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BRONZE AGE FLAT AXES FROM BERKSHIRE

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INTRODUCTION

The purpose of this paper is to make a further contribution to the study of Bronze Age metallurgy in a limited field.[1] The type of axe under consideration is that without flanges, recently discussed by Britton.[2] Eight examples from Berkshire have been analysed as well as two implements from Ireland and Jersey which provide useful comparisons. One axe, whose provenance is simply Berkshire, has not been analysed and two other Berkshire examples which may have been of this form could not be traced.

A purely archaeological consideration of one isolated type from such a restricted and arbitrary area would be of almost no value and this introduction serves merely to place the axes in their national and local contexts. With one exception they are of bronze and include none of the thick-butted type as defined by Coghlan and Case.[3] They do not therefore belong to the earliest class of metal axe in the British Isles although they are the earliest in this area. Britton[4] assigns them to his Migdale-Marnoch tradition and considers[5] that "some at least of the flat and slightly flanged axes" belong to Wessex I, dated 1600–1550 B.C. by him, although the whole Wessex Culture has been tentatively redated to 2100–1700 B.C. on the basis of tree-ring calibration of radiocarbon.[6] On the other hand they must be earlier, in part at least, than the cast-flanged axes of Wessex II.[7] However the two-fold division of the Wessex Culture has been called into question[8] and the chronology of the period must be regarded as fluid.[9]

In Berkshire there are no useful associations of flat axes, two (nos. 2 & 3) probably being found together and one (no. 7) occurring in a Late Bronze Age hoard, the significance of which is discussed below. Other Early Bronze Age metalwork is not common and items[10] that can be assigned to Wessex II or the broadly contemporary Arreton tradition[11] probably post-date the axes under consideration. The Early Bronze Age in Berkshire has not been discussed as a whole since Peake's[12] survey of 40 years ago, although bronzes from the Newbury area have been discussed by Roskill,[13] ring-ditches in the Upper Thames valley by Case[14] and round barrows in the whole county by Grinsell[15] and more recently in East Berkshire by Copsey.[16] Very few barrows have been found to contain primary material of this period although this is almost certainly the result of barrow robbing and early unscientific excavation. Even less is known about settlement in this period, although the ploughed-out enclosure on Rams Hill,[17] now assignable to this period by virtue of its primary series Collared Urn[18] gives a rare glimpse of this aspect.

This is the background, albeit thin, against which one can set these flat axes and it is impossible in the present state of knowledge to integrate them any more closely into this picture. Line drawings of nos. 1, 2, 3, 5, 6, 10 appear on Figs. 1 and 2; photographs of nos. 8 and 9 on Plate I.

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LIST OF ANALYSED BERKSHIRE FLAT AXES[19]

(1) BRAY

Collection
Reading Museum Thames Conservancy Collection 44:52 (TCB 110).

Publication
Not published.

History
This axe was dredged from the Thames above Bray (approximately SU 901800) in March 1952.

Discussion
This specimen is a well-proportioned flat axe in good condition (fig. 1, no. 1). The implement has been chemically cleaned so that patination is absent, the colour being that of the parent metal. Upon one face of the axe there has been little serious corrosion pitting, but as often happens, the opposite face shows marked corrosion pitting. The blade is widely splayed and in both longitudinal and cross sections the axe is symmetrical. One would associate this type with an open mould casting finally shaped by forging. The axe is of slender form and if adequately hafted would be an efficient tool. The cutting edge of the blade is in relatively good condition and still quite sharp. The rounded end of the butt is very thin and has been worked or ground to what amounts to a sharp cutting edge. The sides have been carefully forged or ground to give the effect of a central rib. The total length is 136 mm, width over the splayed blade 92 mm and the maximum thickness of the body 10·5 mm. The weight is 390 grammes. For metallographic examination section A was taken from the cutting edge and section B is from one side at roughly mid-length of the axe.

Examination of section A showed the polished but unetched metal to be clean and sound. Some non-metallic inclusions, probably of slaggy origin, have been plastically deformed and elongated, suggesting hot-working of the metal during some period of fabrication. (pl. II, 1). There has been very little penetrative corrosion. In the case of section B the exterior metal is sound, but in the mass there is some porosity. Non-metallic inclusions are small and do not exhibit deformation. In both the sections a little $\alpha\delta$ eutectoid is seen, suggesting that the tin content may be above rather than below the 6% quoted in the analysis. Freedom from corrosion shows that the environment was a favourable one for preservation of the axe.

Upon etching section A a structure of equi-axed twinned crystals of very low grain size was revealed at the cutting edge. Coring while present is reduced (pl. II, 2). At the point the crystals have been highly deformed and twin bands and strain lines bent (pl. II, 3). Here it is clear the metal has been strongly forged and work hardened. The hardness at the cutting edge is 221 HV_5 and in the mass of the metal remote from the point 193 HV_5. Upon etching section B a general structure of equi-axed twinned crystals of low grain size is seen. Coring has not been eliminated and relics of the original cast structure (dendrites) are observed. The side of the axe has been worked and annealed and left substantially in the annealed state since, no trace of slip banding being detected in the crystals.

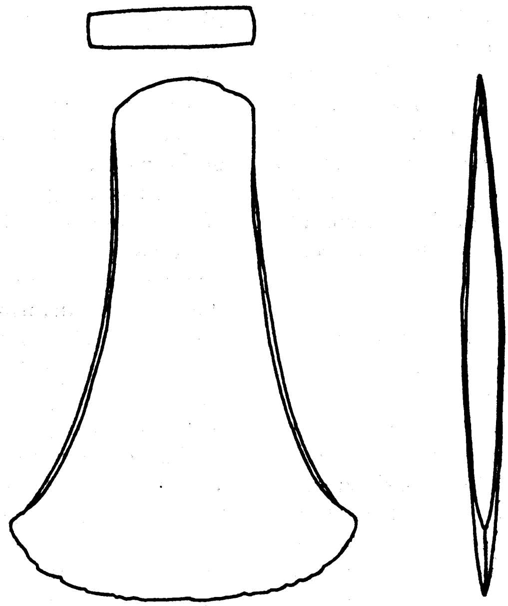
To sum up, the smith appears to have followed conventional methods and very probably employed open mould casting in making this axe. The hardness figure of 221 HV_5 attained at the cutting edge shows that he was skilled in the art of work-hardening cutting tools.

(2 & 3) CHOLSEY

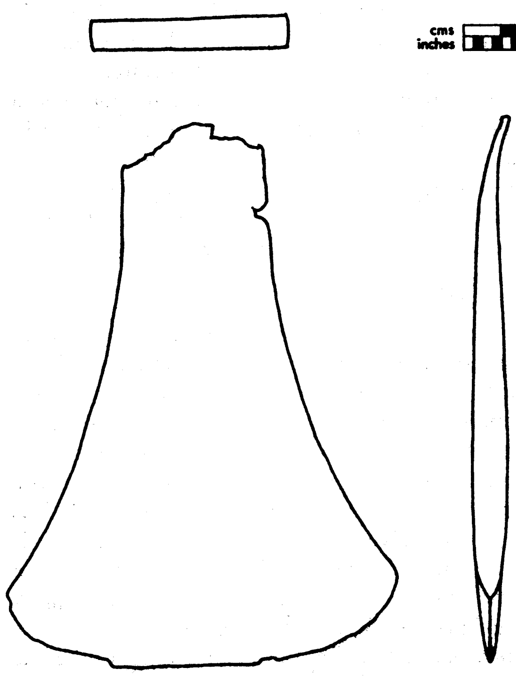
Collection
(2) Reading Museum 19:48/1 (AL44)
(3) Reading Museum 19:48/2 (AL45)

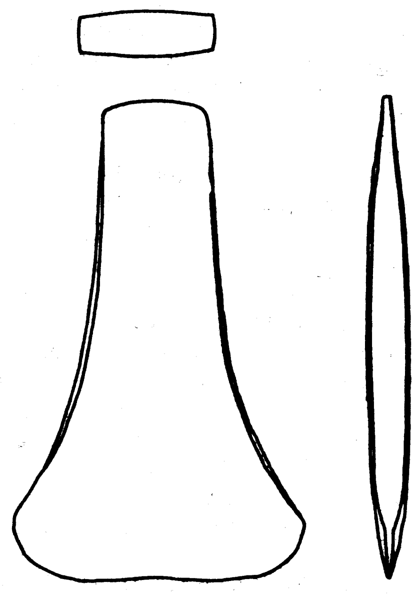
Publication
(1) J. Stevens: Descriptive Catalogue of Reading Museum Part I (1896) 32.
(2) VCH Berks I (1905) 182 & 194 and plate.
(3) H. Peake: Archaeology of Berkshire (1931) 51 & 187.
(4) V. Roskill: Trans Newbury Dist. Field Club VIII no. 1 (1938) 13 & fig. 8.

History
These two axes were deposited by W. R. Davies of Wallingford on 14th November 1883 and their find-spot recorded as Cholsey. One



Axe No. 1





Axe No. 2

Fig. 1

Axe No. 3

(no. 2) is marked "Found near Cholsey Church in ploughing 1878" (approximately SU 584870). Both have therefore been taken to have this provenance and although this seems likely it is not explicitly stated in museum records. The provenance of objects from the Davies collection is however suspect, Peake (p. 65) describing him as "a collector who made his purchases without a too critical inquiry into their source."

Discussion of no. 2

As in the case of no. 3 this axe has a well-splayed blade (Fig. 1, no. 2). Superficially it is in good condition with hardly any signs of corrosion attack and the environment must have been favourable for preservation of the metal. Patination is in general of a dark chocolate colour and no evidence for decoration could be detected. The sides of the axe are fairly smooth although in places forging marks are still seen. The cutting edge of the blade has been blunted and damaged by hammering upon some hard material. It is difficult to say whether this damage is relatively recent or not. The butt has also been slightly damaged by hammering. Both in longitudinal and cross sections the body of the axe is symmetrical and in form the tool is well adapted for practical use. Also it is one we should associate with having been worked to shape from an open mould casting. The total length is 127 mm, width over the splayed blade 76.5 mm and the maximum thickness of the body 11.3 mm. As with no. 3 the butt is much tapered, the metal at the end being only 1.5 to 2 mm in thickness. Its weight is 352 grammes.

For metallographic examination section A was taken from the cutting edge. Owing to damage to the edge by hammering this section had to be removed from towards the flaired end of the blade. Section B was removed from the side where the metal is thickest.

Upon examination of section A, the cutting edge, in the polished but unetched state the metal was found to be remarkably clean and sound and no defects or inclusions were seen. The same remarks apply to section B, from the side, with the exeption that there is some porosity in the mass of the metal. In both sections the patination upon the metal is extremely thin and practically no corrosion attack has taken place. The environment was therefore very favourable for the preservation of the metal.

Upon etching section A a structure typical of a wrought alpha bronze was revealed. Equi-axed twinned crystals of rather low grain size were seen throughout the section and there is no deformation of the crystals or evidence of slip bands. No relics of coring were seen and the metal would appear to be homogenised (pl II, 4). The microstructure suggests that the cutting edge of the axe has been worked and annealed and left in a substantially annealed state. However some cold work has been applied since hardness determination gave values of 125 HV_5 at the point and 91.2 HV_5 in the mass of the metal. Upon etching section B a similar structure to that of section A was revealed but of higher grain size. In the mass of the metal there is some increase in grain size (pl III, 1+2). The side of the axe has been forged and annealed and left substantially in the annealed state.

For this axe the examination suggests a conventional fabrication technique—casting in an open mould and forging, with annealing, to the desired shape. The cutting edge was hardened by cold work but the result is poor and only a low hardness value was attained.

Discussion of no. 3

This is a substantial flat axe with widely flaired blade (Fig. 1 no. 3). Patination is of dark green colour and the surfaces have been much damaged by corrosion and are now rough with deep corrosion pitting. In one or two places there is a slight suggestion that the axe may originally have been decorated, but the extensive corrosion attack renders it impossible to say if this was in fact so. The cutting edge of the blade has been blunted and damaged by heavy hammering and the butt end has been fractured and slightly bent. Undisturbed patination would indicate that the fracture of the butt took place in antiquity.

Both ends of the axe are rough and bear evidence of somewhat rough forging. At about 20 mm below the fracture of the butt there is a large cavity in the metal and as a result of bending stresses cracks have spread into the mass of the metal from this area of defective metal. In form the axe is slender and well suited to use as a cutting tool. The total length of the axe, as existing, is 143 mm, width over the splayed blade 102 mm and maximum thickness of the body 9 mm. The butt end has been strongly tapered, the thickness at the fracture being only 2 to 3 mm. Its weight is 440 grammes.

For metallographic examination section A was taken from the cutting edge. Owing to blunting of the cutting edge by hammering this section had to be removed close to the flaired end of the blade. Hence work-hardening here may be less than in the more central region of the blade. Section B was removed from the side at about mid-length of the axe.

Examination of the polished but unetched metal of section A showed that apart from very small inclusions, probably of slaggy origin, the metal is very clean and sound. Upon one face of the specimen patination is thin and there has been little corrosion attack. Upon the other face there is a thick layer of corrosion products but penetrative corrosion is slight. $\alpha\delta$ eutectoid was not noticed. In the case of section B the exterior metal is clean and sound but in the mass there is porosity. The patination is thin and there has been but little corrosion attack. One or two islands of $\alpha\delta$ eutectoid were detected. As in the case of no. 2 the environment was favourable for the preservation of the bronze.

Upon etching section A it was seen that recrystallisation had occurred throughout the section but in general coring had not been eliminated. In the region of the cutting edge the crystals are of very low grain size and here but little twinning could be detected. Also the crystals are not deformed and do not show slip bands (pl III, 3). In the mass of the metal remote from the cutting edge twinned crystals of greatly increased grain size and showing some slip banding appear. No deformation of these larger crystals was seen. At the cutting edge and also in the mass of the metal remote from the cutting edge the hardness was found to be 124 HV_5. In the case of section B the metal has been more fully annealed since coring is almost eliminated. Except in one place the grain size is much higher than in section A (pl III, 4). Also slip banding of the twinned crystals at the rounded edge of the section shows that the side of the axe has been cold-hammered as a final operation (pl III, 5). Hardness values of 134 HV_5 at the side and 71 HV_5 in the mass of the metal were recorded.

The axe appears to have been fabricated in much the same manner as no. 2. However it is unusual in that for some reason the smith cold-worked and hardened the side to a greater extent than the cutting edge. This is an inversion of the normal practice.

(4) NEWBURY

Collection

Newbury Museum OA 254

Publication

(1) H. Peake: Archaeology of Berkshire (1931) 51 & 213. With earlier references.
(2) V. Roskill: Trans Newbury Dist. Field Club VIII no. 1 (1938) 13.
(3) H. H. Coghlan: British and Irish Bronze Age Implements in the Borough of Newbury Museum (1970) 6 & pl. 5 no. 16.

History

This axe was given to the museum by J. W. Roaks sometime before 1854 and was found in the neighbourhood of Newbury. O. G. S. Crawford suggested that it may be the same as the flat axe found on a gravel heath to the north of Newbury and exhibited in 1846.

Discussion

This axe has been fully described and illustrated and for further discussion the reader is referred to publication no. 3 above. Considering its length and width the axe is slender and one face has quite a marked flat surface as if it were cast in an open mould. Upon one face only, that which shows the flat surface, slight flanges can be seen, but these are very slight and it is clear that the axe must be classified as a flat axe and not a flanged one. The total length is 170 mm, the width over the splayed blade 77 mm and the maximum thickness 11 mm. It was found that the axe had been quite extensively worked and annealed and no doubt it was cast in an open mould and afterwards worked to its present shape by forging. The cutting-edge of the blade has been hardened by hammering but the metal was too unsound for hardness determinations to be of value.

(5) WALLINGFORD

Collection

Reading Museum 1948:64 (AL 42)

Publication

H. Peake: Archaeology of Berkshire (1931) 51 & 237.

History

This was deposited by W. R. Davies of Wallingford in 1886 and its find-spot given as Wallingford. The doubts that are felt about the provenance of objects from the Davies Collection have already been expressed and this is certainly out of place in the Berkshire series. However the possibility that the provenance is genuine should be borne in mind.

Discussion

Harbison[20] has described this type of object as an ingot, a view which Case[21] has disputed. We agree with Case and consider this a misuse of the term ingot since the casting has been prepared with a cutting edge and bears no resemblance to known ingots (Fig. 2, no. 1). Even if one accepts Harbison's argument that such objects are too small to be axes, they are nevertheless edge tools with a cutting function, perhaps used in trimming. We therefore propose to call this a miniature axe. One face (Fig. 1) is very rough and has been deeply pitted by severe corrosion attack. Patination is of dark chocolate colour. The axe is poorly shaped and the blade is asymmetrical. Visual inspection would give the impression that it was cast in an open mould and then badly forged to its present irregular shape. However the metallurgical examination does not bear this out. The cutting-edge of the blade is slender, sharp and relatively undamaged.

The total length is 66.5 mm, the maximum width 43 mm and maximum thickness 5.8 mm. Its weight is 70 grammes. For metallographic examination section A was taken from the cutting edge of the blade and section A was removed from the side where the metal was at its maximum thickness.

Upon examination of the polished but unetched metal of section A slight porosity was observed throughout and the pores have not been deformed by any forging operation. It may be said that the metal is relatively sound and corrosion attack upon the surfaces of the section is very slight. In the case of section B the metal appears to be of very similar characteristics to that of section A and the same remarks apply.

Upon etching section A the cored dendritic structure of the casting was revealed and no recrystallisation could be detected. The cores have not been deformed and the metal has not been worked or the cutting edge work-hardened by cold-hammering. For so small a casting which would normally cool very rapidly from the liquid state, the structure is somewhat diffused and it would appear that after casting the axe was subjected to gentle heating. However the metal is substantially in the "as cast" state. A similar structure was observed in the case of section B, the metal being substantially "as cast" and unworked (pl. III, 6). For such a pure copper the amount of coring exhibited is remarkable. When viewed under polarised illumination both specimens showed an open network of small discrete particles of cuprous oxide, but the oxygen content is not high.

From the above remarks it will be noticed that this axe is unusual and the indication is that it was cast in some form of closed or bi-valve mould. In view of its poor shape it is very unlikely that it was produced by the lost-wax process. The tool is apparently unfinished since the blade has not been hardened by cold hammering and it was probably never used. The unfinished state of this object is not an argument in favour of its being an ingot since this is not an uncommon feature of copper or bronze objects. Indeed one of us has already suggested[22] that finishing may have been left to the customer. It should also be remembered that a similar but slightly larger specimen[23] had been finished.

(6) WINDSOR

Collection
Reading Museum 178:70

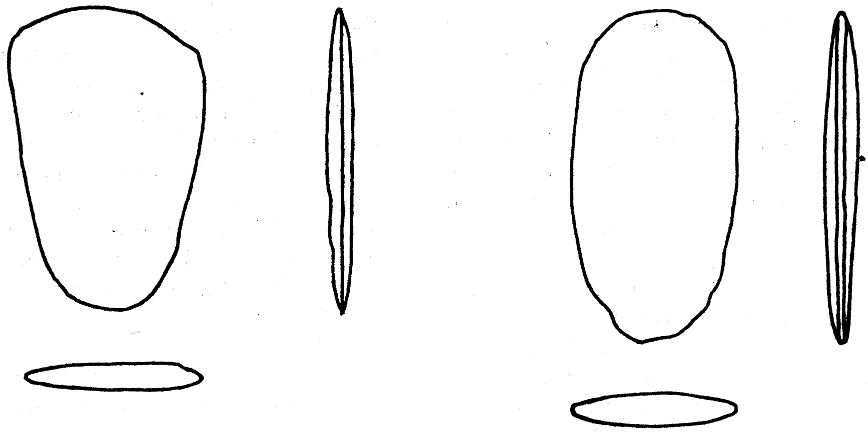
Publication
Not published.

History
This axe was acquired by exchange from the Derbyshire Museum Service in 1970. They had in turn acquired it from Robert Clough who described it in his list no. 33 (November 1956) as coming from the Ball Collection and having been found in "Windsor Great Park". F. M. Underhill informs us that he inspected the Ball Collection when it was offered for sale at Sotheby's in January 1956. It was included several bronzes, one of which was a palstave marked "Windsor Park". None of the others were marked. The flat axe seems therefore to have acquired its provenance from the palstave. It is possible however that another Windsor Park, such as the one in Belfast, is the true provenance. Against this can be argued that "Windsor Park" by itself would normally be taken to refer to Windsor Great Park, that Stanley Ball lived at Binfield, only seven miles from the Great Park, and that the Great Park has produced other bronze implements. All these arguments are at best circumstantial, so that the find-spot must remain doubtful.

Discussion
This specimen is a broad-butted flat axe with a widely-splayed blade (Fig. 2, no. 2). Superficially, except for a little damage at the centre of the cutting edge, the tool is in quite good condition. The original patination is of chocolate colour and the surfaces are now rough and show corrosion pitting. No trace of decoration could be detected. In places and in particular in the region of the cutting edge of the blade and at the butt the metal has been smoothed, apparently by recent filing. The edge of the axe is sharp, slender in profile and the butt is also slender and has been worked to a sharp edge. The axe is symmetrical in cross and longitudinal sections and is of a type which one would associate with casting in an open mould. It would have been quite an efficient working tool. The total length is 141 mm, width over the splayed blade 105 mm, width of the butt 39 mm and maximum thickness of the body 9.3 mm. The weight is 500 grammes. For metallographic examination section A (pl. IV, 1) was taken from the cutting edge of the blade. Section B (pl. IV, 2) was taken from the side where the metal is thickest.

Superficially the polished but unetched metal of section A appears to be fairly clean and sound. The cutting edge has been forged, since non-metallic inclusions have been plastically deformed and elongated in the direction of forging and the metal has apparently been subjected to hot working during some phase in fabrication. A pronounced forging crack and a number of fine elongated fissures were observed towards the point of the specimen. Although a little slip plane corrosion was noticed penetrative corrosion attack is very slight and the environment must have been favourable for the preservation of the bronze. The metal of section B is not good and while the exterior regions are fairly free from porosity there is high porosity in the mass. Corrosion attack has been very slight. Only a few well rounded pools of $\alpha\delta$ eutectoid were noticed and in section A the $\alpha\delta$ eutectoid was not seen.

Upon etching section A a structure of slip banded equi-axed twinned crystals of very low grain size was revealed (pl. IV, 1). The metal has been well annealed since coring appears to have been eliminated and throughout the



Axe No. 5 *Fig. 2* *Axe No. 10*

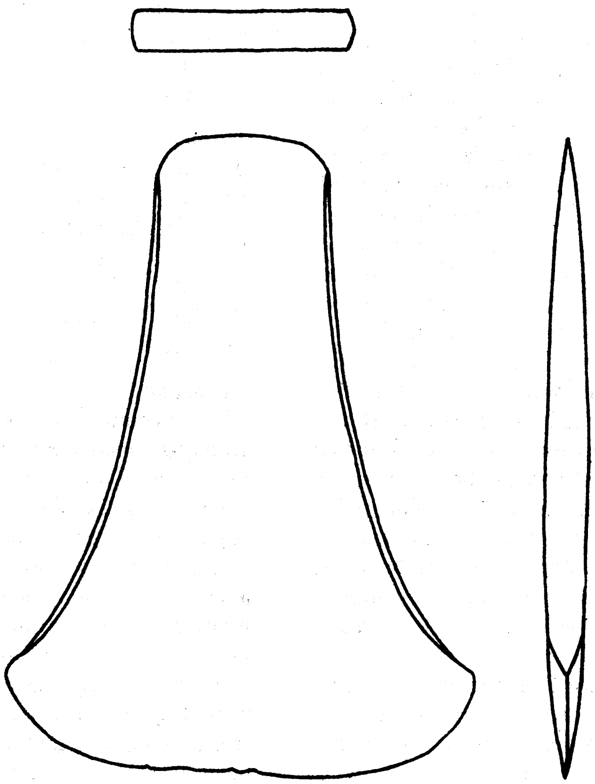


Fig. 2—Axe No. 6

well shaped and symmetrical in both cross and longitudinal sections. The cutting edge of the blade is slender, practically undamaged and still relatively sharp. The narrow butt has also been worked to a thin and sharp end. Visual inspection suggests that the sides have been forged or hammered, but there is no flanging. Adequately hafted this axe would be a useful working tool. The total length is 160 mm, width over the splayed blade 100.5 mm and the width at the butt 37 mm. The maximum thick-thickness of the body is 11 mm and the weight 555 grammes. Two sections were taken for metallographic examination, section A from the cutting-edge and section B from the side where the metal is thickest.

Examination of section A in the polished but unetched state showed the metal to be apparently sound and without any marked defects. Elongation of some non-metallic inclusions, as if in a direction of forging, would suggest that the metal has been subjected to hot-working some time in its history. Patination is thin and corrosion attack upon the surface has been slight. Along the edges of the specimen a certain amount of slip plane corrosion, indicating the presence of existing slip, was observed. In the case of section B the metal is unsound with high porosity. Again the patination is thin and there has been but little corrosion attack upon the edges of the specimen. Areas of slip plane corrosion were noted. (pl. IV, 3).

Upon etching section A it was seen that the metal has been well worked and annealed since coring is practically eliminated. At the cutting edge equi-axed twinned crystals of low grain size were reveled and in the mass of the metal grain size greatly increases. The point of the blade has been heavily cold-worked since twin bands and strain lines are bent. In section B coring was not observed. The structure of medium-sized, slip-banded, twinned crystals indicates that the side of the axe has been forged. In places severe hammering appears to have inhibited grain growth, but in the grain of the metal and at the sides of the section grain size is much increased. The microstructures of the two sections suggest that much at least of the axe may be termed a wrought product. It appears to have been made in the conventional manner by casting in an open mould, shaped by forging and annealing, probably a number of times, and finally the cutting edge was hardened by means of cold hammering. At the cutting edge a hardness value of 204 HV_5 was recorded and 147 HV_5 in the mass of the metal remote from the point. The side, section B, has also been hardened to the value of 158 HV_5.

NON-BERKSHIRE IMPLEMENTS ANALYSED FOR COMPARISON

(9) DUBLIN

Collection
Derbyshire Museum Service

Publication
P. Harbison: The Axes of the Early Bronze Age in Ireland (Prähistorische Bronzefunde Abteilung IX Band I München 1969) 26 no. 570 & pl. 22 no. 17.

History
This axe was acquired by Reading Museum in 1957 and had formerly been part of the Backhouse Collection which was collected largely in the late 19th century. Its provenance is simply Dublin. In 1970 it was exchanged by Reading Museum for the Windsor Great Park axe (no. 6).

Discussion
This specimen is a substantial flat axe with widely-splayed blade assigned by Harbison to his Type Killaha (pl. I, 2). Superficially the axe is in good condition except that the cutting edge has been damaged and blunted by hammering, as has the butt. Absence of ancient patination shows that this damage is of relatively recent origin. Patination is of dark green colour and there appears to have been little penetrative corrosion attack. In places upon the surface ancient score markings can be seen, suggesting that a coarse-gritted stone has been used in the finishing operation to the casting. The axe is well made and the sides

have been carefully finished, forged and presumably ground, to a triangular section. In both longitudinal and cross sections the axe is symmetrical and could well be the product of an open mould, forged and ground to the finished shape. Suitably hafted this would be an efficient working tool. The length is 142 mm, width over the splayed blade 98.5 mm, maximum thickness of the body 10.5 mm and weight 470 grammes.

For metallographic examination section A (pl. IV, 4) was taken through the cutting edge of the blade. Section B (pl. IV, 5) was removed from one side at approximately mid-length of the axe.

Examination of section A in a polished but unetched state showed the metal to be clean, sound and without visible defects. The distribution of some deformation and of $\alpha\delta$ eutectoid is seen. The patination is thin and there has been practically no corrosion attack, so that the environment was favourable for the preservation of the metal.

Upon etching section A a structure of equi-axed twinned crystals of very low grain size was revealed throughout the section and considerable slip banding was observed in the crystals. Relics of coring were seen and the metal has not been rendered homogenous, the core relics being elongated in the direction of forging (pl. IV, 4). The cutting edge has been strongly worked, apparently annealed at low temperature and finally cold hammered to work-harden the metal. The very high hardness value of 236 HV_5 was recorded at the point and 189 HV_5 in the mass of the metal. Upon etching section B a structure of twinned crystals was seen, the grain size being much higher than in the case of the cutting edge section. In the sub-surface metal slip banding of the crystals was observed. Annealing has been much more thorough since coring has been almost eliminated. The side has been annealed and finally cold-worked to some extent, figures of 133 HV_5 at the edge and and 63.6 HV_5 in the mass being recorded (pl. IV, 5).

The axe has been cast in traditional manner in an open mould. It was then forged, with anneals, in order to shape it, and the cutting edge finally cold-worked in order to harden it.

(10) JERSEY

Channel Islands

Collection
Reading Museum 142:61 (AL 41)

Publication
Not published

History
This implement was acquired by the museum probably in 1884, from Mr. C. Bloomfield of Reading. Its provenance is simply Jersey. It has been prepared for use and is therefore an implement rather than a mere casting. A similar, but larger and less symmetrical implement would have been produced by the Burreldales (Aberdeenshire) stone mould[27] and this would suggest that it can be assigned to the Migdale-Marnoch tradition, or one of similar date. It would thus be contemporary with the Berkshire flat axes and may be a miniature axe. Despite a superficial resemblance to the Wallingford miniature axe (no. 5) there are no parallels in the Irish series.

Discussion
Patination is of dark green to chocolate colour and the surfaces are rather rough (Fig. 2 no. 3). A feature, particularly upon one face, is that the surface exhibits deep score markings and these scores, from the overlaying patination, would appear to be ancient. Such markings have been observed upon other prehistoric implements and are probably due to the use of a very coarse-gritted hone or stone applied during the course of dressing up the casting. In the present example they are certainly not modern file marks. In general the axe has been roughly finished, but it is reasonably symmetrical in longitudinal and cross sections. The cutting edge may once have been sharp but is now

blunted. The length is 73 mm, maximum width 36.5 mm and maximum thickness 7 mm. The weight is 75 grammes. For metallographic examination section A was taken from the cutting edge of the blade and section B from the side at the point of maximum thickness. An analysis was not available, but the metal would appear to be a low-tin bronze.

Examination of section A in the polished but unetched state showed the metal to be highly porous and unsound and corrosion attack upon the edges of the specimen has been severe. In areas at the edge of the specimen corrosion following interdendritic porosity has outlined dendrites. No deformation of the porosity was observed in this section. In the case of section B the metal is similar and the same remarks apply.

Upon etching section A a structure of equi-axed twinned crystals of very low grain size was revealed at, and adjacent to, the cutting edge. In the mass of the metal remote from the cutting edge the dendritic structure of the casting appears (pl. IV, 6). The metal has been worked and annealed in the region of the cutting edge, but little slip banding could be detected in the small crystals. Therefore, while the point has been subjected to a measure of cold working, it is likely that is has been only moderately hardened. Section B showed a similar structure with equi-axed twinned crystals of very low grain size widely distributed. Annealing has been more thorough although coring has not been eliminated and the side has been worked (forged) but probably not hardened since slip bands were not detected in the crystals.

This axe appears to have been fabricated in the conventional manner, that is cast in an open mould and then partially annealed and shaped by hammering, the cutting edge being finally work-hardened to some extent. The object differs from the Wallingford miniature axe in that it has been more or less prepared for use. An analysis was not taken but the material is probably a low tin-bronze since $\alpha\delta$ eutectoid was not detected in either of the sections.

BERKSHIRE FLAT AXES NOT ANALYSED OR UNTRACED

(11) BERKSHIRE

Collection
Cambridge University Museum of Archaeology and Ethnology R.C. 23.194.

Publication
(1) H. Peake: Archaeology of Berkshire (1931) 52.
(2) V. Roskill: Trans Newbury Dist. Field Club VIII no. 1 (1938) 13 & fig. 8.

History
Roskill describes and illustrates an axe formerly in the collection of F. Ransom of "Hitchen" (Hitchin, Herts.) with a provenance of simply Berkshire. Peake refers to "another flat axehead . . . found somewhere in Berkshire." These are presumably the same.

Discussion
This axe is now at Cambridge and in view of its vague provenance has not been examined. The possibility that this is the same as one of the untraced axes listed below should be borne in mind, although there is no evidence that this is the case.

(12) CHOLSEY

Collection
Untraced

Publication
(1) J. K. Hedges: History of Wallingford I (1881) 148.
(2) H. Peake: Archaeology of Berkshire (1931) 51 & 187.
(3) V. Roskill: Trans Newbury Dist. Field Club VIII no. 1 (1938) 16.

History
Hedges mentions a "small bronze celt" found in Halfpenny Lane, Cholsey (approx. SU 582845). Peake and Roskill both take this to be a possible flat axe, but from the context it is as likely to be a palstave since he discusses other palstaves[28] in the same section.

(13) WARGRAVE

Collection
Untraced

Publication
(1) H. J. Reid: The History of Wargrave (1885) Appendix I.
(2) Workers Educational Association: The Middle Thames in Antiquity (undated) 44.

History
Reid mentions a "bronze axe of very early date" that was dredged from the Thames at Wargrave "some years" before 1885. This was at the time in the possession of Mr. Rhodes of Hennerton (presumably Hennerton House, Henley). The WEA take this to be an Early Bronze Age flat axe. However Reid may have meant that it was early in a general sense, i.e. prehistoric, and his words cannot be taken to support an Early Bronze Age date.

COMPOSITION

The composition of the various axes examined is given in Table I. It may be said that, with the exception of Wallingford (no. 5), all the axes conform to the usual practice of tin being intentionally added to the basic copper. The axe from Bray (no. 1) is of typical arsenical copper showing the arsenic-antimony-silver trinity in a metal to which tin has been added. The impurities pattern of the two axes from Cholsey (nos. 2 & 3) are not far apart, except that no. 2 exhibits a small percentage of lead. It is not impossible that they derive from the same mineral source. The axes from Newbury (no. 4), Windsor (no. 6), Yattendon (no. 7) and the Thames between Windsor and Maidenhead (no. 8) are of interest in that they are comprised of pure copper to which the tin has been deliberately added. The Yattendon specimen stands out in the present series as it shows a small quantity of zinc in the alloy. The Dublin specimen (no. 9) is an impure copper, low in arsenic, with intentionally added tin. Its analysis does not contradict an Irish origin.

The Wallingford axe (no. 5) is of high purity copper, free from tin, and its composition does not fit in with the present series of Berkshire axes. Recently two copper flat axes of high purity have been recorded[29], but pure copper axes cannot be said to be common in England or Ireland. In Scotland artefacts of pure copper would appear to be more plentiful and some fairly close parallels are found to the metal used in the Wallingford axe[30]. However this does not really help us much and for the present the origin of the Wallingford specimen must remain obscure.

CONCLUSION

To sum up for the eight Berkshire axes examined, it was found that seven of them were fabricated in the well known conventional manner, that is they were no doubt cast in open moulds of stone or clay and then forged to the required finished shape with a final smoothing carried out on a stone of suitable texture. All the cutting edges of the blade have been more or less hardened by cold hammering and in the case of the axe from Windsor Great Park (no. 6) exceptionally high hardness was attained by the application of almost terminal cold working. In this series the Wallingford axe (no. 5) is exceptional, firstly because it is made from a pure copper instead of tin-bronze, and secondly because it has been cast by the use of some form of closed mould. Examples of the application of this casting technique to the flat axe are rare, but not unknown. However there are several puzzling features about this piece and our results can hardly be said to clarify the uncertain chronological and typological position of this class of object, but merely to add a little more evidence. Finally the Berkshire series provides some further useful comparative material for the study of the common flat axe and its composition.

ADDENDUM

It is inevitable that this type of discussion will be to a certain extent out of date before it is published. Further developments which should now be taken into account are:

(a) The discussion of the Scottish evidence (John M. Coles: Scottish Early Bronze Age Metalwork, *Proc. of the Soc. of Ant. of Scotland CI*, 1968–9, 1–110). There is no space to discuss his typology, which he stresses applies only to Scotland, but it is of interest that there is only one ingot in the Scottish series. This strengthens our suggestion of an Irish provenance for the Wallingford example (no. 5).

(b) The question of the Wessex Culture has become even more complex and our discussion should be read in the light of the results of the Newcastle Conference to be held while this is in press.

(c) Our knowledge of Early Bronze Age Berkshire has been augmented by the re-excavation of Rams Hill in September–October 1972 and the discovery by the Thames Conservancy of a bronze dirk/dagger from Boulter's Reach, Cookham (note 10 and Notes from Reading Museum in this volume).

NOTES

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[2] I. M. Allen, D. Britton & H. H. Coghlan: Metallurgical Reports on British and Irish Bronze Age Implements and Weapons in the Pitt Rivers Museum (1970) 73–76.

[3] H. H. Coghlan and Humphrey Case: PPS XXIII (1957) 91 and H. J. Case: *Palaeohistoria* XII 1966 (1967) 141–177. A different classification has been proposed by Peter Harbison in The Axes of the Early Bronze Age in Ireland (Prähistorische Bronzefunde Abteilung IX Band I München 1969) and the two classifications have been discussed by ApSimon in Humphrey Case and Arthur ApSimon: The Neolithic and Earlier Bronze Ages in the North of Ireland (Institute of Irish Studies, Queens University, Belfast 1970). Since Harbison's scheme deals only with Irish finds we have avoided it except where discussing axes of known or supposed Irish provenance.

[4] D. Britton: PPS XXIX (1963) 263–279.

[5] Allen, Britton & Coghlan *op. cit.* 76.

[6] C. Renfrew: PPS XXXVI (1970) 294.

[7] See note 5.

[8] J. Coles & J. Taylor: *Ant.* XLV no. 177 (March 1971) 6–13.

[9] For a discussion of the problem of radiocarbon calibration see E. Mackie and others: *Ant.* XLV no. 179 (September 1971) 197–204; and H. T. Waterbolk: PPS XXXVII part II (1971) 15–33.

[10] An Arreton spearhead from Newbury (V. Roskill: *Trans Newbury Dist. Field Club* VIII no. 1 (1938) 14). An Arreton dagger from the Thames at Bourne End (A. M. ApSimon: *Berks. Archaeol. J.* 54 (1954–5) 119–122). Decorated flanged axes from Bisham, Long Wittenham and Reading (B. R. S. Megaw and E. M. Hardy: PPS IV (1938) 299. The Reading example is now in Reading Museum, accession 14: 68). Wessex graves at Beedon, Stancombe Downs, Yattendon (S. Piggott: PPS IV (1938) 102) and possibly Ashdown Park (A. M. ApSimon: *10th Ann. Rep. of the Institute of Archaeology* (1954) 57).

[11] Britton *op. cit.* 284–297.

[12] H. Peake: *The Archaeology of Berkshire* (1931) 49–52.

[13] V. Roskill: *Trans Newbury Dist. Field Club* VIII no. 1 (1938) 13–16.

[14] H. Case: Oxon. XXVIII (1963) 35–52.

[15] L. V. Grinsell: *Berks Archaeol. J.* 39 (1935) 171–191; 40 (1936) 20–58; 42 (1939) 102–116; 43 (1939) 9–21; and forthcoming.

[16] H. W. Copsey: *Berks Archaeol. J.* 61 (1963–4) 20–27.

[17] S. Piggott and C. M. Piggott: *Ant. J.* XX (1940) 465–480.

[18] I. H. Longworth: PPS XXVII (1961) 296 no. 93.

[19] See the Glossary for explanation of metallurgical terms. In describing the axes the term 'face' is used to denote the part of the axe illustrated in the photographs. The 'sides' are therefore those parts of the edge that are not covered by the terms 'cutting edge' and 'butt'.

[20] Harbison *op. cit.*

[21] H. J. Case: PPS XXXVI (1970) 391.

[22] H. H. Coghlan: A Report upon the Hoard of Bronze Age Tools and Weapons from Yattendon, near Newbury, Berkshire (Newbury 1970) 19.

[23] Allen, Britton & Coghlan *op. cit.* 69–70.

[24] This is the map reference for Yattendon Court. Note that this is not west of the village as in some sources but east.

[25] C. Burgess: *Arch. J.* CXXV (1968) 40.

[26] Britton *op. cit.* 283.

[27] Britton *op. cit.* 269 fig 10 & 321.

[28] e.g. the Lattin Down hoard. Roskill *op. cit.* 20–22.

[29] H. H. Coghlan & George Parker: *Metallographic Research as a Museum Aid.* An Examination of Two Pure Copper Flat Axes (Newbury Museum 1969).

[30] Junghaus, Sangmeister & Shroeder: *Studien zu den Aufangen der Metallurgie* vol II Part 3 (Berlin 1968). See in particular analyses 7307, 7391 & 7486.

GLOSSARY

Some of the metallurgical terms used in the reports may be confusing to archaeological readers. It is difficult to explain the various terms without incurring a danger of over-simplification, but the following notes, mostly taken from the glossary in Mr Tweeddale's book *Metallurgical Principles for Engineers* (London 1962), should be helpful.

ANNEALING: In the case of the prehistoric non-ferrous metals annealing was often merely a softening process, the metal being heated and then allowed to cool. The time and temperature of heating depended on the experience of the smith.

COLD WORKING: The plastic deformation of a metal by forging or cold hammering, usually at room or only slightly elevated temperature. It results in hardening the metal.

CORING: Inequality of composition in an alloy formed by the solid solution of one metal in another. The portions which solidify first will differ in composition from those which solidify later.

CRYSTALLOGRAPHIC PLANES: Characteristic planes of distribution of atoms found in a particular crystal structure.

DENDRITES: A crystal formed during solidification of the metal. It has usually many branches and a tree-like (dendritic) structure.

EUTECTOID: A mixture of two or more constituents which form simultaneously at a constant temperature on cooling from a solid solution and transform back on heating. In bronzes of relatively high tin content a separate constituent, the alpha-delta ($a\delta$) eutectoid is visible between the dendrites. In the cast state 10% tin-bronzes always show some of the eutectoid.

HOT WORKING: May be defined as mechanical working upon a metal held at a temperature at which the metal does not work harden.

RECRYSTALLISATION: A structural change that can occur when a cold worked metal is heated. New crystals are formed often leaving the metal stable and free from strain.

SLIP: The mechanism of deformation wherein one part of a crystal glides over another part along certain planes known as slip planes.

SLIP BANDS: A feature of the microstructure showing as a series of parallel lines across individual crystals in a cold worked metal.

TWINNING: Twinning may be regarded as a special form of slip. Differently orientated zones produced by twinning show up in the microstructure as lighter or darker bands which may run completely or partly across the crystals. Twinned crystals are an indication that recrystallisation has taken place.

WORK HARDENING: Work or strain hardening is the increase in hardness produced by cold working, as in the case of cold hammering in order to increase the hardness in the cutting edge of a tool or weapon.

COMPOSITION OF FLAT AXES EXPRESSED AS % FIGURES

TABLE 1

	Cu	Sn	As	Sb	Ag	Pb	Ni	Bi	Zn	Fe	Au
1. BRAY	—	6	1·6	0·36	0·2	0·04	0·04	0·005	n.d.	Tr	n.d.
2. CHOLSEY	—	8·3	0·03	0·26	0·35	n.d.	n.d.	n.d.	n.d.	Tr	n.d.
3. CHOLSEY	—	9·3	0·95	0·36	0·33	0·17	Tr	n.d.	n.d.	Tr	n.d.
4. NEWBURY	90·2	9·6	0·099	n.d.	0·0099	n.d.	0·013	<0·01	n.d.	0·044	n.d.
5. WALLINGFORD	99·5	n.d.	n.d.	0·34	0·11	n.d.	n.d.	0·015	n.d.	n.d.	n.d.
6. WINDSOR	89·7	10·1	n.d.	0·13	0·068	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
7. YATTENDON	87·3	11·7	n.d.	n.d.	0·042	0·7	0·036	0·024	0·16	n.d.	—
8. THAMES BETWEEN WINDSOR AND MAIDENHEAD	91·2	8·7	n.d.	n.d.	0·056	0·032	0·026	n.d.	n.d.	n.d.	n.d.
9. DUBLIN	—	9·3	0·07	0·75	0·41	0·02	n.d.	n.d.	n.d.	Tr	n.d.

n.d. = not detected   < = less than   Tr = trace   — = not determined