Journal of Danish Archaeology vol. 2, 1983, pp. 43–59

Flint Axe Manufacture in the Neolithic

An Experimental Investigation of a Flint Axe Manufacture Site at Hastrup Vænget, East Zealand

by PETER VEMMING HANSEN and BO MADSEN

This study presents the results of an excavation of an axe manufacturing site of the Funnel Beaker Culture. Interpretations and hypotheses were experimentally tested in qualitative and quantitive investigations of process and product, by means of replicative manufacture of thin-butted, square flint axes and analysis of flake distribution patterns. Design and execution of the experimental activites took place at Lejre Research Centre in Denmark in 1982, performed by a group of archaeologists including two experimental flint workers: Peter Vemming Hansen (University of Copenhagen), Bo Madsen (University of Århus, Denmark) and Jacques Pelegrin (CNRS, France).

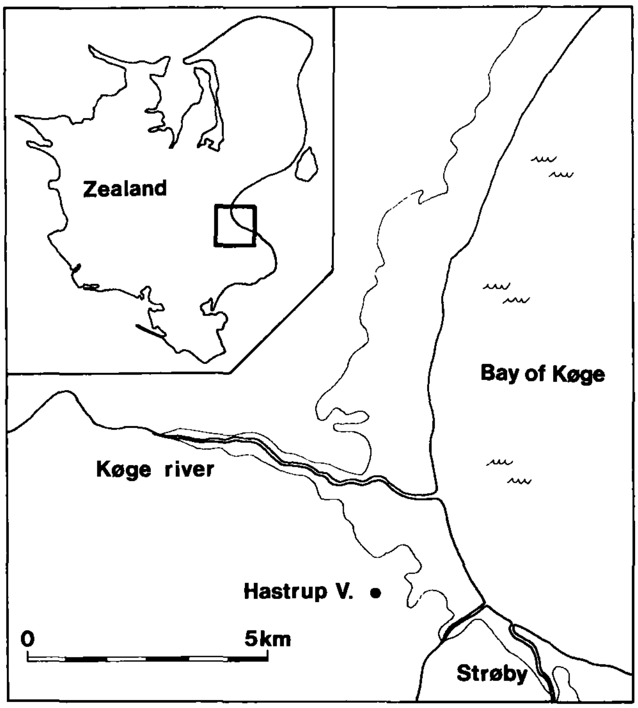


Fig. 1. The location of the Hastrup Vænget site.

THE HASTRUP VÆNGET FIND

The site was excavated in the summer of 1980, lying just south of Køge at Hastrup Vænget (1). It was situated in quite high terrain, on the east side of a gently sloping morainic hill and with a view over the former coast of the Litorina Sea at Køge Bugt (fig. 1).

Immediately north of Hastrup Vænget, the Køge River runs out into what was a former Littorina period fiord. The area round the site is still rich in flint, secondarily deposited both in morainic deposits and raised beaches. The Stevns peninsula is only 10 km to the east; since the early Atlantic period, the sea has there been uncovering the chalk bedrock and thereby has opened the way for exploitation of the richest primary sources of flint known in Zealand.

The Hastrup Vænget find (Hansen 1983) consisted almost entirely of waste flint (a total of 30,487 flakes weighing 168 kg). The flakes were discovered under a secondary, waterdeposited layer of clay, and lay clustered in an area of 6 × 4 m. Traces of normal settlement activities or definite features were not observed either at the find site or elsewhere in the vicinity.

The few other finds discovered consisted of sherds of a funnel beaker of type C or D (Becker 1947), and resharpening flakes from the edges of thin-butted polished flint axes, the narrow sides of which were polished. A few tools were also found: flake scrapers, a curved knife, borers and a transverse arrowhead.

The find is regarded as a single, closed unit, and the finds indicate a dating in the later early neolithic or middle neolithic I, around 3200 BC (calibrated).

The flint waste flakes were excavated using the »Lejre Method« (Fischer et al. 1979), i.e. collected up in units of 1/4 m^2. The map (fig. 2) shows the distribution of the find's flakes. There is a clear bimodal distribu-

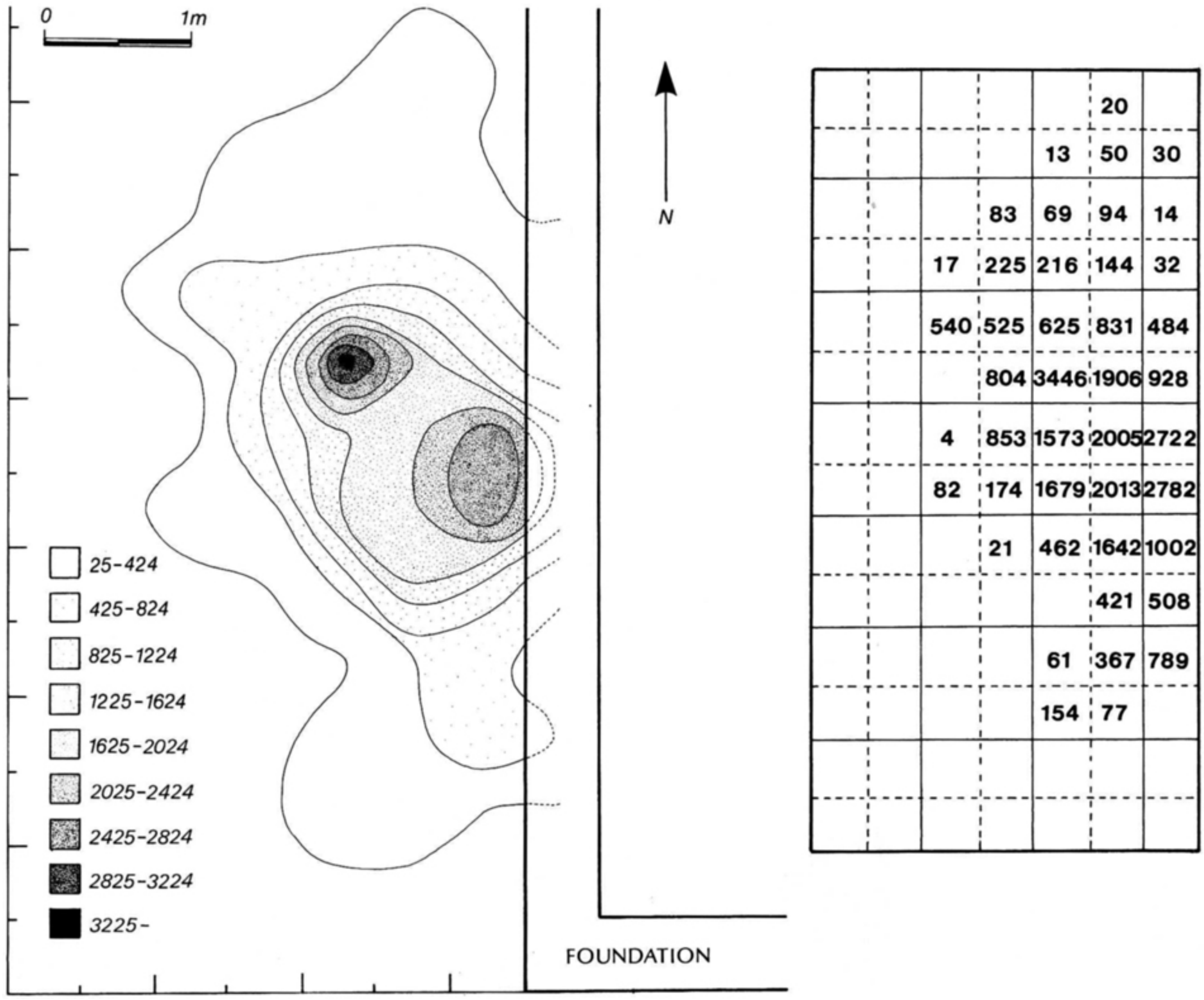


Fig. 2. Map. showing the distribution of all the flakes at Hastrup Vænget. Right: flakes per 1/4 sq.m. unit.

tion, with two almost identical scatters. Each has a centre with a large number of flakes, away from which the intensity gradually decreases to the northwest and southeast respectively.

During classification, it became clear that the overwhelming majority of the finds were waste products from the production of foursided axes (Arnold 1974). The diagnostic debitage from the bodies of axes showed (Hansen 1981) that thin-butted axes had been produced from flint blanks; these blanks had been brought to Hastrup Vænget from elsewhere. This is supported by the presence of a flint blank, rejected because of frost damage. Remains of cortex on some of the flakes suggested that these were most probably produced from flint which had been strongly rolled, in just the way which is now characteristic of material deposited in raised beaches both in Køge Bugt and on Stevns.

The observations from Hastrup Vænget raised a number of questions:

1) Can the flake distributions mapped in fig. 2 be interpreted as a site specialising in the production of thin-butted axes?
2) Is it possible to say how many axes the Hastrup Vænget waste material might represent?
3) What does production on this scale mean in terms of work effort, if it is assumed that flaking was a continuous process?

4) Can the waste flakes generated during the production of flint blanks and axes be used to make smaller tools?

The experiments which took place at Lejre Research Center in August 1982 were designed to answer among other things these questions (2). In the following, the lithic experiments will be described. The main emphasis is laid on the general aspects which have primary importance for an understanding of Hastrup Vænget and future finds of a similar type. Detailed descriptions of the technical methods behind foursided axe production are beyond the scope of this work.

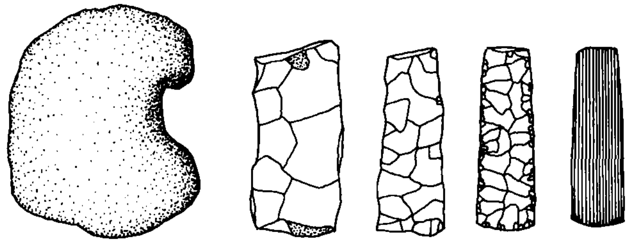
THE LITHIC EXPERIMENTS

Experimental replication of prehistoric flint tools is an old tradition within archaeological research. In the last 10 years it has gained a place as a recognised mode of analysis, alongside other branches of experimental archaeology (Johnson 1978).

Modern production of foursided axes has already been described by Kragh and Meldgård (1964). Since then, the German flint knapper Harm Paulsen has been active in this field, and among other things demonstrated his results at the flint seminar at Lejre Research Centre in 1979 (3).

In 1981 the quadrifacial method was the main subject examined at a similar seminar at Lejre. Among others, E. Callahan, B. Madsen and J. Pelegrin produced an experimental series of thin-butted axes in order to study the length of time involved, the distribution of waste products etc. An interpretation and demonstration of the stages involved in producing a thin-butted flint axe was also presented by Bo Madsen (Callahan 1981, Wickham-Jones 1982). This interpretation was the result of several years experimenting with quadrifacial technique and studying of the TRB material (4).

Recognition that the more thorough-going preparation of the body of the flint took place in stages is not new, and has been experimentally shown by Crabtree (1966), Callahan (1975), Burton (1980) and Stahle (1982). It has turned out that experimental observation can elucidate missing stages in prehistoric production methods, not least with regard to TRB culture axe production. Production of a thin-butted flint axe thus goes through five stages (fig. 3).



1 2 3 4 5

Fig. 3. Stages in the manufacture of thinbutted flint axes.

STAGES IN THE MANUFACTURE OF THINBUTTED SQUARE AXES

1) Obtaining the Raw Material. This either comes from coasts and fiords where marine erosion has exposed flinty deposits, or from regular mining in the chalky bedrock. The quality is tested; the nodule may be cleaned of any chalk adhering to it, and is »opened« by removal of the first flake; rejected if the quality is too bad, i.e. if it contains concretions of crystal and impurities, or is damaged by ice pressure, transport or frost action.

2) Making the Blank. This takes (and took) place at the flint source, in order to minimise the weight before further transporting the blank, and also to check the quality of the flint. Blows from hammerstones of various weights (such as may be collected along the tideline) reduce the weight of the roughout in some cases to under half – and the removal of large, clean flakes shapes the blank's main proportions: square shape, and the correct longitudinal cross section. This must be regular, as near as possible to the shape of the finished axe, as thinning on the broad sides will be difficult later on. Preparation of flint blanks needs much experience and practice. Each removal must be »economic«. The flake size must be calculated against the likelihood of hinge fractures, i.e. flakes which do not »go far enough«. Other risks are that overenthusiastic flaking may spoil the square shape, or that the blank may break with an orthogonal fracture because of an incorrect striking angle. This seems to have been much the riskiest stage in the production of prehistoric axes. Many rejected blanks, found a flint sources, show just these problems.

3) Preforming the Axe. The blank is now prepared with greater precision, using indirect percussion with antler

Fig. 4. Blank with tools made of flakes: 5 flake axes, 8 disc scrapers, 1 backed knife.

flakers, so-called punches. The flakes become smaller and thinner. The impact points are placed closer together and nearer the edge of the piece. As a result, the size of the platform remains are reduced. The axe width and the inclination of the lateral sides are corrected. A decisive operation is now the flat flaking of the broad sides. The flakes should reach in to near the middle of the face, without meeting any obstacles which would remain as raised areas. These are inexpedient as they increase the time which later has to be spent polishing the broad sides. Finally the edge and butt are roughed out.
4) Final Shaping of the Axe. The edge is finally formed either by direct blows from an antler hammer, or by indirect flaking using an antler flaker. The angle and splay of the edge is shaped. The angle of the edge may be completed with very precise pressure flaking. Longitudinal seams are made, either with fine, indirect percussion with a hard, pointed antler flaker, or with pressure flaking which gives the most precise finish. This treatment increases the angle between the broad and narrow faces to over 90°, giving rise to the strongly arched cross section. Stages 3 and 4 require the most time.
5) Polishing the Axe. This takes place on the edge and the broad sides, sometimes also the narrow sides. Nearly all the negative scars from the previous stages are removed. The better the execution of the previous flaking, the quicker the physically demanding polishing can be completed.

That these stages in fact correspond with the prehistoric mode of manufacture can be demonstrated archaeologically by finds of axes at varying stages of manufacture. Roughed out blanks (stage 2) are common from northeast Denmark (Mathiassen 1934, Ebbesen 1980). Axes in stage 3, where the negative scars have not yet been removed by the zig-zag flaking which produces the seams, are more rare, while complete but un-

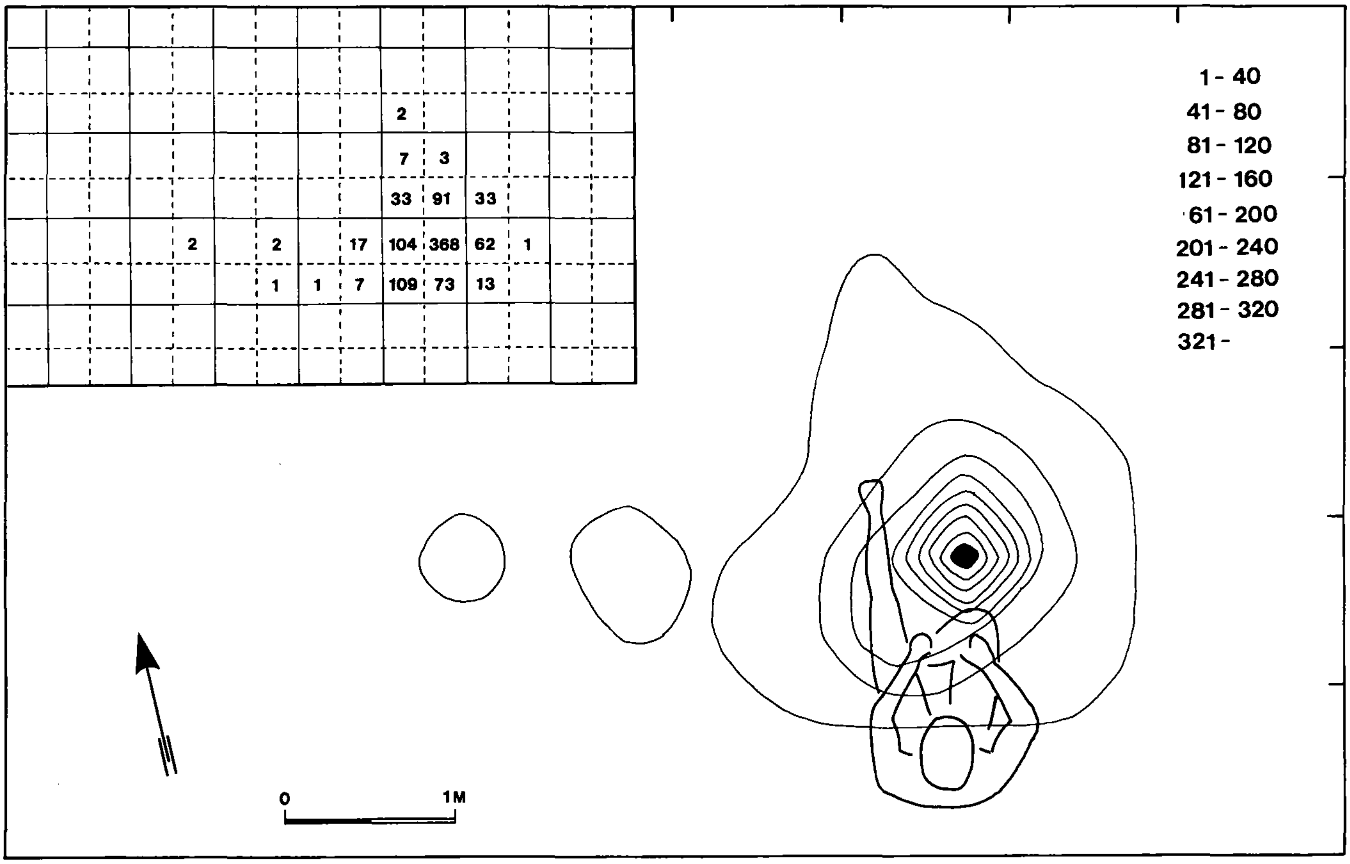


Fig. 5. Map showing the distribution of all the flakes from making the blank (Exp. II A,B,C,D,E).

polished axes (stage 4) are known from numerous hoards in southern Scandinavia and northern Germany.

One factor supporting the interpretation of the process as a series of stages is that the fabricators employed change between the stages. Techniques also change during the process, from direct to indirect blows. The position in which the object is held changes. Last but not least, the flint debitage changes character, at least in a statistical sense, from stage to stage (6).

ESTABLISHING THE EXPERIMENTAL AREA

The experiments were carried out at the Lejre Research Centre. In a landscape corresponding to the topographic conditions at Hastrup Vænget, a rectangular area 5 × 8 m was laid out oriented east-west at the foot of a gentle slope. The area was cleared of vegetation, and covered with a smooth layer of light beach sand c. 10 cm thick. The north-south angle of slope was 3–5°, but the surface was even, without any depressions. The aim was to produce exact agreement between the excavation and the experiment.

A fixed position was adopted. The flint knapper faced north throughout. Both the participating knappers are right handed, and were therefore placed in the south-eastern corner of the area so that the flakes could spread freely to the left (west) for 7 to 8 m. Subsequent procedure was: exact time measurement of the work, and documentation of the tools used, the positions in which objects were held, and scatter pattern for each test. Altitude measurements were taken whenever the work produced heaps of waste. All flakes within the 40 m^2 area were collected by ¼ m^2, and the sand was then sieved through a 0.5 mm mesh.

THE RAW MATERIAL

The raw material used for the experiments was good quality east Danish flint, similar to that from Stevns used at Hastrup Vænget. The flint chosen was a local type from the island of Falster, in which both knappers had confidence. This type is notable for the large size of its raw nodules, its homogeneity, and ease of access. The raw material is nodular in form, often broken (the so-called »jambons«), with a thin, primary chalk cortex and often with a clear, subcortical opalescent layer. It has few macrofossil impurities, and is in secondary deposit, eroded out from the nearby chalk bedrock by marine and agricultural activity.

Over 50 kg of nodules were selected for the roughing out experiments. For the axe production experiments, 6 already prepared blanks of the same flint type were used, weighing a total of 40 kg.

Thus a good 90 kg flint was used to produce experimentally 6 blanks of stage 2, 6 thin-butted axes ready for polishing (stage 4), and 26 small tools; this took in all 13 hours and 11 minutes. More than 11,000 waste flakes were produced, weighing c. 62 kg.

TOOLS USED FOR FLINT WORKING

Organic fabricators are rarely found. Such tools were, however, described in the last century by Müller (1888, 1896). These strongly curved antler tines were linked with flint working, and were believed to have been used as billets, pressure flakers, or indirect flakers. Antler fabricators of the strong, straight type used in the experiments are very similar to those from the Bundsø settlement on Als (Mathiassen 1939).

THE EXPERIMENTS

Experiment I A (flintworker: BM). A nodular fragment weighing 8250 g was made into a blank of stage 2. Direct percussion was used, with a medium hard sandstone hammer weighing 820 g. It was ovoid, measured 12.5 × 7.5 cm, had a smoothly rounded surface, and was collected from a beach on Stevns.

During work, the knapper sat on the sand with his left leg extended, and his right leg bent (fig. 5). The object was rested directly on the sand and supported with the left hand. The hammerstone was held in the right hand, with a precision grip using the thumb and first two fingers; striking involved moving the forearm, while holding the elbow fixed. Precision rather than power was the aim. The blank was ready in 11 minutes, and weighed 4000 g. During the work, a total of 14 disc-shaped flakes were put aside for use in the flake scraper manufacturing experiment, no. I B. 291 flakes remained on the ground.

Experiment I B (flintworker: BM). 14 large discoidal flakes were selected during experiment I A, and were worked into 8 disc scrapers, 5 flake axes and 1 backed knife (fig. 4). Direct percussion was employed, using a sandstone fabricator weighing 160 g, measuring 6 × 4.5 cm. The scraper edge was produced using a club of elk antler tine, weighing 265 g. This work took 15 minutes and was conducted outside the experimental area.

Experiment II A, B, C, D, E (flintworker: BM). This was a continuous experiment, producing 5 blanks (stage 2) in the same way as in experiment I A. The intention was to create a stronger and more reliable scatter pattern. 34,240 g of nodular flint were used. The 5 completed blanks weighed a total of 20, 287 g; 929 waste flakes were produced. The work took 38 minutes, i.e. rather over 7.5 minutes per blank; the quickest one took only 4 minutes. The waste flake distribution can be seen in fig. 5. It must be noted that here, as in experiment I A, efforts were made to keep the working area where the blank rested during preparation, free of waste – out of consideration for the knapper's hands. Waste from here was moved to the right or east.

Experiment III A (flintworker: JP) A flint blank weighing 5500 g was worked from stage 2 up to being ready for polishing in stage 4. The intention was to produce a more developed type of thin-butted axe, the so-called type VI (Nielsen 1977), characterised by a relatively thick blade and a flat butt. The knapper was seated on a 30 cm high section of oak, in the southeastern part of the experiment area. Throughout, he sat with thighs horizontal and legs a little bent. The item was mainly held between the thighs in the area above the knees, supported by the slightly flexed muscles of the inner thighs. His legs were protected by pieces of leather. The item was thus about 50 cm above the experimental area surface. When the narrow sides of the axe was being

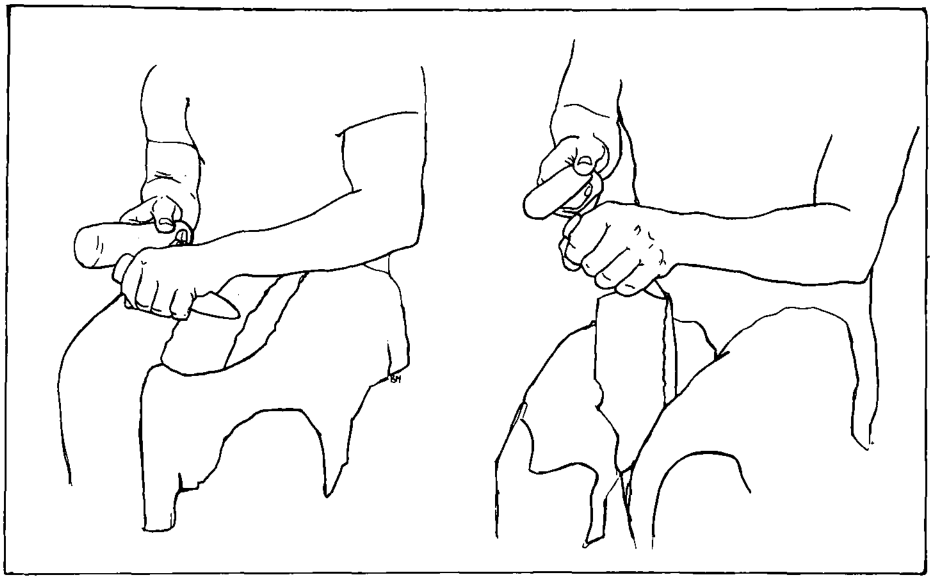


Fig. 6. Holding positions for making a thinbutted axe, stage 3&4.

worked, it usually rested lightly on the left thigh, but supported by the right thigh. Raising and lowering the thighs in relation to one another altered the angle from the horizontal at which the piece rested. Indirect percussion was used. The fabricator was held in the left hand, the whole hand gripping it. The blow was delivered with a light wooden club.

Direct percussion was used only for the bifacial method of working the edge. At this point the piece was held in the left hand, supported on the outside of the left thigh. The waste flakes fell in a group, partly underneath, partly immediately to the left of the knapper; this is usually the case when bifacial work is carried out by a right-handed knapper.

When flakes were removed from the body of the axe, this took place on its left side, the piece continually being rotated through 180°. As a result, the waste flakes were mostly projected to the west, the left hand side of the knapper. In a few cases flakes flew more than 7 m from the knapper. During indirect flaking, a fairly light wooden club was used, in order to have maximum control over the speed of the fabricator at the moment the flake was removed. This was often attained by means of a rapid swing of the forearm. It was particularly important that the strength and direction of the blow was closely controlled during working of the narrow sides; if this was not the case, overpassed flakes could spoil the foursided shape; or the opposite could occur, namely the production of too short, so-called »diving flakes«, which also spoiled the shape.

5 antler fabricators were used in experiment III A and are listed below. The heaviest piece, A, was used for indirect removal of large flakes from the broad side of the axe during the early part of stage 3. A was also used as a billet, delivering direct blows during the forming of the edge area. The flakers B, C and D were used later for indirect flaking. The small flaker E, made of hard elk antler, was ony used for the completion of the seams, between stages 3 and 4. The »retoucheurs« F and G were used to prepare special platforms. H functioned as a whet stone, for resharpening the points of the flakers. The wooden club J, which was used to strike the flakers, was made from the trunk of a boxwood.

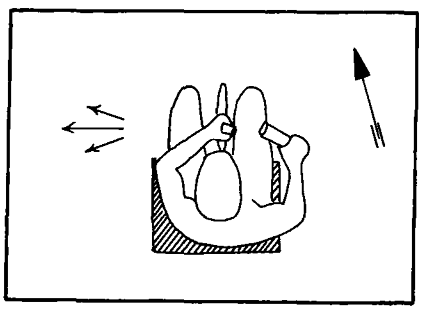


Fig. 7. The spreading direction of flakes when making the axe.

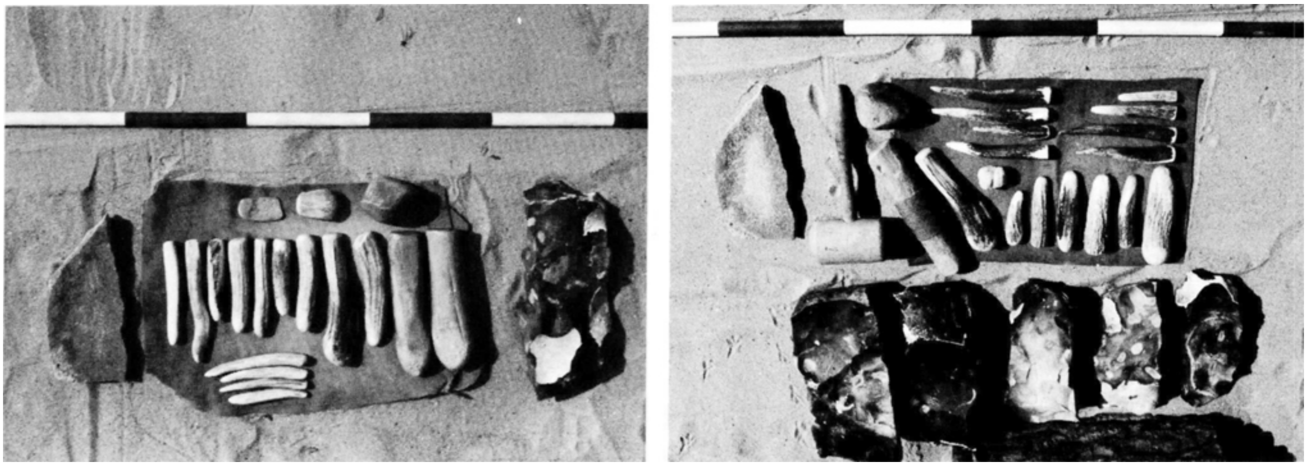


Fig. 8. Fabricators used at the axe experiments (left: J.P., right: B.M.).

A: billet/flaker of antler base (*Rangifer tarandus*).
22 × 5 – 3.5 cm. Weight 350 g.
B: flaker of antler base (*Rusa unicolor*?).
19 × 4 – 2.5 cm. Weight 230 g.
C: flaker of antler base/tine (*Rusa unicolor*?).
16.3 × 2.5 – 2 cm. Weight 110 g.
D: flaker of antler tine (*Rusa unicolor*).
17 × 2 – 1.5 cm. Weight 70 g.
E: flaker of antler tine (*Alces alces*).
14.5 × 1.2 cm. Weight 40 g.
F: hammerstone (retoucheur) of sandstone.
7 × 5.2 × 3.8 cm. Weight 200 g.
G: hammerstone (retoucheur) of sandstone.
7.5 × 4 × 1.1 cm. Weight 50 g.
H: whet stone, fragment of flat sandstone.
25 × 15 × 3 cm.
J: club of boxwood (*Buksus sempervirens*).
23 × 7 cm. Weight 510 g.

The general tendency during the work was for progressively lighter and more pointed flakers to be used as the work progressed. Impact points were often placed in series, ever closer both to each other and to the edge of the piece. This resulted in a gradual diminution of flake size, and in the size of the striking platform remnant (6).

In experiment III, a typical, heavy, thin-butted axe was produced, 28 cm long, 9 cm wide and 2.5 cm thick, weighing 2250 g. The work took 1 hour 56 minutes. 1234 flakes were produced. 14 of these were put aside as the raw material to be used in experiment III B. The scatter of the remaining waste flakes, together with those from experiment IV, can be seen in fig. 13.

Experiment III B (flintworker: BM). The object of this experiment was the production of smaller tools from waste flakes resulting from experiment III A. 14 flakes were used, from which were produced 4 disc scrabers, 2 backed knives, 1 blade sickle, 1 flake burin, 1 borer and 3 transverse arrowheads; 2 further transverse arrowheads were failures. Working took place outside the experimental area, but was carried out in the same way as in experiment I B. During the making of the transverse arrowheads, a wooden branch was used as an anvil. Direct percussion with a hammerstone was used. The work took 19 minutes.

Experiment IV A, B, C, D, E (flintworker: BM). Five flint blanks with a total weight of 39,880 g were worked through from stage 2 to stage 4, axes ready for polishing, in one continuous process under the same conditions as experiment III A.

During this experiment, the same types of fabricator were used, with a few exceptions. Firstly, only flakers made from elk and red deer antler were used (7). Furthermore, the largest elk antler flaker, 18 × 5 cm, had a rather larger weight, namely 430 g. Use of this piece was deemed necessary because several of the blanks were rather large. Working of the seam, near the end of stage 4, was done with not one but two light, pointed flakers with lengths of 19 and 14 cm, and

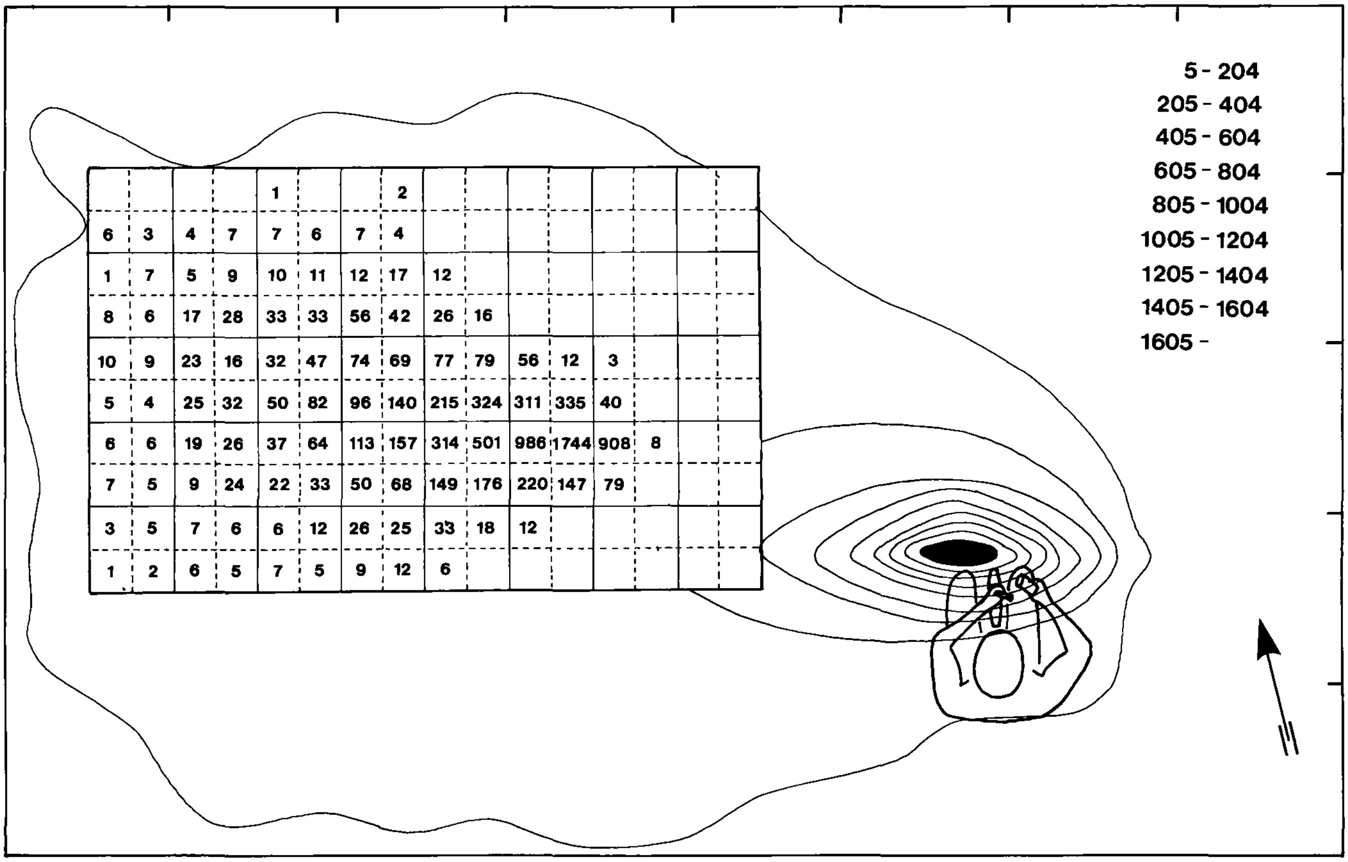


Fig. 9. Map showing the distribution of all the flakes from making the axes (Exp. IV A,B,C,D,E).

weights of respectively 50 and 30 g. These two pieces were also used as pressure flakers during the final treatment of the edge. During this work, the axe was held in the left hand, which had a leather protector, and the pressure flaker was used with the right.

As the fan-shaped scatter developed during the experiment, more and more qualitative tendencies appeared in waste distribution. In some cases, however, it was noted that some of the flakes were trapped by the knapper's left leg, while others, particularly during the working of the seams, spread as far as the western edge of the experiment's area even though these were of small size and weight (fig. 9).

On average, each axe took 2 hours. Time taken for the individual type VI replica axes was as follows:

Experiment IV A: 1 hour 48 mins.
Experiment IV B: 1 hour 20 mins.
Experiment IV C: 2 hours 12 mins.
Experiment IV D: 2 hours 17 mins.
Experiment IV E: 2 hours 15 mins.

A total of 9 hours 52 minutes was involved in producing the 5 axes, which between them weighed 6760 g. 8636 waste flakes were produced.

COMPARISON BETWEEN EXCAVATION AND EXPERIMENTS

The waste flake scatters from the experiments is seen in fig. 9. It can be seen that the fan is rather larger than at Hastrup Vænget, and the limit of the distribution is much more uniformly convex. These differences could be due to several things. If the knapper, for example, had worked directly on the ground in all the experiments, not just in the one for blank production, a smaller scatter fan would probably have resulted among the larger flakes – but not for the smaller ones resulting from forming the seams of the axes, which are often projected a long way, high into the air (Newcomer and Sieveking 1980: 345–52).

The distribution of flakes at Hastrup Vænget could

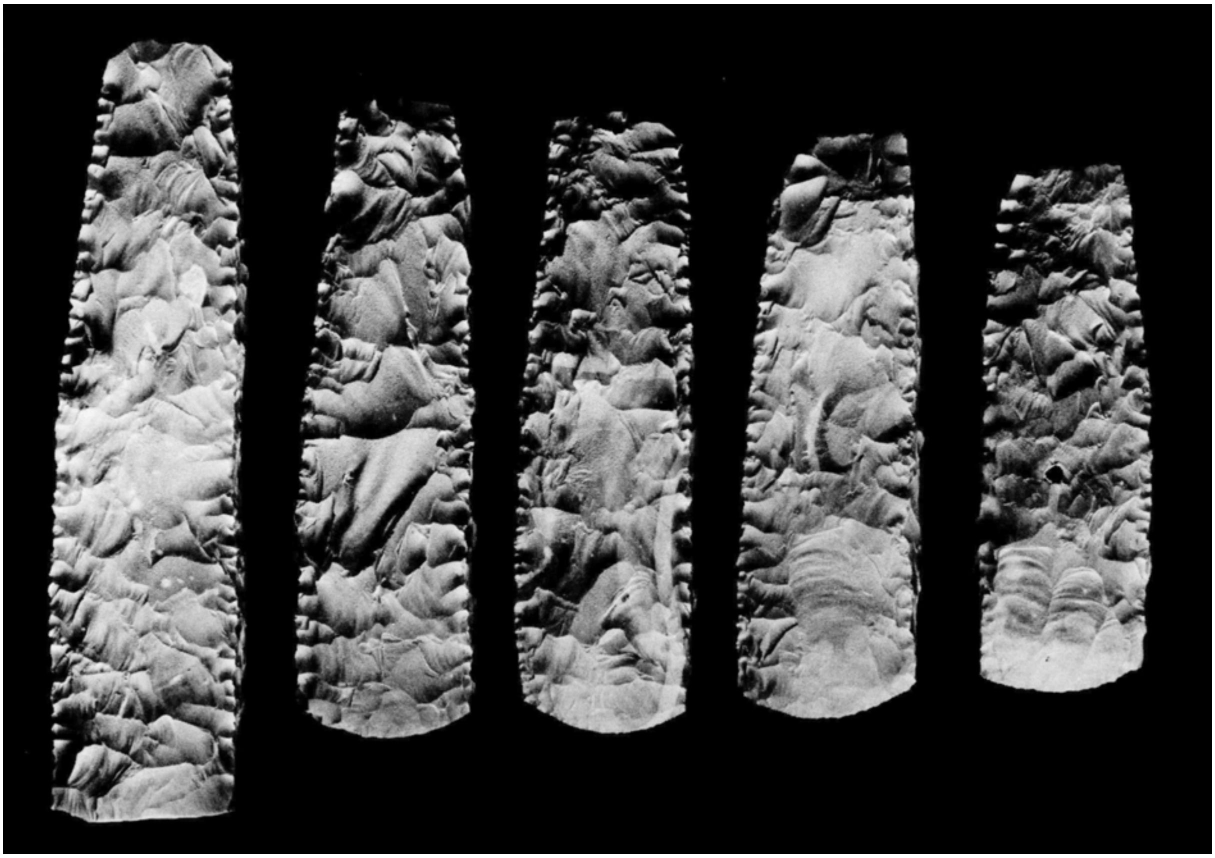


Fig. 10. Five type VI flintaxes from exp. IV A,B,C,D,E, ready for polishing. Photo: L. Larsen.

be due to factors which have interfered with the spreading of flakes. Vegetation in the form of grasses and small bushes could trap flakes, creating a »wall effect«. Nor is it without significance that the find was in a slight depression in the subsoil surface, a factor which preserved the find but may also have influenced the spread of flakes. Finally, it must be noted that the Hastrup Vænget flakes were not collected by sieving. Many small peripheral flakes may therefore have been missed.

Horizontal distribution of flakes from the experiments did, however, show a clear similarity to the Hastrup Vænge find. Classification of the flake types showed further parallels between the diagnostic wasters from experiments III A and IV, and Hastrup Vænget.

The percentage distribution of flake sizes agreed particularly closely (Table I), so that the experimentally produced axes really can be regarded as true replicas. Not only were the axes made to the correct proportions, established by means of a large measured sample of prehistoric axes (Nielsen 1977), but the attempt to mimic the method of production was also successful.

The experiments with the production of flint blanks revealed first and foremost the differences in the size distributions of waste flakes from producing blanks and true axes (Table I). Most of the weight produced in blank production is concentrated in a few large, round flakes. This showes that the Hastrup Vænget wasters are not in this class. It was clearly not flint blanks which were being produced at Hastrup Vænget. The size distribution of flakes, together with the scatter analysis, can clearly be interpreted as a workshop, where the primary task was the production of flint axes, working from stage 2 through to stage 4 items, ready for polishing.

Experiment no.	flake categories (D = maximum dimension in cm) 0<D≤1	1<D≤2	2<D≤4	4<D≤6	6<D≤8	8<D	total number of flakes	weight of blank (g)	weight of product (g)
I A	181	65	20	11	9	5	291	8250	4000
II A,B,C,D,E	311	252	142	66	85	73	929	34240	14400
III A	299	459	306	108	34	14	1220	5500	1630
IV A,B,C,D,E	3301	2551	1925	573	179	107	8636	39880	6760

Axe manufacture site	flake categories (D = maximum dimension in cm) 0<D≤1	1<D≤2	2<D≤4	4<D≤6	6<D≤8	8<D	total number of flakes	flakes, total weight
Hastrup Vænget	11289	10696	6087	2225	176	14	30487	168050

Average values used in calculations:
Weight
Stage 1: 8–12 kg
Stage 2: 4–6 kg
Stage 4: 1.5–1.7 kg

Number of flakes
Stage 2 yields 2–300 flakes in total (with 150–200 < 1 cm).
Average number of excavated flakes: c. 100.

Stage 3,4 yield 1650 flakes in total (with 600 < 1 cm).
Average number of excavated flakes: c. 1000–1100.

Table I. Comparison between the flakes from the experiments and from the site at Hastrup Vænget.

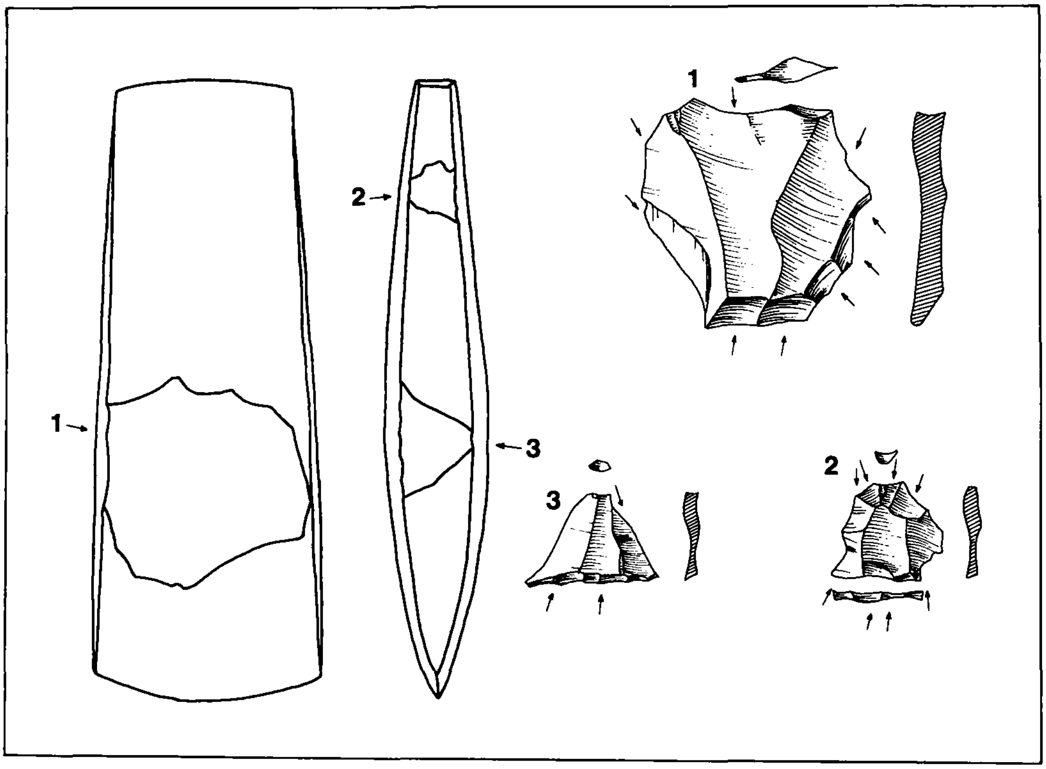
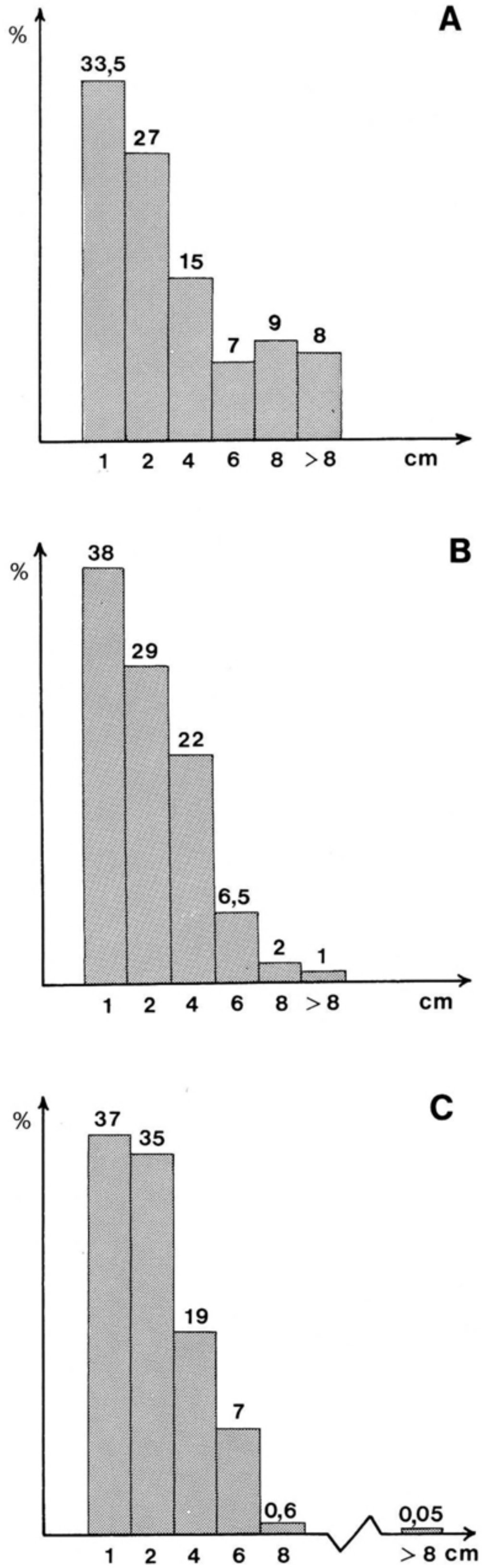


Fig. 11. Diagnostic flakes from axe production. Note the following characteristic elements: platform remnant with facets; counter flake negatives; frequent occurrence of overpassed flakes (*outre passage*).



HASTRUP VÆNGET – THE SCALE OF AXE PRODUCTION

An interpretation of the Hastrup Vænget flake distribution pattern is given in fig. 13. The bimodal scatter is explained by there having been two working areas close together. Either the same knapper had changed position, or else two knappers were at work at the same time.

What was the scale of axe production at Hastrup Vænget? How many axes were produced? Fig. 12 shows the size distribution of the flakes, and agreement can be seen between Hastrup Vænget and the experiments. One difference, however, is the relative lack of large flakes (over 7–8 cm) at Hastrup Vænget. If it is assumed that the experiments represent a »normal« situation, the following interpretations are possible for the prehistoric workshop:

1) It might be that the axes produced at Hastrup Vænget were worked so as to produce proportionally fewer large flakes – which is to say, the blanks used may have been lighter and narrower than those used in the experiments.

2) The difference could also be due to the removal of these large flakes from the site in order to make them into flake tools.

The most likely hypothesis is that Hastrup Vænget's waste represents a production episode with a »normal« distribution of flake sizes. No other axe workshops are, however, known from the early TRB for comparison.

In the experimental production of thin-butted axes, thick and heavy blanks were used (6–9 kg apiece). This is at the upper end of the range of the stage 2 flint blanks so far known from Danish hoards of blanks (Mathiassen 1937, Ebbesen 1980). In the experiments, many large, heavy flakes were produced at the start of the reduction process. These the prehistoric flint-workers would presumably have left at the place where the blanks were roughed out. Hastrup Vænget and experiments III A and IV are assumed, despite quantitative differences, to represent a real range of variation, which would also have occurred in prehistory, depending on whether the intention was to produce large or medium axes.

The experiments at Lejre Research Centre in 1981 and 1982 showed that there is a clear connection between the number of waste flakes, weight of flakes, the

Fig. 12. Graphs showing the size distribution of flakes. A: Exp. II A,B,C,D,E. B: Exp. IV A,B,C,D,E. C: Hastrup Vænget.

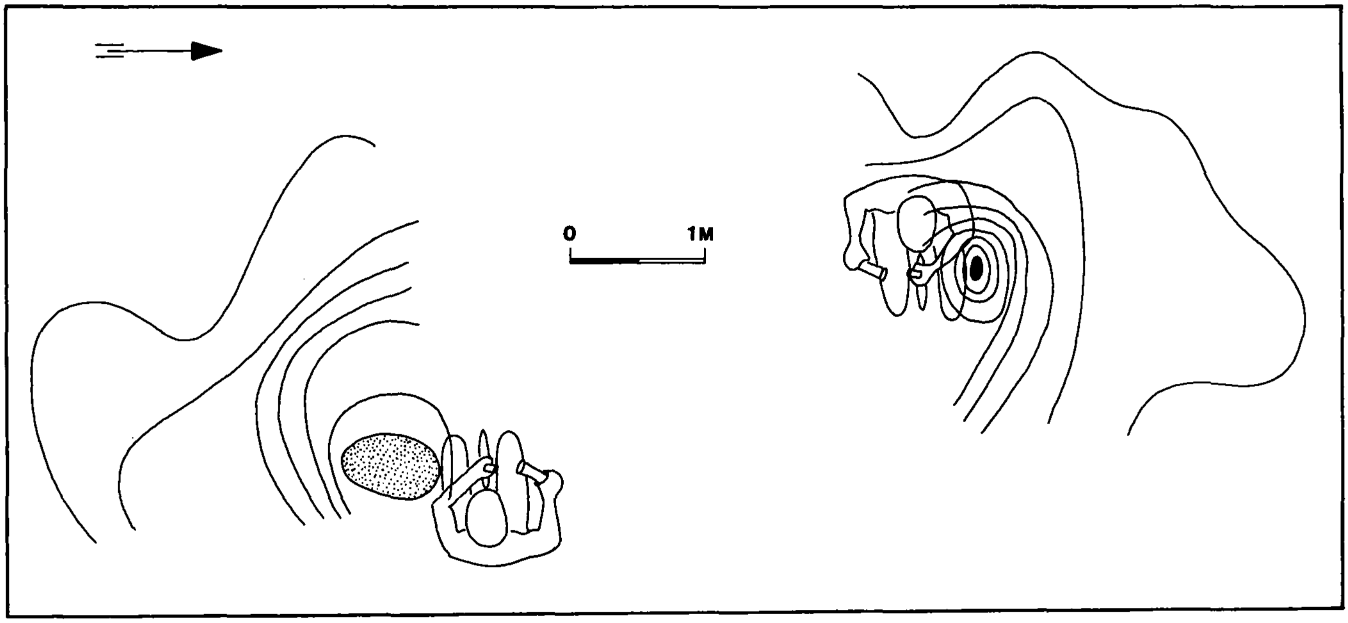


Fig. 13. The hypothetic position of the flintworker at Hastrup Vænget.

blank and the finished axe, at least in the case of the experimentally produced axes. No finds of prehistoric workshops have yet been published at which it was possible to join up the flakes, in order to get an idea of the size of the axe. But the known material, with hoards of unpolished, thin-butted axes (Nielsen 1977) does suggest that production was uniform, even though some stylistic differences can be seen between one hoard of axes and another.

If the average value for weight of waste flakes per axe (c. 6200 g) is used, a rough calculation demonstrates that at least 27 medium sized thin-butted axes were produced at Hastrup Vænge. If the average number of waste flakes per axe is used (c. 1650), the result is that at last 18 medium sized thin-butted axes were made there.

THE TIMESCALE OF AXE PRODUCTION

The purpose of these rough estimates is to do no more than give a rough *order of magnitude* of production at Hastrup Vænget. If we continue in this vein, and assume that production took place continuously over a number of days (8), and that the experimental times are roughly similar to those of prehistoric knappers at around 2 hours per axe, then the minimum work time involved at Hastrup Vænget is between 40 and 60 hours of concentrated work. Maybe 8 to 12 man/days at 5 hours per day? If the raw flint was collected from raised beaches on Stevns, where the flint is suitable for axe production, then about 250–350 kg of selected material would be needed to produce 30 thin-butted axes. The blanks, which had to be transported to the workshop, would weigh in the region of 120–180 kg, if the correct blank weight is 4 to 6 kg. Only 10–20% of the original raw material would have been used as finished axes. Another 10% would have been usable for flake tool production.

FLINT ON NEOLITHIC SETTLEMENTS

In the introductory presentation of Hastrup Vænget the question was raised as to whether waste from axe production could be used to make smaller tools. Experiments I B and III A attempted to examine this. It is noted that the waste from blank production gave many more possibilities of producing large flake tools like flake axes, disc scrapers, borers etc. Some of the flakes produced during blank production are indeed big enough to be used for producing flint halberds or very small, thin-butted, four-sided axes.

The waste from true axe production is also a source of potential raw material for rather smaller flake tools and transverse arrowheads. By examining the flint inventory from neolithic settlements, it should be possible to evaluate the scale of axe production in the settlement sphere. This waste from the working process has in some cases accompanied the finished product, whether this was an early neolithic axe or a late neolithic dagger, when these were exchanged far to the north, as far as the flintless areas of middle Scandinavia (Becker 1952).

PRODUCTION AND DIFFUSION

It is interesting to note that Hastrup Vænget is close to Stevns, a raw material source of a scale comparable to the largest exploited in Europe during the neolithic, such as: Grand Pressigny, France; Spiennes, Belgium; Ryckholt, Holland; Lousberg, W. Germany; Krzemionki, Poland; and Grimes Graves, England. At all these sites is evidence of flint extraction in the form of mines, pits etc., with an associated production system and distribution network based on roughout workshops and axe workshops, with nearby hoards of roughouts and axes.

The Stevns area is noted not only for the presence of many finds of finished axes and daggers, but also qualitatively because of many large artifacts from hoards and single finds. What is of particular interest in this connection is the evidence of nearby finds of hoards of stage 2 roughouts. An important discovery was the open find of hundreds of faulty stage 2 roughouts in a Litorina beach at Strøby (Mathiassen 1934, Ebbesen 1980), 10 km east of Hastrup Vænget. This suggests that these beaches, very rich in flint (and now removed by gravel digging) were the sites of mass production of blanks in the middle neolithic. Production of axes ready for polishing took place close to the same area. Excess production is shown not only by the depositing of so-called overlarge polished axes of very fine quality in boggy areas, but also by the hoards of axes ready for polishing. In a diachronic perspective, the Hastrup Vænget workshop was in an area which was an important centre of production throughout the neolithic, despite several changes in the directions in which the axes spread to areas without flint. According to Becker (1947), a change in the »flint trade« is visible during the middle neolithic, when distribution to the north German area becomes more important. In middle neolithic B, finds of finished axes become more common to the east; Zealand and Scania in particular must have been of central importance to the production of flint (Nielsen 1977). In the late neolithic, distribution of Danish flint again includes north Germany, and in the course of this period achieves a continental distribution as wide as that of Grand Pressigny blades.

Understanding the difference between the diagnostic waste from blank and axe production is of decisive importance for an understanding of workshops like Hastrup Vænget. The absence of associated features and settlement deposits means that these workshops have a rather modest appearance, and during a rescue excavation might be mistaken for a chance collection of flakes. Such isolated piles of unretouched flakes can on the other hand be the most important indicators of how raw material collection and supply occurred. Hastrup Vænget can be seen as an intermediate link both in the production and in the distribution of thin-butted axes in the area round the estuary of the Køge River; production of the blanks would have taken place at the flint source, and production of the finished axes closer to or at settlements, where they would be polished or distributed further.

Archaeology testifies to the existence of large scale blank production sites at other coasts as well as Stevns. From east Jutland, a find is known at Rugård Strand yielding hundreds of flint blanks in a raised beach (9). Blank production is also known in connection with neolithic hunting stands on islands with flint sources, such as Hesselø (Becker 1950, Skaarup 1973) and Anholt. The extent of axe production on the larger inland settlements associated with agricultural activities and megaliths is as yet unknown. Such excavations often took place some time ago, when unworked flint flakes were often discarded or not regarded as significant in the report.

How large a role the collection of flint and manufacture of axes might have played in the »site catchment« for a given settlement on Stevns is still unknown. It is likely that several settlements here would be located with a view to combining several resources, so that flint would be one determining factor. Just the realisation of the amount of flint that must be collected to produce a single hoard of axes is thought-provoking, not least if the »Hastrup Vænget model« should be applied to the late neolithic, when increased demand for the best

Archaeological find contex	Many large flakes with a high percentage of cortex Flakes from blanks Fragments of blanks Hammerstones Raw flint nodules	Assemblage like the Hastrup Vænget site – also occurring with preserved fabricators of antler and hammerstones	Assemblage as found at a hunting site (i.a. Hesselø), associated with a type I or type II production	Assemblage as found on larger base camps, associated with axe production (i.a. Bundsø) The assemblage includes grinding stones, antler fabricators, unpolished axes (fragments), and used/discarded axes
Flint production	Blank production	Axe production	Blank production Axe production Production of cutting and scraping tools Blade and arrowhead manufacture	Final preparation of axes Polishing of axes Resharpening of axes Production of 'basic tool kit', besides axes
Topographical position	Close to natural flint sources (coast – mine)	Near natural flint sources	On islands, on coasts, and in fiords, near natural flint sources	Inland location, on lakes, rivers, and fiords
Type of manufacturing site	I	II	III	IV

Increasing exploitation of the flint material —▷

Table II. Four types of find accumulations with evidence of axe production.

quality flint led to the establishment of mines in north Jutland and Scania. Several of the known mines could by themselves hardly have produced much more flint than was needed for the work carried out at Hastrup Vænget.

From this superficial perspective, use of flint mines seems irrational. The large amount of work involved would have produced only a limited quantity of relatively irregular and small nodules. The north Jutland flint mines cannot be compared, for example, with the English ones, either in size or in production quantity. A copying of the Grimes Graves 1971 shaft took 6–7 people about 6 months, removed 800–1000 tons of sand and chalk, and produced 8 tons of flint! As far as north Jutland is concerned, it must be remembered that the long neolithic coastlines were close to the mines and had large amounts of easily accessible flint. One wonders whether this coastal flint was monopolised by others, and inaccessible either physically or economically to those who established the mines. A more likely explanation is that the north Jutland mines are an expression of the need for raw flint of the best quality, regardless of nodule size. The late neolithic mines show just this need of top quality flint, which was an essential precondition for the pressure flaking of the various bifacial tool types.

In connection with mining and axe production in Papua, Flemming Højlund (1979) has suggested that these activities cannot be regarded as specialisations. Anyone can make an axe, participate in raw material procurement etc. One is tempted to draw an exact analogy with prehistoric European mining areas, and maintain that the main picture here is one of resource exploitation by the local inhabitants, who owned the land and the resources – specialists to a considerable degree, but not at the level of the individual; everyone in the local group took part in the production process. This could not only manifest itself in the form of a raw material monopoly, but would also explain concentrations of highly developed flintworking »know how«, as shown by e.g. the Livre de Beurre production in Touraine, and in the Danish dagger production in areas like north Jutland.

EPILOGUE

The lithic experiments at Lejre Research Centre in 1982 tested hypotheses that were formulated as a result of the excavations at Hastrup Vænget, the first detailed examination of an axe workshop in Denmark. It is clear that many questions remain to be answered. As Hastrup Vænget is the only find we have with stage 3–4 axe working, we have no idea how representative it might be. Another question concerns the validity of the research model, which involves several untested assumptions – which cannot be examined until more finds are available. Finally, there are questions which in a general way apply to the theory and method of experimental archaeology: can one copy a product if one does not closely copy the method of production? (10)

The practical experiences on which this study was based have been a twofold exercise; both to train manual skill and to investigate the archaeological context of the thinbutted flintaxe. It is important that replication in the true sense of the word (Crabtree 1966), rests on a feedback system between the two aspects.

Translated by Peter Rowley-Conwy

Peter Vemming Hansen,
Institute of Prehistoric Archaeology,
University of Copenhagen,
Vandkunsten 5,
DK–1467 Copenhagen K.

Bo Madsen,
Kulturhistorisk Museum,
Stemannsgade 2,
DK–8900 Randers

NOTES

[1] The investigation has Køge Museum no. 687. Carried out be Peter Vemming Hansen and Flemming Kaul.

[2] The experiment could be carried out thanks to a grant from the Lejre Research Centre. Thanks are due to Hans Ole Hansen (director), and Dorthe H. Nielsen (area administrator) for economic, practical and scientific support.

[3] Harm Paulsen of Schleswig has worked on experimental flint manufacture for several years. See e.g. Bokelmann and Paulsen 1973, 1974 and Broadbent and Knutsson 1979.

[4] The practical conclusions and results were developed by Bo Madsen together with the flint knapper Thorbjørn Petersen from Copenhagen, who together with Ivan Andersen of Jutland has specialised in the four-sided technique. The basic work was however undertaken at the Culture Historical Museum, Randers, in close collaboration with Jacques Pelegrin. A »lithic workshop« has operated here since 1975 under the auspices of B.G. Stürup.

[5] The documentation is kept at Lejre Research Centre.

[6] In connection with the Lejre flint seminar in 1981, flakes from the bodies of several experimentally produced thin-butted axes were analysed. Graphic plotting of among other things the width of the remains of the striking platform against flaking sequence showed clear steps corresponding to manufacture stages.

[7] The fabricators of the two knappers differed in that Jacques Pelegrin, who did not have access to large quantities of elk antler, used pieces cut from antlers of deer of Asiatic origin (maintained in Paris Zoo).

[8] An idea inspired by the description of work organisation among several stone using groups in Australia and New Guinea. See particularly Højlund 1979 and 1981.

[9] Rugård Strand, Rosmos parish, Djurs Sønder district. Culture Historical Museum, Randers, J. no. 91/76.

[10] *Replication* is seen as opposed to *simulation*, for example when flint tools are made with the aid of copper fabricators (i.e. Olausson 1983: 24–35).

REFERENCES

ARNOLD, V., 1974: Jungsteinzeitliche Flintwerkstätten in Ditmarschen. *Ditmarschen*, vol. 3.

BECKER, C.J., 1947: Mosefundne Lerkar fra Danmarks yngre Stenalder. *Aarbøger for nordisk Oldkyndighed og Historie*. Copenhagen.

– 1952: Die Nordschwedischen Flintdepots. *Acta Archaeologica*, Vol. 23. Copenhagen.

BOKELMANN, K. and PAULSEN, H., 1973: Die Steinzeit in Schleswig-Holstein. 1. Teil: Flintbearbeitungstechnik. *Die Heimat*, Vol.l 80, Heft 4. P. 110–116.

BROADBENT, N. and KNUTSSON, K., 1979: Några reflektioner kring eksperimentell arkeologi och dess tillämpning i Norden. *TOR*, vol. 13. Uppsala.

BURTON, J. 1980: Making sense of waste flakes: New methods for investigating the technology and economics behind chipped stone assemblages. *Journal of Archaeological Science*, vol. 7. London.

CRABTREE, D.E. 1966: A stoneworkers approach to analyzing and replicating the Lindenmeier Folsom. *Tebiwa, Journal of the Idaho State University Museum*, vol. 9. Idaho.

CALLAHAN, E.C. 1974: *Experimental Archaeology Papers*, no. 3. Virginia commonwealth University. Richmond.

– 1981: The second international work seminar in lithic technology. *Flintknappers exchange*, vol. 3. Albuquerque.

EBBESEN, K. 1980: Die Silex-Beil-Depots Südskandinaviens und ihre Verbreitung. *5000 Jahre Feuersteinbergbau*. Deutsches Bergbau-Museum, no. 22. Bochum.

FISCHER, A., GRØNNOW, B., JÓNSSON, J.H., NIELSEN, F.O., PETERSEN, C. 1979: Stenaldereksperimenter i Lejre. *Working Papers*, no. 8. Copenhagen.

HANSEN, P. VEMMING, 1981: Neolitisk bopladsflint. *Kontaktstencil*, vol. 19. Copenhagen.

– 1983: Hastrup Vænget – et flintværksted fra yngre stenalder. *Antikvariske Studier* 6. Copenhagen.

HØJLUND, F. 1979: Stenøkser i Ny Guineas højland. *Hikuin*, vol. 5. Aarhus.

– 1981: The function of prestige weapons in the reproduction of New Guinea highlands tribal societies. *Oral History*, Vol. IX nr. 3. New Guinea Studies, Institute of Papua.

JOHNSSON, L. LEWIS, 1978: A history of flintknapping experimentation, 1938–1976. *Current Anthropology*, vol. 19., no. 2.

KRAGH, A. and MELDGAARD J. 1964: *Mand og flint*. Copenhagen.

MATHIASSEN, T. 1934: Flinthandel i Stenalderen. *Fra Nationalmuseets Arbejdsmark*. Copenhagen.

– 1939: Bundsø. *Aarbøger for nordisk Oldkyndighed og Historie*. Copenhagen.

– 1948: *Danske Oldsager*. Vol. II. Copenhagen.

MÜLLER, S. 1888: Ægredskaber fra ældre Stenalder. *Aarbøger for nordisk Oldkyndighed og Historie*. Copenhagen.

– 1896: Nye Stenalders Former. *Aarbøger for nordisk Oldkyndighed og Historie*. Copenhagen.

NEWCOMER, M.H. and SIEVEKING, G. DE G. 1980: Experimental flake scatterpattern. A new interpretive technique. *Journal of Field Archaeology*. Vol. 7. no. 3. Boston.

NIELSEN, P.O. 1977: Die Flintbeile der frühen Trichterbecherkultur in Dänemark. *Acta Archaeologica*. Copenhagen.

– 1977: De tyknakkede flintøksers kronologi. *Aarbøger for nordisk Oldkyndighed og Historie*. Copenhagen.

OLAUSSON, D.S. 1983: Flint and groundstone axes in the Scanian Neolithic. *Scripta Minora* 1982–1983: 2. Lund.

SKAARUP, J. 1973: *Hesselø–Sølager*. Arkæologiske Studier, Vol. 1. Copenhagen.

STAHLE, D.W. and DUNN, E.D. 1982: An analysis and application of the size distribution of waste flakes from the manufacture of bifacial stone tools. *World Archaeology*, vol. 14. no. 1.

WICKHAM-JONES, C.R. 1982: The second international seminar in lithic technology. *Scottish Archaeological Review*. Vol. 1. no. 2. Edinburgh.