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In "push" flaking the rigid support of both SLOne and pressor is required to insure an even stress distribution. Resulting long, slender scars are distinguished by high, parallel sides forming common anises from, at or very near the edge. The classical example of this style of flaking is found in the parallel flaked Frederick points.

"Pull" flaking detaches the chip with a relatively quickly applied force. In addition to the force being primarily a pulling action away from the edge, the stone and pressor both may be loosely held so that the force is of shorter duration. Scars produced by this pulling action tend to be bulbous with rapidly expanding edges and the unchipped space between chips (interspace) tends to be large and triangular. Most varieties of arrowheads exhibit "pull" flaking.

The direction followed by the pressor causes a limitation in the type of bite depending on the technique used. Pulling the chip allows a deep bite in the center of the tool tip and therefore also accommodates severe blunting of the tool as long as it can swing away from the edge without any crushing. Pushing the chip forms a scar slightly more than the width of the pressor tip and crushing can be avoided only by using a pointed tool or a bite on the extremity of a blunted pressor.

The trajectory followed by the chip determines whether the termination is apt to be abrupt or feathered. Flat trajectories favor the feathered termination usually seen in

"push" flaking. Rapidly changing stress distribution causes

"pull" flakes to continue arcing until they are abruptly terminated due to excessive leverage. The flat trajectory of "push" flaking in the case of collateral chipping results in a very sharply defined median ridge. "Pull" chips also can create a median ridge but the definition is less sharp because of the characteristic arc of trajectory which carries across the high point. The extent of overlapping of opposing scars determines the median regardless of style so this is a diagnostic feature of limited use.

"Push" flaking probably requires the most attention to platform preparation because of the flat separation trajectory and because a great deal of force must be transmitted along the chip. The most effective platform is a segregated spur which serves to confine the applied force. Folsom fluting represents the ultimate in the use of this technique. Such careful preparation results in highly organized scar patterns. Because "pull" chips can be detached without much attention to edge preparation as long as a deep bite is obtained, the organization tends to be looser. Also important is the fact that "pull" chips have low ridges away from the origins which can be easily worked across in contrast to the high ridges of "push" scars.

While an experienced knapper can apply either technique to most materials, "push" flaking is easily accomplished only on very fine quality stone. Heat treating is usually apparent on the best examples of paleo "push" flaking. Coarse textured stone allows too much change in stress distribution to accommodate "push" flakes.

Seldom will the style be pure "push" or "pull" because of the difficulty of controlling such a large number of variables. For a given point type, however, the style will be a blend made consistent by cultural habit. Careful analysis of an artifact should identify the manufacturing tradition which in turn should provide a clue as to which point type it corresponds. The following chart shows both the differences

of appearance and of technique involved in "push" or "pull" flaking.

Although percussion has been deliberately avoided for the present, it appears that a strong analogy to pressure exists. As they appear here the principles of stone working are based solely on the experience of the author so it is quite possible that techniques exist which do not fit the "push, pull" idea.

The principal objective of this paper is to generate templates which will allow the control of knapping along an accurate prediction of results.

"PUSH" chips

"PULL" chips

DIFFERENCES OF APPEARANCE

parallel sides	expanding sides
small interspace	large interspace
long, narrow scars.	far scars
high ridges	low ridges
usually organized	often random directed
flat trajectory	arced trajectory
lacking bulb	prominent bulb
feathered termination	abrupt termination
compression rings @	compression rings with
consistently large radii	expanding radii
fine material	coarse material
(usually heat treated)	
sharp median ridges possible rounded median	

DIFFERENCES OF TECHNIQUE

steady support of stone	loose support of stone
firm support of pressor	loose support of pressor
force in direction of fracture	force away from fracture
slow detachment	fast detachment
segregated platforms	simple platforms
shallow "bite"	deep "bite"
pointed pressor	pressor may be dull

ARTICLES

A TYPOLOGY OF THE WEST EUROPEAN LITHIC POLISHED AXE

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1. Introduction

As axes are a very common feature of recent prehistory, they have been studied very often. In a recent publication, D.

Hoef (1970), constructed a typology of the West European

axes. The properties of axes he used in his typology were the shape of the section, the shape of the butt and finally, for further subdivision of his types, the edge curve. He made no attempt to evaluate these properties quantitatively. This resulted in a typology that remains rather speculative.

It seems to us that a typological study of axes should be concentrated on the study of the axe as a tool, where the mechanical properties, and not the form, are the distinctive elements. The major properties of such a tool are connected with the problem of the stability of the axe in its haft and the properties of the working part of the axe, i.e., the cutting edge. The results of such a study can be used in constructing a typology. Our typological differentiation is expressed as a code number. The code number is an indication of the function for which the axe could have been destined.

To arrive at the proposed typology, the mechanical properties of a sample of 92 axes (52 of flint and 40 of another material) were studied (Dopere, 1966). These axes belong to the so called West European type, with lenticular section. They belong to the collection of the Laboratory of Prehistory of the Katholieke Universiteit te Leuven, Belgium and they come from different localities in Belgium and France.

This typology of the axe is based on the cutting properties and on the method by which the tool could have been fixed in its haft.

The material, the mass and the size are not considered in our classification. With the elimination of size, it becomes possible to use reduced dimensions. Comparison and classification are thereby facilitated.

The method of classification rejects all individual characteristics such as fabrication errors, wear, damage and resharpening. Local irregularities are therefore considered as accidents, so that limited intra- and extrapolation can be tolerated. For the same reason, a method enabling the reconstruction of the original cutting-angle and the tool edge becomes a necessity.

No importance is attached to the quality. The principle is put forward that any tool which was used by man, no matter what the quality may be, must be considered as such and consequently be dealt with in the same way.

The present classification method confers a code number

on each specimen. This number is composed of 4 parameters, each of which indicates a well-defined characteristic. These characteristics, which will be defined in the following pages are:

- a. the nature of the possible method of fixing the tool in its haft (classes 1000 and 2000);
- b. the reference profile (classes 100, 400);
- c. the position of the tool profile in regard to its reference profile (classes 10 - 40);
- d. the cutting-angle (classes 1 - 3).

When a parameter cannot be determined, the symbol is given. The code number may be followed by one or more of the following complementary symbols:

- A: the original bit is asymmetric (fig. 3);
 B: the horizontal profile is asymmetric (fig. 4);
 C: the tool was doubtless intended to deal with an axial force; R: the projection of the profile of the tool has undergone a relatively important, though justified interpolation or reconstruction;

V: the form is to be considered as abnormal.

Fig. 1a.

$$F = 2R \sin(\alpha + \phi)$$

Fig. 1b.

$$F' = 2R \sin(\phi - \alpha)$$

Fig. 1 - Equilibrium of the wedge

Fig 2.- Definitions - The $\tan \alpha$ - diagrams

Fig. 3 - The asymmetrical cutting edge

Fig. 4 - The asymmetrical horizontal profile

If demand is made for specific information concerning elements which have not been dealt with in the study, or if further investigation on the base of the obtained numerical results is judged necessary, the code number can eventually be completed with one or more distinct parameters \ § 6).

3. The Stability of the System Axe-Haft

a. Introduction

If an axial force F is applied to a wedge which is pressed between two supponing surfaces, the condition of equilibrium, motion impending, will be expressed by the triangle of forces and the relation:

$$F = 2R \sin(\theta + \varphi)$$

where $\tan \theta$ is the inclination of both inclined planes, φ the angle of static friction (fig. 1a).

Assuming that the material of the supporting planes is homogeneous and perfectly elastic, complete recoupera. tion of force will be obtaine.d when application of F ceases. The magnitude of the reactions R will therefore be equal to the foregoing when a force F' is appiied to the wedge in the opposite direction attempting to drive the wedge out. Motion impending, the expression of equilibrium is then given by (fig. 1b):

$F' = 2R \sin(\theta - \varphi)$ The ratio of both forces:

b. Application on the Axe

The combination axe-haft is a hyperstatic system which prevents any approach by means of statics. In addition, complete elasticity does not exist and numerous other imponderables are present. It is necessary therefore, to adopt the following working hypothesis.

The axe is considered as a coplanar system, the s\ edges (fig. 2) alone being responsible for the reactions R: The axe is rigid and the material of the haft completely elastic.

Fig. 6 represents such an axe with a curved symmetrical profile and an effective cross section A1 - A2' The

axial force F is distributed uniformly. each elementary cross section dA of the effective cross section receiving an equal force dF . The local efficiency of self-locking in any point of the profile is given by the

expression:

$$k = \frac{1 - \tan \alpha_y}{1 + \tan \alpha_y} \tan \theta$$

where k varies with $\tan \alpha_y$ and $\tan \theta$. The variation of $\tan \alpha_y$ is represented in the $\tan \alpha_y$ - diagram of the vertical profile (figs. 2, 6, 16, 17, 18).

Investigation has shown that the coefficient of friction $J.I. = \tan \theta$ which can be relied upon for stability is $\tan \theta = 0.125$. For this value of $J.I.$ the diagram $k = f(\alpha)$ is represented in fig. 5. It will be noted that if $\tan \alpha_y > 1$, self-locking is excluded and replaced by a tendency of expulsion of the axe (fig. 5).

An analogous diagram is shown to the right of fig. 6 opposite to the effective cross section. It represents the local stress p' in the section when F' is acting. Graphic integration of this diagram leads to F' and the resulting $k = -F'$ of the system.

The value of k depends on the outline of the side edge. Comparison of different profiles was therefore to be carried out.

The value of $J.I. = 0.125$ having been adopted for the purpose of this study, a straight edged specimen with a constant $\tan \theta = 0.100$ ranging over the entire length of the edges was chosen to act as a reference. The following results were obtained for 4 typical profiles, all possessing an equal working breadth (fig. 7):

Type A. - The side edges are linear with a constant inclination of $\tan \alpha = 0.110$. k was calculated by means of the expression given in § 3a. This lead to $k = 0.110$.

Type B. - The side edges are curved. the linear

inclination diagram ranging over $0 \sim \tan \theta = 0.200$. It is possible to trace the corresponding outline with the same working breadth of the haft and an equal cross section $A_1 - A_2$. Graphic integration gives $k = 0.042$.

Type C. - The side edges are curved. the linear $\tan \alpha_y$ - diagram ranging over $0 \sim \tan \theta = 0.125$.

The profile of an axe showing this diagram can only then be traced if the effective cross section is reduced to 67.5% of the section of type A. The force which can be supported is therefore reduced in the same proportion. On the contrary, the efficiency of self-locking amounts up to $k = 0.251$.

Type D. - The side edge is curved. The variation of $\tan \alpha_y$ is nonuniform, ranging over $0 \sim \tan \theta = 0.200$. The specific case which was studied shows the broken $\tan \alpha_y$ - diagram of fig. 7.

In this case reduction of the effective cross section is necessary and is brought to 85% of the section of type A. The efficiency of self-locking was found to be $k = 0.131$. It is not surprising that diagram D. taking up an intermediate position between Band C. has a value

between those types Band C.

Types A and B, showing an effective cross section greater than the sections of C and D. consequently have a greater capacity of handling forces than do C and D. The relative importance of these forces is indicated in fig. 7 by a coefficient F .

When judging an axe. both strength and self-locking are to be considered. It will be noticed that the types Band C offer the most outstanding differences. Able to support a considerable force, B shows a reduced value of efficiency of self-locking. The properties of C are exactly the contrary. Although axe A possesses both properties in a high degree, such an axe was not encountered in the studied sample.

The majority of the axes studied (75%) show a type B $\tan \alpha_y$ - diagram. Distinction must be made between a diagram, the length of which is totally needed for hafting, and the diagram with an extension which enables the breadth of the haft to be limited to the range $0 \sim \tan \theta = 0.125$. In this case the axe finds itself in the condition of type C. Axes of this kind exist though not in the highest proportion. In the case of type B it is therefore necessary to inspect the length of the $\tan \alpha_y$ diagram before deciding whether the axe is to be considered as belonging to type B or C.

The foregoing results make it clear that axes of the types B, C and D exist with a preference for type B. It is necessary to emphasize here that $J.I. = 0.125$ is a low limit of what can be expected in practice. The low value of a k (type B) must therefore not immediately be considered insufficient. On the other hand, combined wedging, which will be mentioned here after (§ 3e), is usually present and is apt to compensate the low value of k in a measure which however is impossible to express numerically.

It must finally be added that the types C and D with their reduced coefficient F are capable of handling equally important forces as those of the types A and B on condition of increasing the breadth of the haft, i.e., the size of the tool.

The preceding considerations have led to the definition of the working breadth of the haft: it is the length of the $\tan \alpha_y$ - diagram ranging over $0 \sim \tan \theta = 0.200$. In practice the breadth may eventually be reduced (type C), but not increased.

Comparison of the Relative Positions of the Haft of the Axes with Curved and Straight Side Edges

Fig. 8 compares the types A and B of fig. 7. The lower half shows the straight edged axe. the upper half the axe type B. Both axes are in equilibrium, both possess the same point of intersection of forces O and an equal cross section.

It is important to note that when the intersection of forces is situated in the centre O of the bit. as in fig. 8. that the tool is able to deal with a non-axial force without showing any tendency of rotation of the axe in its haft.

Fig. 7 - Influence of the $\tan \alpha_v$ -diagram on the properties of the tool.

The following conclusion can be made:

- 1). the haft of type B is situated nearer to the bit than the haft of type A.
- 2). the resulting reaction R of type B intersects the side edge very near the point where $\tan \alpha_v = 0.125$. The axis of its haft intersects in the point where $\tan \alpha_v = 0.100$. The point on the x.a.xis corresponding to $\tan \alpha_v = 0.100$ is denoted by C_v .
- 3). the distance CC_v which in the present case equals the distance of the axis of both hafts, depends on the breadth of the axe, but is generally far from being important in the case of type B. In the particular case of

fig. 8 the reduced value (§ 3d) of CC_v is $\frac{C_v}{C} = \frac{6}{6.6} =$

0.093. C and C_v are taken the centre of the axe in their respective cases.

Considering that in fig. 8 both axes possess the same point a and respective points C and C_v situated at little distance from each other, a certain relationship seems to exist between the straight edged axe and the curved edge, type B. Furthermore, investigation has shown, not only that the majority of the studied specimens possess a $\tan \alpha_v$ - diagram as mentioned above, but a bit representing the segment of a circle. A reference profile was therefore introduced on the base of the straight edged axe with a $\tan \alpha_v = 0.100$.

Fig. 8 - Comparison of axes with curved and straight side edges

d. The Reference Profile

The reference profile (fig. 2) of an axe is a theoretical, symmetrical, vertical profile, the circular edge of which corresponds with the original edge of the specimen studied, while the linear sides, with an inclination $\tan \alpha_v = 0.100$, are tangent to the outline of the real axe. The axis of the reference profile, on which the centre of the edge is situated, determines the x-axis of the axe studied.

The centre a is the origin of a 3-dimensional coordinate system and acts mechanically as the centre of percussion. The radius r of the bit is considered as the module of the profile, while half the angle, subtended by the circular edge, is termed the angle of force α . The line of action of any applied force is situated in the angle 213 and directed towards the centre O . and α specify any particular reference profile (fig. 13).

It has already been suggested that the axe-centre C must be considered as a reference point. The abscissa OC of C is easily calculated. If the reduced value of OC is denoted

by x_c , then:
$$x_c = \frac{\sin(\alpha - \alpha_v) \sin(\alpha_v + \alpha)}{\cos \alpha}$$

with $\tan \alpha_v = 0.100$ and $\tan \alpha = 0.125$, x_c depends only on α . The value of $OC = x_c r$ can be estimated with sufficient accuracy with the help of the nomogram fig. 9.

The definition of the reference profile implies the possibility of reconstructing the original cutting edge. This point will be discussed in § 4.

e. Influence of the Variation in Typology

In practice, an important variation in typology exists. The conditions represented in fig. 8 are therefore not always present and the properties which were mentioned in § 3c not all obtained.

Two possible fundamental differences can be mentioned:

1). C is not situated on or near to C . In this case a non-axial blow will produce reactions R which do not intersect in the centre O of the bit, therefore generating a couple of forces leading to instability and even to dismantling of the tool. Even if the $\tan \alpha_v$ - diagram gives entire satisfaction, the possibilities of the tool are restricted. These are tools which are meant to deal with axial forces, as in the case of a chisel.

2). The $\tan \alpha_v$ - diagram cannot account for satisfactory hafting. In this case it is almost certain that the flanks are responsible for self-locking. To make sure that the necessary conditions are fulfilled, the $\tan \alpha$ diagram of the horizontal profile will be traced (fig. 2). Contrarily to the 75% type Band 25% type D which was obtained with the $\tan \alpha_v$ - diagram, the $\tan \alpha$ diagrams are equally distributed over the types Band D.

No reference profile is constructed for the horizontal profile. The working breadth of the haft will, as before, be fixed by the same numerical limits: $\alpha \sim \tan \alpha : h \sim 0.200$ and the point on the x-axis, corresponding to $\tan$

$\alpha_h = 0.100$ will be denoted by Ch . The reference profile, of the vertical profile will still be used for matters of classification although C is now of no avail.

In principle, an axe which is only wedged by the flanks can only support an axial force. This method of hafting is therefore restrictive and offers a first indication that the tool was possibly used as an adze.

If the haft covers both diagrams to an important extent, combined wedging takes place, that is wedging on both sides and flanks. It has already been mentioned that combined wedging can improve the value of the efficiency of self-locking of the instrument (§ 3b).

4. The Cutting-Angle

a. Resharpener of the Cutting-Angle

Resharpener of the axe can be carried out on a limited area of the surfaces forming the cutting edge. This treatment leads to a relatively important increase of the cutting-angle and consequently in a change of the cutting properties of the tool (fig. 11). The operation can be extended to a larger area or even the complete surfaces of the bit, in which case the cutting-angle may be considered as having been restored to its original value, or, having undergone a renewal.

The first resharpener method, being the most easy and also the most rapid to carry out, it can be expected to occur the most frequently.

If the result of wear or resharpener is compared with the original profile, a profile-shortening to x and a profile-bluntness z can be defined as illustrated in fig. 10.

It will be clear, not only that correct measurement of a cutting-angle, even a new one, is extremely difficult and subject to considerable error, but that, even in the best operating conditions, the result obtained will not have the slightest significance. A statistic based on such a procedure would not be a statistic of the cutting-angle, but rather one of wear. The necessity of discovering a method which would enable the reconstruction of the original cutting-angle is therefore of utmost importance.

b. Preliminaries to the Determination of the Original Cutting-Angle

The study of the cutting-angle of 84 axes of various origin, material, size, shape and wear, lead to the following conclusion.

The mean inclination $\tan \alpha = 2z/h - 2x::1$ of the profile of the cutting-angle with reference to the local symmetrical axis of the cutting-angle, over the distances 0- 2.5mm, 2.5 - 5mm, 5 - 7.5mm and 7.5 - 10mm, measured from the extreme point of the existing cutting-angle, results in a $\tan \alpha$ - diagram which has the general disposition shown in fig. 12.

The diagram is linear, but shows a break in K . It is evident that wear and resharpener must be held responsible for this local accident.

It can be expected that, although the general trend between 02 and 04 is linear, in practice certain irregularities will occur which render the diagram more or less discontinuous (fig. 12a). This point was investigated. A statistic was built up which showed that, for 78.6% of the material examined, the maximum deviation $60n = 1/4 (02 + 04 - 203)$ from the linear interpolation (fig. 12a) showed an approxi-

mat e Gaussian distribution. This was not the case for the entire collection which shows an asymmetrical dispersion of approximately 10%, 60% of the total having $60n > 0$ (fig. 12a), 40% $60n < 0$. It is easy to recognize reshaping over a distance greater than 5mm as being responsible for $60n > 0$. The discontinuous diagram is therefore not solely the result of the inevitable errors in construction and measuring.

Fig. 12a.

Fig. 12 - Determination of σ and Δx 14

Furthermore, the importance of the linear errors leading to the irregularities up to $\alpha_n = 11.5^\circ$ I. which was the case for 97.7% of the specimens studied, was compared with the tolerances applied in the present mechanical production. The result was rather surprising, the calculated errors being comparable to the usual tolerances for a non-fit.

It is obvious, that when $\alpha_n' < 11.5^\circ$, the irregularity of the diagram may be treated in the same way as the dispersion which is tolerated for a corresponding quality in mechanical construction. In practice, linear interpolation will therefore be applied and termed the diagram of the nominal cutting-angle.

This conclusion is thus also accepted for the material responsible for the asymmetrical distribution, as long as $\alpha_n' < 11.5^\circ$. The extension to these specimens is made not only because of the impossibility of knowing which tool is responsible for the asymmetrical dispersion and which is not, but also because the combined error does not exceed the fixed limit.

Only for irregularities $\alpha_n > +1.5^\circ$ the interpolation is not indicated. It is necessary to apply a correction to a_2 , which was certainly influenced by resharpening. The corrected a_2 is given by $a_2 = a_4 - 2a_3'$

$\alpha_n < -1.5^\circ$ is to be considered as an anomaly, verification being necessary. If the anomaly persists, the function $\alpha_n = f(x)$ is not linear and the method is therefore inapplicable. The symbol 0 will replace the corresponding parameter. Although b_x is unknown, it is generally possible to determine the other three parameters in a satisfactory way. Subjective interpretation must nevertheless be avoided.

c. Working Hypothesis

The results of the study which were summarized above lead to the following working hypothesis:

- 1). The outline of the two sides of the cutting-angle were, originally, identical. The α_n - diagram of both sides are therefore identical. The corresponding symmetrical axis may or may not lie on the reference axis of the axe. with which it may or may not form an angle.
- 2). The original cutting-angle was identical over the whole working area of the cutting edge. Therefore, if measuring cannot take place at the point where the plane XOZ intersects the cutting edge (fig. 2), a place will be chosen giving the best guarantee, though preferably as near to the above named point as possible
- 3). The function $\alpha_n = f(x)$ of the cutting-angle is linear over its entire range. Any interpolation and correction of a_2 will be carried out as mentioned before. The linear diagram determines the nominal cutting-angle.
- 4). Tools which display wear show a break in the α_n diagram at a point K situated at 3.75mm from the extreme edge of the existing cutting-angle.
- 5). Asymmetric edges will be treated in the same way as symmetrical ones.

d. Procedure for the Determination of a and b_x

The original, nominal cutting-angle will be determined as follows (fig. 12):

1). The actual limit of the cutting-angle is considered to be the origin of a rectangular system of coordinates, the x-axis being the symmetrical axis of the nominal cutting-angle. The double ordinates $2z_1, 2z_2, 2z_3$ and $2z_4$, corresponding to the abscissae 2.5 - 5 - 7.5 10mm are measured.

2). The mean inclination $\tan \alpha_n$ and the angle α_n of each domain line calculated. The angles α_n are set off in the centre of each domain and the polygonal line $\alpha_n = f(x)$ is drawn. If $\alpha_n < 11.5^\circ$ interpolation between a_2 and a_4 is carried out and the linear diagram, the nominal $\alpha_n = f(x)$, is extrapolated beyond $x = 3.75\text{mm}$. $\alpha_n > +1.5^\circ$ requires a correction to be applied to a_2 before interpolation (§ 4b).

3). The length of the domain 0 - 2.5mm is successively extended by 0.5 and 1mm, the corresponding angles α_1' and α_1'' are calculated and set off in the centre of their respective domains. The line $\alpha_1 - \alpha_1' - \alpha_1''$ (the α_1 line) is constructed. This line shows no noticeable deviation from the straight line.

4). The intersection of both the α_n - and α_1 - lines determine α_0 , the mean angle of the nominal cuttingangle over the length $TS = 2\text{ MS}$ (fig. 12).

The ordinate of $\alpha_n = f(x)$ in T gives the value of the nominal, therefore of the original cutting-angle a in the extreme point of the original cutting edge. The profileshortening b_x is the length, beyond 0, in the negative direction.

If there is no intersection point, $b_x > 1\text{mm}$. Sufficient supplementary angles α_1''' a IV . . . will be calculated corresponding successively to supplementary extensions of the domain by 0.5mm. The α_1 - diagram thus obtained is non-linear.

5. A Typology of the Axe

a. Classes 1000 and 2000

The C-classes 1000 and 2000 specify the nature of the most probable self-locking method.

An axe belongs to class 1000 if self-locking is effected by the side edges of the axe. The length of the axe corresponding to 0 . . . ; $\tan \alpha_0 = 0.125$ is generally fully used, the haft usually extending up to $\tan \alpha_0 = 0.200$.

An axe belongs to class 2000 if self-locking is produced by the flanks. Generally full use will be made of the flanks between the limits 0 . . . ; $\tan \alpha_0 = 0.125$, the haft reaching up to $\tan \alpha_0 = 0.200$.

If the haft covers both diagrams to an significant extent, combined wedging takes place. The axe belongs to class 1000 or 2000, depending on the relative importance of the two situations. Such specimens may be recorded as 1000/2000 or 2000/1000.

In each particular case the projection of the outline of the axe is traced by any method which guarantees

parallel light rays, or by the simple method of a high, centrally positioned, concentrated light source. The minimum height above the object to be projected is 2m.

The centre 0 of the edge-profile thus obtained is determined geometrically and, after 6x (§ 4d) has been calculated, the original edge of the axe is traced. It is necessary to inspect the edge of the axe to make sure that possible slight asymmetry, which may be due to wear, damage or reshaping, is taken into account.

The reference profile is then traced in such a manner that its x-axis passes through the centre of percussion 0 and its sides touch both sides of the projection of the axe. The inclination at these points is therefore $\tan \alpha_v$.

0.100. It is necessary to bring both points as near possible on to the same perpendicular to the axis, the intersection of both being denoted by Cy (fig. 2.6). If the abscissae of both points of contact are slightly different, Cy will be half way between them.

If the abscissae are far apart, no notice will be taken of the centre 0 and the reference profile will be traced in such a manner that the points of contact lie on the same vertical line. In this case the cutting edge of the axe possesses a certain asymmetry (fig. 3). If this is only slight, inspection will show whether sufficient importance has been attached to possible local wear and reshaping.

Fig.13 - Classes 100 to 400. The profiles are represented with identical breadth and the values of β indicated.

Fig.14 - Classes 10 to 40. The profiles are represented with identical side-edges and the values of v indicated.

With an asymmetric edge may be conceived as an e with a symmetrical edge one of whose sides is trans'rated towards the x-axis (fig. 3). The sides of the axe may therefore be treated in exactly the same way as in the case of a symmetrical axe and the x-axis thus determined. The parallel axis passing through the centre O is the axis of the basic symmetrical reference profile from which the asymmetrical type is deduced.

After tracing the reference profile the angle $\{3$ is calculated and the original radius is measured. The value of $OC = xcr$ is then calculated (§ 3d) or determined with the help of nomogram fig. 9. The corresponding point C is plotted on the x-axis.

Although no reference profile is constructed for the horizontal profile, the position of its x-axis is not arbitrary, even though it be less well-defined than the axis of the vertical profile.

On principle, the x-axis is drawn through the extreme point of the cutting-angle, so that the $\tan CX:h$ - diagrams of both flanks are centered in the range $0 < \tan CX:h < 0.125$, with a preference for both points where $\tan CX:h = 0.100$ to have the same abscissa (fig. 2). If the result obtained is not satisfactory, a translation and/or rotation of the axis is to be considered, centering the regions mentioned above, even if the cutting-angle should leave the axis.

The $\tan cx:v$ - and $\tan CX:h$ - diagrams are now constructed. The use of tracing paper is recommended, together with a ready-made bundle of lines with inclinations $\tan cx: = 0.000 - 0.125 - 0.140 - 0.160 - 0.200$. The polygonal $\tan cx: -$ diagrams thus obtained will then be interpreted in their relation to the profile of the axe. Interpreting will be done on the following lines:

1). C_v is situated near to C. the length intercepted by the $\tan cx:v$ - diagram being sufficient for the breadth of the haft, the latter allowing enough freedom for the bit: class 1000

Identical result as above, the haft covering a fraction of the useful $\tan C::h$ - dia., "I am: combined wedging 1000/2000, class 1000.

2). The distance separating C and C_v is important, C directed towards the bit, the other conditions being fulfilled: class 1000, the wol is meant to deal with axial forces.

3). C is distant from C'' and directed towards the butt-end. The haft will generally find itself too near the bit. Class 1000 is possible but 2000 is probable.

4). If the $\tan c::v$ - diagram is unsatisfactory, the axe almost certainly belongs to class 2000. The $\tan C::h$ dia., "I am will show if hafting can be carried out in a normal way, that is, if sufficient breadth of the haft can be guaranteed. If this is not the case, there is serious reason to believe that the specimen is false or faultily constructed.

If the haft covers part of the $\tan cx:v$ - diagram, combined wedging takes place and 2000/1000 may be noted although the axe belongs to class 2000.

The a.xes of class 2000 are generally intended to deal

with axial forces. It is therefore unnecessary to add the complementary symbol C to the code number. Only in case of combined wedging can non-axial blows be expected to be dealt with to a limited extent.

b. Classes 100 - 200 . 300 .400

The classes 100 - 400 deal with the general outline of the axe, in particular the angle of force $\{3$, and therefore with the shape of the reference profile. The shape being dependant only on the value of $\{3$, it is this which will determine the different classes (fig. 13).

It may happen that no intersection of the circular bit with the sides of the reference profile is obtained. In this case, which applies to some tools only capable of handling an axial force, $\{3$ is recorded as > 900 .

The following convention is adopted:

Class	t
100	$\{3 \ 30$
200	$30 < \{3 \ 40$
300	$40 < \{3 \ 60$
400	$(3 > 60$

c. Classes 10 . 20 . 30 . 40

The classes 10 - 40 specify the general outline of the axe, in particular its position in regard to its reference profile. This position is fixed unequivocally by means of the displacement OC_v and specified by the reduced value $v = \frac{v}{v}$ (fig. 14).

The following convention is adopted:

Class	v
10	$v-0.6$
20	$-0.6 < v < -0.3$
30	$-0.3 < v < +0.3$
40	$v > +0.3$

d. Classes 1 . 2 . 3

The classes 1 . 3 specify the value of the nominal cutting-angle a .

The measuring of the double ordinates $2zn$ (§ 4d) will be done with the utmost care and precision. use will be made, for example, of an instrument for measuring the tickness of the teeth of gears.

The calculations necessary for tracing of the an diagram (fig. 12) will be facilitated by the use of the calculating paper (Appendix).

As precision will equally be aimed at in the execution of these diagrams, a large scale is therefore indicated. In practice, only the bottom half of fig. 12 will be constructed (Appendix. Fig. 15).

The following convention has been adopted:

Class	a
1	$a35$
2	$35 < a \ 40$
3	$a > 40$

The code number as determined above is based on the functional properties of the axe. Geometric or other properties can equally be dealt with and a corresponding complementary code number determined. It is necessary to separate the functional code number and the complementary code numbers with a dash.

7. Geometric Complementary Code Number

a. Classes 1 - 2 - 3

Considering the number of axes with the butt missing, it is impossible to integrate the length of the tool in the complementary code number. The classes 1 - 3 will therefore deal with the more general specification of size. The following convention is adopted:

Class	length I, breadth b
1	I 90mm or b 40mm
2	90 < I < 150
	and 40 < b < 70
3	I > 150mm or b > 70mm

In case I > 150mm and b ~ 40mm, the specimen will be recorded as class 3.

b. Classes 10 - 20 - 30 - 40 - 50

The classes 10 - 50 specify the relative thickness $d \approx$. The following convention has been adopted:

Class	d=
	b
10	0.2 > d
20	0.4 > d 0.2
30	0.6 > d 0.4
40	0.8 > d 0.6
50	d 0.8

The breadth b and the thickness e will be measured on the projected side profile of the axe.

When a parameter cannot be determined, the symbol given. The complete code number now takes a form 0 which 32-1342.C is an example. 1342 is the functional code number, 32 the geometric code number.

Conclusion

Analysis of the code number, attributed to each of the 92 axes of our collection, indicates that some code numbers are more frequent than others. This may be the result of a different use of the axe. Thus a preponderance of code number 1230, with some code numbers 1130 and 1330, can probably be correlated with an all-purpose type of axe, while a preponderance of code number 1340, with some code numbers 1240 and 1440 suggests an axial use. Axes with a code number 2120, extending also over 2110, 2130, 2220 and 2320, were possibly used as adzes (fig. 16, 17, 18). Of course no definite conclusion can be made without the contribution of other investigations, such as of the haft type.

Further research will indicate if these typological subdivisions, expressed by the code number and based on the mechanical properties of the axe, can be used in the study of large collections of axes. We are aware that some non-functional properties of the axe, such as the form of the butt, probably also need to be studied. Some of these non-functional properties may be very important in respect to specific cultural traditions. In that case, such properties should be included in the typological definitions. However, it is to be hoped that future research will use more objective criteria for these definitions, than in the past.

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Dopen L. H.

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N° 9668 - Genk (Belgium)

Flint $r = 45.5 \text{ mm}$

$\sigma = 37.5^\circ$ $\Delta x = -0.85 \text{ mm}$

$r = +0.96$ $\beta = 44^\circ$

Code n°: 32-1342-C

Fig. 16

0-Calculating Paper

O'''n-11ne									
hl -		2'1		O.HO					
	7.0)	„an cr 1 -			1			H.72	
212 -	7.H	212-Z'1		. C. }8		v.		Z8.72	
		tan q'''2 - ---r-			2				
		21 -Z'Z							
h).	7.8Z	Un <r} . + .0.86				(j''.		25.20	
		21. \ -2z							
2%, -	11.6}	Un cr. - ---r' - 0.66				a''		20.10	
Irr.g\&lart ty								I	
		.6 z: - t (U'Z . 17. - 2 Gj) . -C..O}				∴ o; "11,}1			
						Au; >-1,5 ---,			
CChreeUon								I	
		U'2 . 6 - +Za' .		tan Ci2					
hl-2'2-5.anaz-		2'1				0'''1			
		t'''11 ITI . -;-							
a - 11ne								j _I	
		12%1				(f'''			
		'on (J'''1 -		0.775		1		7.78	
		Ax , 1							
		.. 2%.1				(T''' -			
				0.66.		1 .		".60	
Appendix		ten V 1 . 1							
An example of each specific case which was mentioned in the conclusion (code numbers 1230, 1340 and 2120) is given in figs. 16, 17 and 18. One specimen is treated in extenso; of the following two, only self-locking is discussed.									
		AX;>1 tan 1T1 - "9				1			
		... 2.1							
		tan 1T1 .				(T .			
Specimen nO 9668 (fig. 15, 16 and calculating paper)									
		hi				(1'''			
a. The calculating paper and the diagram fig. 15 give full information concerning the determination of the cutting angle α (§ 4d).						1 -			
Results: α = 37.5°, D.x = 0.85 mm. Class 2 (§ 5d).		1''' 27.1							
		tan a''1 - U				(1''1 c			

b. The vertical and horizontal profiles are traced (§ 3b, 5a), C₀ is plotted on the x-axis (§ 3c). The profile shortening f₀: x is added to the bit at the point where measuring of 2zn took place. 0 is determined geometrically and the original cutting edge is traced. The radius r = 45.5mm is measured and {3 calculated.

Result: {3 = 44°. Class 300 (§ 5b).

The displacement OC_y = vr-43.5mm is measured. Result:

v = 0.96 = 4.96. Class 40 (§ 5c).

xcr is determined with the help of the nomogram fig. 9,0 which the operation is traced. xcr = DC - 6.2mm. C is plotted on the x-axis (§ 3d).

c. Self-locking.

1). Cv and C lie far apart: the axe is meant to deal with axial forces (§ 5a).

2). The tan cx:v - diagram is normal, rather similar to type B (§ 3b) and extended. Hafting is possible. self.locking produced by the side edges. Class 1000 (§ 5).

3.) The tan CX:h - diagram is nearly entirely enveloped by the tan ccv - diagram, therefore combined wedging 1000/2000 (§ 5).

Conclusion: Axe to be used with an axial force. Non-axial use to be avoided. Combined wedging 1000/2000. Class 1000 (§ 5).

The functional code number of the specimen is 1342C. The symbol C attracts the attention to the axial use of the tool.

Specimen nO 9514 (fig. 17)

1). Cv and C are situated in approximately the same position. The axe can deal with non-axial blows (§ 5a).

2). The tan cx:y - diagram is normal, very similar to type B (§ 3b) and extended. Hafting is possible, self-locking produced by the side edges. Class 1000 (§ 5).

The extreme point of the diagram being situated too near the bit, a fraction of the most interesting part of the diagram is rendered useless. k attaining a very low value (§ 3b).

3). The tan CX:h - dia"araro is nearly entirely enveloped by the tan cx:v - diagram. the latter well situated with respect to the former. Combined wedging 1000/2000 will therefore be present and k improved (§ 3e). Conclusion: Allpurpose type of axe. Combined wedging 1000/2000, Class 1000 (§ 5).

Specimen nO 909 (fig. 18)

1). Cv and C lie far apart, C directed towards the butt. The axe is meant to deal with axial forces (§ 5a).

2). The tan cx:v - diagram is abnormal the minor values up to tan cx:v = 0.125 having a limited extension and being situated too near the bit. The diagram is not suitable for hafting.

3). The tan CX:h - diagram of type D (§ 3b) is extended and well situated. The efficiency of self-locking may be estimated at k = 0.130. The dia"aram does not envelope the use full fraction of the tan cy - diagram, therefore class 2000. Conclusion: Axe Class 2000, axial use. Possibly used as an adze (§ 3e).

Fig. 18