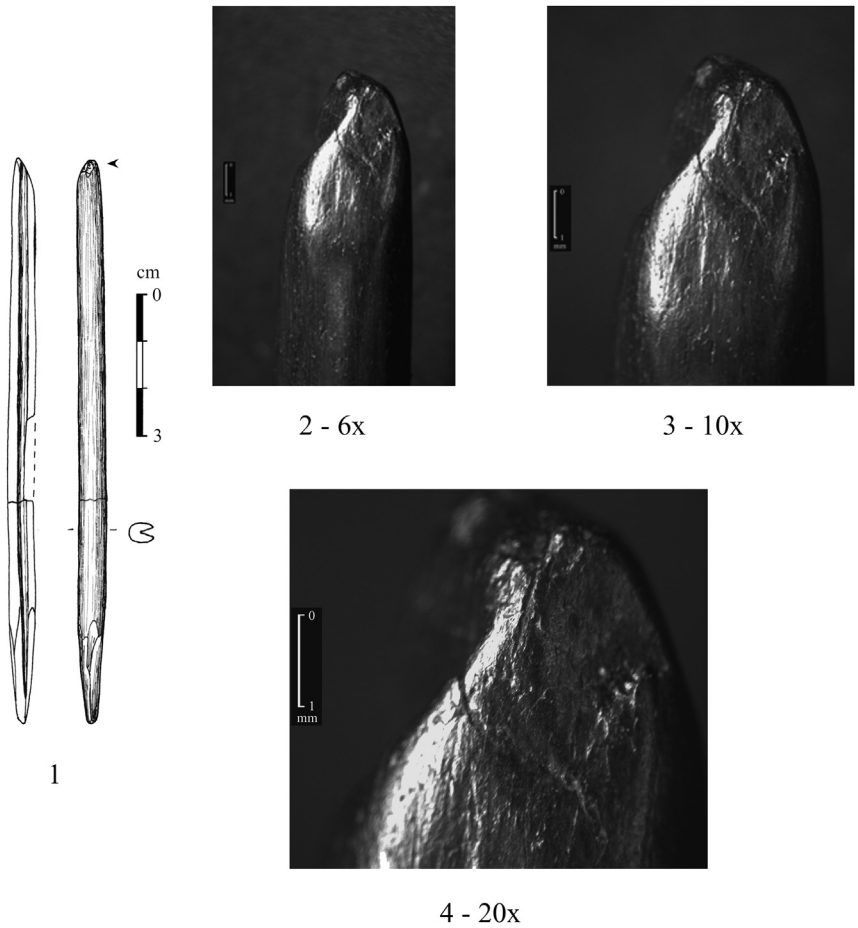

Fig. 10. A needle-shaped slotted arrowhead, layer IV.

on archaeological and ethnographic data researchers supposed softening bone by wetting (Zhilin, 2001; Savchenko, 2010), wetting and heating (Gurina, 1956; Semenov, 1965), and/or chemical treatment (Malinova and Malina, 1988). The best results were achieved by wetting bone preforms in water mixed with ash for two months (Serikov and Tupikov, 2015). After it, preforms made from mammalian long bones were easily worked by whittling, as if one was whittling wood. Long regular traces of whittling, observed on some preforms (Fig. 2: 1) and finished arrowheads suggest that similar treatment of bone could be used in all Mesolithic layers of Ivanovskoye 7. That employment of direct percussion technique needs dry bone, which is more fragile and rather easily knapped by a hammerstone. Probably fragments of long bones were dried after extracting marrow before shaping into preforms by percussion. Preforms were also put into water, as indicated by the preform made by percussion from a long elk bone in layer III, found in gyttja near the shoreline of the site (Zhilin et al., 2002, Fig. 29). The preform was 43 cm long, and it is hard to loose such a thing. It was intact and very carefully treated to throw it away. Another preform (Fig. 5: 3) displays long regular traces of whittling removing percussion facets, which indicate most probably softening of preforms after percussion. Our experiments showed that it took about 3–4 h to produce the majority of studied arrowheads with flint tools, similar to those found at the site. We used simple softening of blanks and preforms by wetting, and if chemical softening was employed, less time could be needed.

4.2. Operation sequence (Chaîne opératoire)

The following operation sequence in the manufacture of bone arrowheads in Mesolithic layers of Ivanovskoye 7 site was established: preparing long elk bone by wetting (for future grooving) or drying (for future breaking by percussion) → obtaining blank by "groove and splinter" technique or by percussion → shaping preform by coarse scraping or whittling → carving details, grooving slots (for slotted arrowheads) → fine longitudinal whittling or scraping → engraving ornamentation → fine abrasive grinding → bright smooth polishing → placement of inserts (for composite arrowheads). This operation sequence was not always full, a number of studied artifacts were used without ornamentation and/or polishing.

In only one case, a pattern composed of very fine crossing lines was engraved over the brightly polished surface on the stem of an arrowhead from the lower layer (Fig. 2: 6), while ornamentation of its head was done before polishing, following the standard scheme for Mesolithic bone arrowheads of the forest zone of Eastern Europe (Zhilin, 2001). This arrowhead was found in an unusual position – deeply vertically stuck up to its tang in the sandy lake bottom near the ancient shoreline which existed during the site habitation (Zhilin et al., 2002). The use-wear is in its initial stage and includes chipping and rounding of the tip of the point, and only several short grooves and striations running from the tip along the arrowhead axis (Fig. 12). Such use-wear most probably emerged from a single shot from a very short distance into the sandy lake bottom. Other studied arrowheads of this type from Ivanovskoye 7

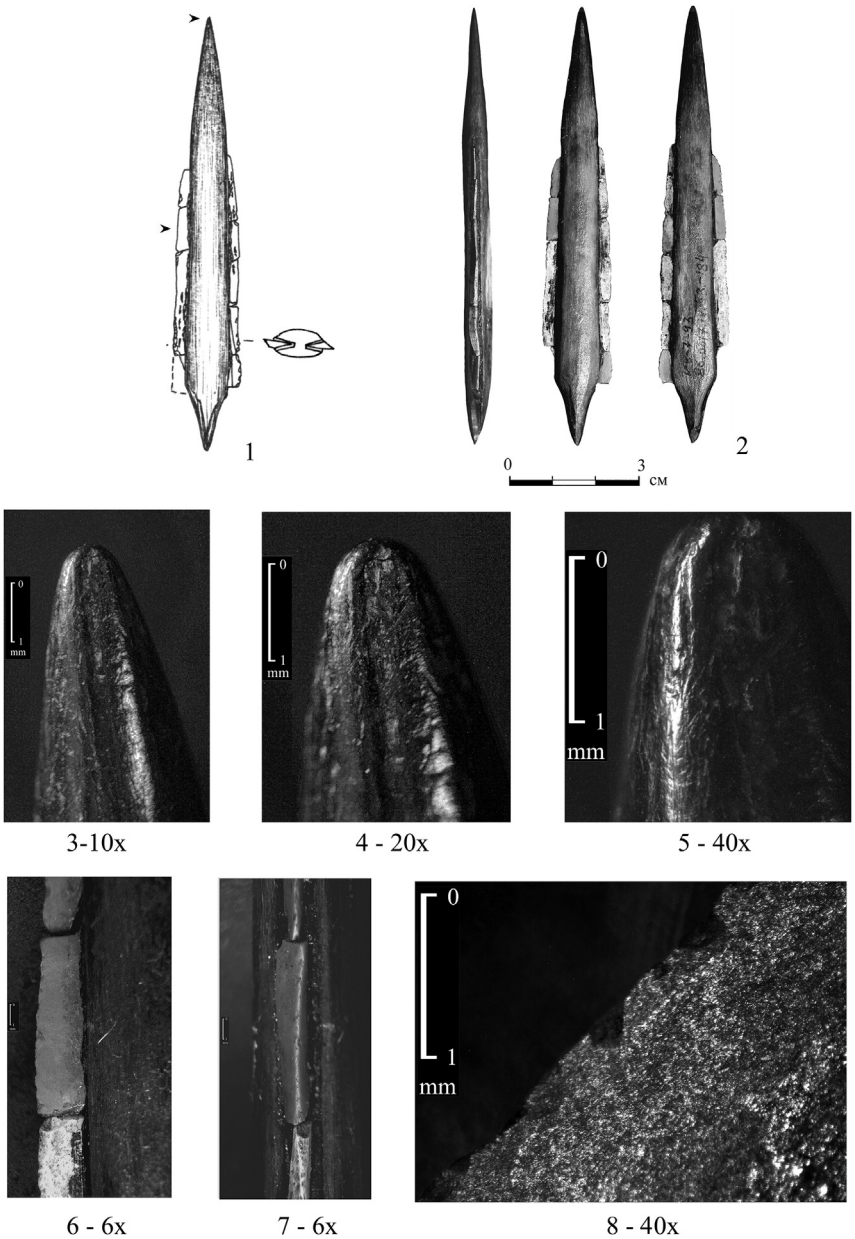

Fig. 11. A narrow flat slotted arrowhead with flint inserts, layer IV.

and some other Mesolithic sites from European Russia and Trans-Urals displayed usual use-wear traces, described above. These facts (very careful treatment, rich ornamentation, additional engraving, unusual position and evidently use of the artifact for a single shot) put together may indicate a special meaning of this arrowhead, probably connected with some ritual activity.

4.3. The use of turning lathe

The use of a turning lathe for decoration of bone arrowheads before polishing also deserves some special attention. In Central Russia, such arrowheads are scarce and were found, besides the lower layer of Ivanovskoye 7, also in the lower layer of Ivanovskoye 3 (Oshibkina et al., 1992), Berendeevo 18 (Zhilin, 1993), lower layer of Ozerki 16 (Zhilin, 2006b) and as a stray find from the Dubna river near Moscow (Zhilin, 1993). The lower layer of Ivanovskoye 7 and Berendeevo 18 are dated to the Pre-boreal period. In the lower layer of Ivanovskoye 7, the long arrowhead (Fig. 2: 5) was found in horizontal position in the main concentration of artifacts. During habitation of this site, it was a dry lake shore near the water. The arrow was not shot into the lake bed. In the middle of the Preboreal period about 9500 BP this area was submerged, and a layer of sterile gyttja about 20 cm thick without any archaeological finds sealed it. The lower layer of Ozerki 16 is dated to the early Boreal period. Two fragments of an arrowhead decorated in a turning lathe manner were found in horizontal position at a distance about 2 m from each other among other finds in the bottom of the peat layer. During the habitation of the site, it was also a lake shore, and swamping started there about 8770 BP and buried the site. The arrowhead from Ivanovskoye 3 site was found deeply stuck in the lake bottom and overlaid by the late Mesolithic layer, which indicates it is early or middle Mesolithic, i.e. Pre-boreal or Boreal periods. After the middle Mesolithic, such treatment and the use of a turning lathe are not known in Central Russia until the Middle Ages. The turning

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

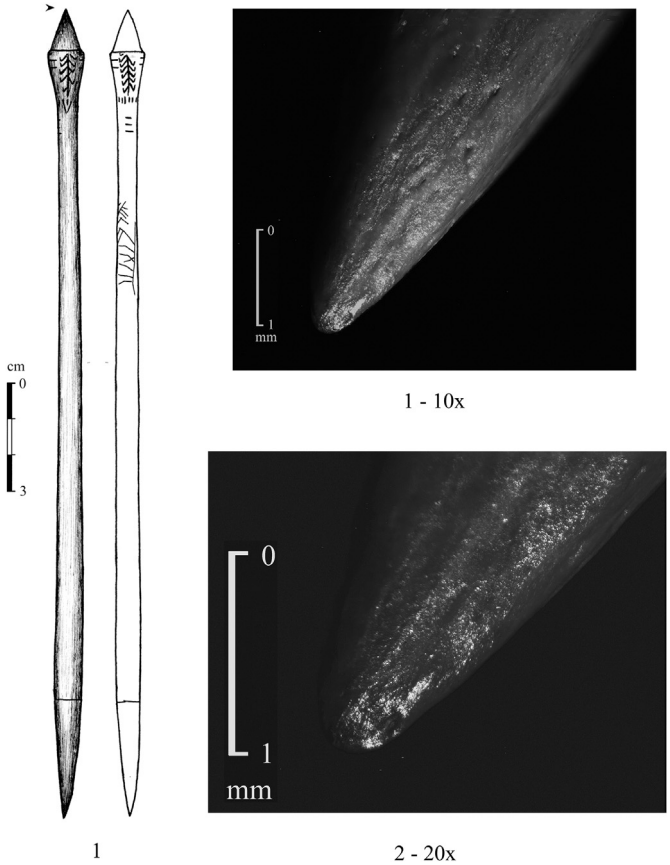

Fig. 12. An arrowhead with thickened biconical head, layer IV.

lathe treatment was not used for shaping arrowheads, but only for decoration of already finished artifacts before final bright polishing. Scarcity of such finds and a very specific treatment may also indicate a special meaning of these arrowheads, or special care of their makers. During the late Neolithic – Aeneolithic, similar decoration of bone arrowheads was used in Trans-Urals (Serikov and Tupikov, 2015, Fig. 1). This technology was also used not for shaping, but for decoration of arrowheads, and it was applied only to short biconical arrowheads, which were produced in large numbers. Yu. B. Serikov made an experimental reconstruction of a horizontal turning lathe supplied with a bow and operated by two persons – one was pulling and pushing the bow, while the other was holding the burin fixed in a handle (Serikov and Tupikov, 2015, Fig. 2). This lathe and method of its use were quite useful for the decoration of arrowheads. Most probably, a similar turning lathe was also used in the early and middle Mesolithic in Central Russia, although we cannot exclude other possible constructions.

4.4. Linear traces and rotation of an arrow

Two types of striations observed at arrowheads from Mesolithic layers of Ivanovskoye 7 indicate different behavior of arrows supplied with the studied arrowheads. Straight striations, running along the artifact axis, emerge when the arrow is not rolling over its axis when it hits the target. Screw-like traces originate when the arrow is rolling over its axis when hitting the target. Experiments showed that this is controlled by the fletching of the arrow. The coexistence of both types of linear traces on one arrowhead (Fig. 11: 5) most probably indicates the change of fletching and, possibly, the shaft during the use of this arrowhead. Most probably it was connected with its breakage and reshaping of the tang. Some screw-like traces overlap the straight ones, indicating that first the arrow was not rolling, and started rolling after repair.

4.5. Duration of use

Long slender arrowheads were rather fragile, and many of them were found broken. After breakage, most arrowheads were abandoned, but some were repaired and reused (Fig. 2: 7, 14; 3: 6). The point of one was broken, resharpened, and used afterwards (Fig. 9: 4–6). The other was broken in the middle, and a new tang was made at the place of the breakage, partly removing the slots, while the point and inserts remained unchanged (Fig. 11). The third, most probably, was repaired several times, the point was resharpened and the tang reshaped, and the slot was partly removed at both ends (Fig. 10). All three repaired arrowheads display very well pronounced use-wear indicating long use. From Siberian ethnographic data, we know that arrows that have taken the hunted mammals were considered the best ones and were treated with special care (Teploukhov, 1880; Serikov, 2009). Probably we can say the same about these three arrowheads from Ivanovskoye 7.

4.6. Development and analogies

Comparison of studied arrowheads from different layers of Ivanovskoye 7 shows that almost all methods of their production and more than half of their types were already represented in the early Mesolithic layer. During the middle and late Mesolithic, most of these methods and types survived, while some were abandoned and new ones invented. Development of bone arrowheads, their production and use were following the general pattern characteristic for the Butovo culture which developed in Central Russia from the beginning until the end of the Mesolithic (Zhilin, 2001, 2006a, 2009).

Comparison with nearby and more distant territories shows a number of similar schemes of the production of similar types of arrowheads from Eastern Baltic (Jaanits and Jaanits, 1975, 1978; Zagorska, 1980; Zagorska and Zagorskis, 1989; David, 2003) through Central and Northern Russia (Oshibkina, 1999; Zhilin, 2001) to Trans-Urals (Savchenko, 2014). There are a number of local types of bone arrowheads and technological solutions. During the entire Mesolithic, bone points played the main role as arrowheads from Eastern Baltic to Trans-Urals, the number and diversity of flint arrowheads at sites over this vast territory were substantially inferior (Zhilin, 2001). Needle-shaped arrowheads were found in Pulli in Estonia; Zveinieki 2 (lower layer) and Sulyagals in Latvia. An arrowhead with a smooth thickened head was found in Pulli. Narrow flat arrowheads without a tang or with a short tang were found in Pulli and Sulyagals. Similar artifacts with a long slot for inserts along one or both sides come from Pulli, Zveinieki 2 (lower layer) and Sulyagals. A fragment of a paddle-shaped arrowhead was found at Zveinieki 2 (lower layer). Such types as one-winged slotted and barbed arrowheads are not known from early Mesolithic sites in Eastern Baltic, and points of Lubana type were not present at early Mesolithic sites of the Upper Volga. However, the semblance in types of early Mesolithic arrowheads and technology of their manufacture in the Upper Volga area and in Eastern Baltic is greater than the difference, which indicates regular communication and existence of social networks among population of these regions, what is also confirmed by the spread of Pulli type flint arrowheads, some types of retouched inserts, and specific types of flint raw material from Eastern Baltic to the Upper Volga (Zhilin, 2003a, 2003b; Jussila et al., 2012). During the Boreal period, there was further development of bone arrowheads in Mesolithic cultures of Eastern Europe. Stronger semblance in types and technology of the manufacture of bone arrowheads can be seen

between Veretye and Butovo cultures, and the difference between them and Kunda culture is more pronounced. On the other hand, the presence of single finds of typical Lubana type points in Veretye 1 and Ivanovskoye 3 indicates that contacts between population of different regions of this territory were still active (Zhilin, 2001). Arrowheads from late Mesolithic sites of the Upper Volga show more semblance with Oleneostrovski cemetery, while some common types (with irregular thickened head, one- and two-winged with barbs) are also observed at synchronous sites of Eastern Baltic. Comparison of arrowheads of described sites with arrowheads of Duvensee and Maglemose cultures shows much more difference than semblance. Bone arrowheads in general played no significant role in the latter, arrows here were supplied mainly with various flint points and microliths. Only one type of points which was probably used as arrowheads – needle-shaped points find close analogies in Eastern Europe. Slotted bone points with flint inserts appear in Denmark and Scania in the second part of the Boreal period and differ from East European artefacts in the position and morphology of inserts in slots (Althin, 1954; Clark, 1975; Gramsch, 1990; Larsson and Sjostrom, 2013).

Peat bog sites of the Trans-Urals area also produced bone arrowheads: needle-shaped, narrow flat slotted, one-winged with barbs, paddle-shaped and arrowheads with thickened head (Savchenko 2010, 2014). Some look very similar to bone arrowheads from Mesolithic peat bog sites of Butovo, Veretje and Kunda cultures, but difference in details is observed. Further in Siberia, only needle-shaped and slotted arrowheads were met at Mesolithic sites which can be compared with similar artefacts from Eastern Europe.

5. Conclusions

Microscopic and experimental research of bone arrowheads from a multilayer peat bog site Ivanovskoye 7 in Central Russia made it possible to determine how they were made and used. All arrowheads were rather well made employing a standard operation chain, and some artifacts were treated with special care. Since the early Mesolithic, technology of the manufacture of bone arrowheads was rather sophisticated and made possible production of various types of these artifacts. During the middle and late Mesolithic, most of these methods and types survived, while some were abandoned and new ones invented. Development of bone arrowheads, their production and use followed the general pattern characteristic for the Butovo culture which existed in Central Russia from the beginning to the end of the Mesolithic. Use-wear traces indicate hitting some soft medium dirty, occasionally hard material, most probably hunted animals. Some arrowheads also display traces from hitting the ground, evidently, when the arrow missed the target. Only one small barbed arrowhead showed traces of multiple hitting a silty and sandy lake bottom, and was used, most probably, for shooting fish. Use-wear traces on the majority of studied arrowheads indicate their use for a rather short time, but some arrowheads display very well developed use-wear and traces of repair which point to their long use. Described research showed the skill of Mesolithic inhabitants of Ivanoskoye 7 site in the manufacture of bone arrowheads, which they used for hunting various animals. Numerous bones of the latter from Mesolithic layers (Zhilin, 2014) confirm this, and together with hunting and fishing gear demonstrate successful adaptation of the Mesolithic population of Central Russia to the early Holocene environment.

References

Althin, C.-A., 1954. Man and environment. A view of the Mesolithic material in Southern Scandinavia. Meddelanden franLunds universitets historiska museum VI, 1–19, 1953/1954.

Cattelain, P., 1997. Hunting during the Upper Paleolithic: bow, spearthrower or both? In: Kneht, H. (Ed.), Projectile Technology. Plenum press, NY, pp. 213–240.

Chairkin, S.E., Zhilin, M.G., 2005. Mesolithic materials from cave sites of the forest Trans-Urals. In: Zhilin, M.G. (Ed.), The Stone Age of the Forest Zone of Europe and Trans-urals. Academia, Moscow, pp. 252–273 (in Russian).

Clark, J.G.D., 1975. The Earlier Stone Age Settlement of Scandinavia. Cambridge.

David, E., 2003. The Mesolithic Zvejnieki site (Latvia) in its European context: preliminary results delivered by a technological study of the bone and antler industry. Eesti Archeologia Ajakiri 7 (2), 99–122, 2003.

Gramsch, B., 1990. Die Frühmesolithischen Knochenspitzen von Friesack, Kr. Naumen. In: Veröffentlichungen des Museums für Ur- und Frügeschichte Potsdam, Bd. 24/1990, pp. 7–26.

Gurina, N.N., 1956. Oleneostrovskiy Cemetery. Materials and Research of the Archaeology of the USSR. Nauka, Moscow-Leningrad (in Russian).

Hartz, Sonke, Terberger, Thomas, Zhilin, Mikhail, 2010. New AMS-dates for the Upper Volga Mesolithic and the origin of microblade technology in Europe. Quartar 57, 155–169.

Jaanits, L., Jaanits, K., 1975. Fruhmesolithische Siedlung in pulli. In: Eesti NSV Teaduste Akadeemia, Toimetised, Uhiskonnateadused, pp. 64–70. Roide 24, N 1.

Jaanits, L., Jaanits, K., 1978. Ausgrabungen des Fruhmesolithische Siedlung in Pulli. In: Eesti NSV Teaduste Akadeemia, Tjimetised, Uhisknnateadused, pp. 56–63. Roide 27, N 1.

Jussila, T., Kriiska, A., Rostedt, T., 2012. Saarenoja 2 – an early mesolithic site in south-Eastern Finland: preliminary results and interpretations of studies conducted in 2000 and 2008–10. Fennoscandia archaeologica XXIX, 3–27.

Larsson, L., Sjostrom, A., 2013. Mesolithic research in the central part of Scania, southern Sweeden. In: Johanson, Kristiina, Tõrv, Mari (Eds.), Man, His Time, Artefacts and Places. Collection of Articles Dedicated to Richard Indreko. Muinasaja Teadus, Tartu, pp. 487–516.

Malinova, R., Malina, Ya, 1988. A Jump into the Past. Experiment Opens Secrets of Ancient Epochs. Mysl, Moscow (in Russian).

Oshibkina, S.V., 1989. The material culture of the veretye-type sites in the region to the east of Lake Onega. In: Bonsall, Clive (Ed.). The Mesolithic in Europe, Edinburgh, pp. 402–413.

Oshibkina, S.V., 1999. Tanged point industries in the North-West of Russia. In: Kozlowski, S., et al. (Eds.), Tanged Points Cultures in Europe. Lublin University, Lublin, pp. 325–332.

Oshibkina, S.V., Krainov, D.A., Zimina, M.P., 1992. The Art of the Stone Age. Nauka, Moscow (in Russian).

Petillon, J.-M., Plisson, H., 2006. The effect of frost on the breakage patterns of antler projectile points. In: II Northern Archaeological Congress. Abstracts. Charoid publishers, Ekaterinburg – Khanty-mansiisk, pp. 251–252.

Petillon, J.-M., Langlaix, M., 2011. Evolution of bone and stone weapons of final Paleolithic epoch: Magdalenian communities (20000–14000 cal. BP) in south-western Europe. In: Khlopachev, G. (Ed.), Bone Weapons and Art Objects in Ancient Cultures of Northern Eurasia (Technological and Functional Aspects). Nauka, Sankt-Petersburg, pp. 69–96.

Savchenko, S.N., 2010. Experiments on manufacturing techniques of mesolithic and early neolithic slotted bone projectile points from eastern urals. In: Legrand-Pineau, A., Sidéra, I., Buc, N., David, E., Scheinsohn, V. (Eds.), Ancient and Modern Bone Artefacts from America to Russia. Cultural, Technological and Functional Signature, British Archaeological Reports International Series 2136, 324, pp. 141–147.

Savchenko, S.N., 2014. Continuity and innovations in the development of bone industry of the Mesolithic of mountainous forest Trans-Urals. Stratum plus 1, 181–208 (in Russian).

Semenov, S.A., 1965. Prehistoric technology. Cambridge.

Serikov, Yu B., 2009. Cave Sanctuaries of the Chusovaya River. Tagil print, Nizhnii Tagil (in Russian).

Serikov, YuB., Tupikov, I.N., 2015. To the question of chemical softening of bone in antiquity. In: Chernykh, I.N. (Ed.), Tver Archaeological Proceedings. Tver, vol. 10, pp. 304–311 (in Russian).

Skakun, N., Zhilin, M., Terekhina, V., 2011. Technology of the processing of bone and antler at Ivanovskoje 7 Mesolithic site, Central Russia. Rivista di Scienze Preistoriche LXI, 39–58.

Skakun, N., Zhilin, M., Terekhina, V., 2014. The history of one arrowhead from a peat bog site in Central Russia (Technological and use-wear studies). In: Marreiros, João, Bicho, Nuno, Gibaja Bao, Juan (Eds.), International Conference on Use-wear Analysis: Use-wear 2012. Cambridge Scholars Publishing, Newcastle upon Tyne, pp. 430–440.

Teploukhov, A.E., 1880. About prehistoric sacrificial places in the Urals mountains. Proceedings of the Urals Society of Natural Sciences vol. 6 (1), 1–31. Yekaterinburg.

Velichko, A.A.(ed.), 1994. Short period and sharp landscape-climatic changes during last 15000 years. Moscow, 1994.

Zagorska, I., 1980. Das Fruhmesolithicum in Lettland. In: Veroffentlichungen des Museums fur Ur- und Fruhgeschichte. Potsdam, Band 14/15, pp. 73–82.

Zagorska, Ilga, Zagorskis, Francis, 1989. The bone and antler inventory from Zvejnieki II, Latvian SSR. In: Bonsall, Clive (Ed.), The Mesolithic in Europe. Edinburgh, pp. 414–423.

Zhilin, M.G., 1993. Bone Weapons of the Ancient Population of the Upper Volga. Russkaya ravnina, Moscow (in Russian).

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095

Zhilin, M.G., 1998. Technology of the manufacture of mesolithic bone arrowheads on the upper Volga. European Journal of Archaeology 1 (2), 149–175.
Zhilin, M.G., 2001. Mesolithic Bone Industry of the Forest Zone of Eastern Europe. URSS, Moscow (in Russian).
Zhilin, M., 2003a. Early Mesolithic peat bog sites on the Upper Volga. In: Bauerochse, Andreas, HaBmann, Henning (Eds.), Peatlands. Archaeological Sites – Archives of Nature – Nature Conservation – Wise Use. Proceedings of the European Peatland Conference 2002 in Hannover, Germany. Hannover, pp. 48–61.
Zhilin, M.G., 2003b. Early Mesolithic communication networks in the East European forest zone. In: Larsson, L., Lindgren, H., Knutsson, K., Loeffler, D., Åkerlund, A. (Eds.), Mesolithic on the Move. Papers Presented at the Sixth International Conference on the Mesolithic in Europe, Stockholm 2000. Oxbow Books, Oxford, pp. 688–693.
Zhilin, M.G., 2006a. Das Mesolithikum im Gebeist zwischen den Flussen Wolga und Oka: einige Forschungsergebnisse der letzten Jahre. Praehistorische Zeitschrift 81/1 (2006/1), 1–48.
Zhilin, M.G., 2006b. Mesolithic Peat Bog Sites of Tver Flow of the Volga River. IA RAN, Moscow (in Russian).
Zhilin, M.G., 2007. Mesolithic wetland sites in Central Russia. In: Lillie, Malcolm, Ellis, Stephen (Eds.), Wetland Archaeology and Environments. Regional Issues, Global Perspectives. Oxbow books, Oxford, pp. 65–78.
Zhilin, M.G., 2009. Chapter 23. Chronology and evolution in the Mesolithic of the Upper Volga – Oka interfluve. In: Crombe, Philippe, Van Strydonck, Mark, Sergant, Joris, Boudin, Mathieu, Bats, Mached (Eds.), Radiocarbon Chronology and Evolution within the Mesolithic of North-West Europe. Cambridge Scholars Publishing, Newcastle, pp. 451–472.
Zhilin, M.G., 2014. Early Mesolithic hunting and fishing activities in Central Russia: a review of faunal and artefactual evidence from wetland sites. Journal of Wetland Archaeology 14, 92–106.
Zhilin, M.G., Kostyleva, E.L., Utkin, A.V., Engovatova, A.V., 2002. Mesolithic and Neolithic Cultures of the Upper Volga Region. After Materials of the Site Ivanovskoye 7. Nauka, Moscow (in Russian).
Zhilin, M.G., Karhu, A.A., 2002. Exploitation of birds in the early Mesolithic of Central Russia. In: Proceedings of the 4th Meeting of the ICAZ Bird Working Group, Krakow, Poland, 11–15 September, 2001. Acta Zoologica Cracoviensia, 45, pp. 109–116 special issue.

Please cite this article in press as: Zhilin, M., Mesolithic bone arrowheads from Ivanovskoye 7 (central Russia): Technology of the manufacture and use-wear traces, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2015.09.095