Early Near Eastern Steel Swords

HERBERT MARYON

with technical reports by Mr. R. M. Organ, Dr. O. W. Ellis, Dr. R. M. Brick, Dr. R. Sneyers, Dr. E. E. Herzfeld and Dr. F. K. Naumann

PLATES 65-72

Surveys of the early history of iron-working have been made by many experts. Here it is necessary to refer only to some of the earliest known examples of worked iron. For it seems that in the fourth and third millennia B.C. the craftsmen to whom the smelting of copper and the working of bronze was a traditional craft, with many centuries of skillful and artistic workmanship to their credit, sometimes became curious as to what use they might put some of the numerous masses of iron ore which came to the surface of many hills on the southern side of the Black Sea, and in various districts of India and of China. The craftsmen began to smelt the ore and to forge the bloom into useful tools, though, as Homer tells us, their iron was "wrought with much toil." A few specimens of worked iron of the fifth and fourth millennia are known, such as the iron beads found in prehistoric graves at Gerar in Egypt, which are of meteoric iron. A millennium later is the iron blade from Tell Asmar (ca. 2800 B.C.), which Desch found to be made from man-smelted iron. Later again is a sword with a crescent-shaped gold pommel and a long golden hand-grip of rectangular section. Two half-tubes of gold, with crenellated edges, decorate the scabbard. This weapon, dating from 2400-2100 B.C., was found at Alaca Hüyük, near Ankara, by Dr. Hamil Kosay, and is now in the Archaeolgical Museum at Ankara (pl. 65, fig. 1). Later, by perhaps a millennium, is the sword of Tutankhamen (ca. 1360 B.C.), which was found within his innermost, gold coffin and was evidently one of his most cherished possessions. When the coffin was opened the weapon was found to be in perfect condition, uncorroded, and with but a few small spots of tarnish. It is believed to have been made of meteoric iron (nickel steel) and in all probability was a present from the ruler of one of the iron-working districts of Asia Minor. How keenly such presents were appreciated may be learnt from the well known letter from a Hittite king, Hattusilis III (ca. 1283-1260 B.C.) to another ruler, probably Shalmaneser I, King of Assyria.

"As to the good iron about which thou hast written to me. Good iron is not available in my sealed store-house in Kizzuwadna. It is a bad time for producing iron. I have written that they should produce some good iron. So far they have not finished it. When they have finished I will send it to you. To-day however I have sent you a dagger-blade of iron."

Kizzuwadna, it is now agreed, was situated in Cilicia. The letter proves that iron weapons were still rare, and that even at this period, the thirteenth century before Christ, the king of the Hittites had no easy access to supplies of smelted iron.[1]

In the earliest Near Eastern examples of iron-working the smith's actual workmanship is of a fairly simple character; flattened strips of iron coiled to produce beads, and straightforward forge work for the blades. Many early tools and weapons were unhardened. But until a method of hardening iron had been discovered this metal was a less useful

[1] It is no uncommon thing for the fame of some rare product to spread far from the country of its origin. Throughout the ages the search for an efficient weapon has been universal, and fine weapons travelled far. The story of the "pattern welded" swords is a case in point. These are swords with twisted strips of steel and iron welded into the blade. Though in all probability made only at a few places in the Rhine Valley, their efficiency and beauty were so great that their reputation spread throughout Europe, and warriors from many lands sought to possess them. They became the favourite weapon of the Teutonic and Scandinavian warriors of the first to the eleventh centuries, and the Sagas and Eddas contain many stories which enshrine their fame. The Vandals in their passage from Eastern Germany through Europe acquired some of these weapons and carried them through Spain to their campaigns in North Africa, where they conquered Carthage in A.D. 439. Then they built a fleet, captured Rome (455), and made themselves masters of the greater Mediterranean islands. A few years later their king sent to Theodoric, the Ostro-Goth, King of Rome (493-526), a present of some pattern welded swords, thus repeating the gesture made by the Hittite king, Hattusilis, seventeen centuries before.

material than bronze, which could be hardened by hammering. We come now to work in iron and steel of much higher quality than the smith's earlier efforts could produce.

In recent years a number of finely designed steel daggers or short swords, all having their hilts decorated with human heads and figures of crouching lions, dating from some unknown early period, have found their way from the Near East into various collections. No closely comparable material is known, and their place of origin has not been exactly ascertained, though a number of the weapons have been found in tombs in Luristan.

The modern history of these weapons begins with Herzfeld's discovery at Leningrad, in 1935, of a catalogue of the Khanenko collection at Kiev, Russia, in which reference was made to a dagger, said to be of iron, which was in that collection. Herzfeld made a special journey to see the piece in question. Of it he wrote "It is the identical dagger, from the same mould, acquired at Samsun, east of Sinope, before 1900—I believe about 1890. No such dagger had come from Luristan before 1930, and the Khanenko piece was certainly not brought from Luristan to Samsun before 1900, but was found in one of the many tumuli of that region of Pontus. The iron daggers are indeed a foreign element among Luristan bronzes, and though only one of the specimens is known to have come from Pontus, that must be the original provenance of them all. In Pontus, iron, easily workable, lies above ground. This rare occurrence accounts partly for the important political role this land played after the middle of the second millennium, when Egyptians bartered their gold, Babylonians their lapis lazuli, for iron."[2]

Now if Herzfeld is correct in attributing the centre of manufacture of these weapons to Pontus, his opinion fits in well (a) with the extensive iron ore deposits along the south coast of the Black Sea, (b) with the location in E. Pontus of the Moschi and Tibareni (= Meshech and Tubal of the Bible) the original smiths who worked iron, and (c) the location of the Chalybes who, in the western world, tradition says invented steel.

Herzfeld does not explain what he means by the words "the identical dagger. . . ." We may ask "identical with what?" Presumably he means that the weapon he saw in the Khanenko Collection at Kiev was the same weapon as that which had been acquired many years before at Samsun on the Black Sea coast. He believed that it had been found in one of the many tumuli of that region of Pontus. But he gives no evidence that this was so, nor does he state where the tumulus was situated. Also, he evidently believed that the weapon was of cast iron, for his words "from the same mould" imply that the technique employed in its manufacture was that of the foundry. But, as is shown in this paper, these weapons prove to be of wrought steel.

At the present time swords of this type are to be found in the following collections, and without doubt further specimens will be recorded, as fragments of many others are said by Godard to have been discovered in tombs in the Zagros mountains.

1. Khanenko Collection, Kiev.
2. Royal Ontario Museum of Archaeology, Toronto.
3. British Museum, London.
4. University Museum, Philadelphia.
5. Musées Royaux d'Art et d'Histoire, Brussels.
6. Louvre, Paris.
7. University Museum, Hamburg.
8. Oriental Institute of the University of Chicago, Chicago.
9. Museum, Teheran.
10. Deutsches Klingenmuseum, Solingen-Gräfräth.
11. Dusseldorf.

Although these works are generally recorded as coming from Luristan there is no evidence to show that they were made there. A characteristic feature of so many of the early works found in Luristan is that their makers were interested in the casting of bronze rather than the forging of iron. For the development of that craft we should look further north—to the lands known to the Greeks as those of the Chalybes—to Pontus and the western slopes of the Caucasus.

Kermanshah in Luristan, in whose neighbourhood many of these swords are said to have been found, is but 400 miles from Lake Van, and 600 miles from the Black Sea coast: distances within easy trading-caravan range.

From early times in the Near East, as elsewhere, direct work was done with knife, chisel, punch and

[2] E. E. Herzfeld, *Iran in the Ancient East* (1941) 135-39; fig. 252.

drill upon stone, wood and bone; and with tracer and punch on bronze, gold and silver. But it is improbable, so soon after the introduction of iron, when worked specimens were rare and much-treasured possessions, that the skill of the smiths had advanced sufficiently to enable them to make carved or wrought dies or stamps for the mass production of the human heads or the crouching lions which are to be found on these sword handles. Such dies would have been useful if they could have been hardened, when they might have been employed as shaped punches to produce on the red-hot metal an eye or perhaps a head. However, in the extremely smooth, level and true surfaces between the transverse ridges on the handles of these swords (pl. 65, fig. 6) we seem to have evidence for the use of the "flatter." This is a smith's tool, a solidly-made steel punch, employed with a handle made from an iron rod (or perhaps, in early times, a withy). The tool has a flat face, perhaps 1½ inch square. It is held upon the red-hot work and blows are struck on it either by the smith or his helper. Still, we must remember that the hardening of steel was in its infancy until about the 12th-9th centuries B.C. when, as a direct result of the discovery of methods of hardening and occasionally of tempering steel, the true Iron Age can be said to begin.

Although there is a superficial resemblance between all the known specimens of these swords, yet if they are closely examined no two are found to be quite alike. A comparison of the published measurements of the component parts of the hilt, the shape of the transverse ridges and their position in relation to each other, the varied tapering forms of the intervening rectangular-sectioned portions of the hilt, the position of the heads on the pommel-disc and the inclination of their beards to the rectangular hilt below them, confirm the impression that, though corrosion has made direct comparison difficult, the weapons were forged individually, though from a single design.

The formation of the lions and of the human heads would have been effected first by forging, then the finer details would be added by means of chasing tools and punches, for there is no indication of the employment of cutting tools upon them. The blade of the Toronto specimen has been tested for evidence of hardening by heat treatment. A sample from the tip of the blade showed it to be of unhardened unlaminated steel, with a Vickers hardness number of 190. The omission of hardening treatment on this weapon suggests that it was probably made before 900 B.C. For early in the first millennium before Christ the discovery of the method of heat-hardening steel led to the great development in the use of iron which is so characteristic a feature of the centuries which followed. So the lack of hardening in a weapon of this importance is a fairly clear indication that the process was as yet unknown at the time and place of its manufacture.

Just as the earliest books printed with moveable type are in many ways unsurpassed, so here, the sword handles forged in the new metal, steel, by these pioneer smiths of the Near East, exhibit skill of a high order, and no comparable steel sword-hilts have been found in any other land before the time of the Renaissance in sixteenth century Europe.

Some of the wedge-shaped lateral pieces, formed like crouching lions, as on Herzfeld's drawing and on the other specimens, were fastened to the body of the hilt by welded joints. That on the British Museum specimen, as shown in the attached metallurgical report by R. M. Organ,[8] proved to be not a good weld, though the joint had held for 3,000 years. The smith had tried to make it strong by hammering round it the edges of the recess in which the piece fits, but these edges were not welded. In some of the other specimens, in that of Toronto, for example, the weld seems to be perfect.

An interesting characteristic of these weapons is the thickened, blunted section of the blade adjoining the hilt. It extends about ¾ inch along the cutting edges. Many of the swords and rapiers of the Middle Ages in Europe were provided with this device, which is known as the *ricasso*. It was intended to protect the forefinger from injury when it was curled round the upper part of the blade in some modes of attack or defence. It should be remembered that in the East a dagger or knife is not held in the manner so beloved by the illustrators of our melodramas, with the blade next to the little finger. It is generally held pointing forwards in preparation for the characteristic upward thrust

[8] Like the joint on the iron head-rest of Tutankhamen (1360 B.C.).

at abdomen or chest. The effective grip on these weapons therefore includes the *ricasso*. The hand is placed well forward, clear of the pommel, which here, with its projecting bearded heads, would seriously interfere with the use of the weapon if it were grasped in the ordinary manner of the swordsman. It is probable that the spaces between the projecting collars on the hilt were filled by gaily coloured coiled and plaited cords, or leather thongs.

Herzfeld's specimen was examined many years ago, and reported that "a chemical and microscopic analysis . . . speaks of wrought iron." Analyses of the London, Toronto, Philadelphia, Brussels and Hamburg specimens have been made, and in each case the material was found to be wrought steel, as shown in the reports given infra; and the sword and bracelet of similar fabric, at Philadelphia, were found to be of forged iron, though no note of their carbon content seems to have been published. References to the specimens reported include the following:

1. "Antiquités de la region du Dnieper. Collection B. Khanenko," Kiev. *Livraisons* 1-6 (1899-1922) pl. XXVII. E. E. Herzfeld, *Iran in the Ancient East* (1941) fig. 252; pp. 135-39.

2. M. Spence and W. Needler, "An Iron Dagger from Luristan," *Bulletin of the Royal Ontario Museum of Archaeology* 23 (May 1955) fig. 14, pp. 14-24, with a careful survey of the evidence for origin and dating.

3. *British Museum Catalogue*. No. 1933 10-16-7. And report by R. M. Organ, printed infra.

4. University Museum, Philadelphia. *U.M.* 30-38-18. Leon Legrain, "Luristan Bronzes in the University Museum," pl. XI; p. 16.

5. Musées Royaux d'Art et d'Histoire, Brussels. Speleers, *Bulletin des Musées* 5 (1933) 111.

6. The Louvre, Paris. David Weill Collection.

7. The Museum, Hamburg. *ZAssyr* (17 May 1953) 187; pl. 1. And Dr. F. K. Naumann, "Examination of an Iron Luristan Short Sword," infra.

8. Chicago. Oriental Institute of the University.

9. Teheran Museum.

10. Teheran, Maleki Collection.

MEASUREMENTS

The measurements of some of these weapons, as quoted in their published descriptions, are:

	British Museum	*Toronto*	*Philadelphia*
Blade	270 x 26	280 x 25	279 x 31 mm.
Hilt	160	130[4]	140 mm.
Top	86 x 70	76	80 x 62 mm.
Guard	44 x 18	—	42 x 21 mm.

	Hamburg
Total length	430 mm.
Length of handle	175 mm.
Diameter of disc	75 mm.
Diameter with heads	95 mm.
Thickness of disc	8 mm.

	Hamburg	*Brussels*
Total length	430 mm.	540 mm.
Maximum width of blade	30 mm.	—
Maximum thickness of blade	5 mm.	—
Width of handle	26 mm.	—
Thickness of handle	9 mm.	—

The width of the handle is greater in its upper third, as it approaches the pommel.

[4] Or 165 mm. measured from the top of the heads to ½ inch below the lions.

REPORTS ON CERTAIN SPECIMENS[5]

A. London. B. Toronto. C. Philadelphia. D. Brussels. E. Kiev. F. Hamburg.

A. LONDON

The London specimen was examined by Mr. R. M. Organ, Chief Experimental Officer, Research Laboratory of the British Museum. He reports:

A Steel Sword. 9th-7th century B.C.
British Museum No. 123304 (W.A.A. 1933, 10-16-7)

INTRODUCTION

Metallographic observation of the features of this weapon have been limited to those which could be made without seriously altering its appearance. Thus it was at first intended to carry out a careful examination merely of the metal of the pommel disc together with a cursory examination of the interesting welded-on side lions. These showed weld-lines not apparent on any of the other weapons of this type. However, an accident led to one of the "welded-on" lions becoming detached, so a more detailed examination became possible. But the fragile state of the blade made it unsafe to attempt metallographic examination for evidence of tempering.

DESCRIPTION

The weapon (pl. 65, fig. 2) is a long blade, apparently made in one piece with the handle. Two side pieces, lions, pl. 66, fig. 3A & B, appear to have been added to the main piece. Overall length 43 cm. Centre of gravity 104 mm. from the top of the head decorations.

THE METAL OF THE POMMEL DISC

In order to observe the structure of the metal, a section was polished on one edge of the pommel disc. In order that successive polishing operations should take place in parallel planes it was necessary to provide additional points of support for the object. This was done by rigidly attaching to the blade (with a temporary fastening) a crosspiece of wood carrying a steel ball at each of its ends. Thus a three-point support on the polishing plane was provided, two points being steel balls and the third the edge of the disc to be polished. The location of the section made was of necessity midway between the heads. The edge of the disc was rubbed on abrasives carried on the plate glass which supported the steel balls of the polishing jig. Abrasives used were, in turn: wet silicon carbide papers 240 and 400: diamantine (30μ) in wax, dry: diamond dusts 4-8μ and 0-1μ, lubricated with paraffin oil: a paste of heavy magnesia.

The general appearance of this section is shown in pl. 66, fig. 4.

The metal is heavily mineralized and exhibits an outer layer of haematite (a), which is soft, red-brown in colour, and has little power of specular reflection from the polished surface. Inside this layer is a fissured layer of magnetite (b), hard, black and very reflective. In the centre is the polished metal (c), deeply entered from the side and from above by magnetite. The centre of this section is about 2 mm. below the original oxide surface, which has been removed by the polishing.

The polished surface contains lines of slag inclusions running parallel with and near the mid plane of the disc.

The polished section was etched with 3% nital and a series of photographs (one of these is pl. 66, fig. 5) was taken along the path marked in pl. 66, fig. 4. The structure revealed is of ferrite in pearlite and indicates a normalized steel. It may contain about 0.5% carbon, although this estimate would have to be modified if manganese were known to be present. The group of non-metallic inclusions shown in pl. 66, fig. 4, may be seen as black areas on the centre-line of fig. 5.

The ferrite crystals have been laid down at the grain boundaries of the austenite from which the steel cooled. The rate of cooling has been rapid enough to prevent all ferrite diffusing to the grain boundaries and so the beginnings of a Widmanstätten pattern are visible in some grains. The fact that there is no preferred direction of the ferrite grains shows that no working of the metal has taken place while it was cooling for the last time below Ac3 (750.° C. for 0.5% carbon steel). Perhaps other parts of the weapon were being worked on during this particular cooling.

The section is uniform in structure along its width and length, no case-hardening or decarburization being observable. This may be because the

[5] Not all of the photographs referred to in these reports have been reproduced.

whole section is limited to a portion near the surface of the metal.

It is thus certain that the disc of the hilt is not made of cast iron, as some descriptions have suggested, but is of steel forged into shape.

THE CROUCHING LIONS BESIDE THE TOP OF THE BLADE

The fixing of the side-pieces A & B (pl. 66, fig. 3) is of some interest. The shape of the junction between them and the hilt (fig. 3) suggests that the ancient smith aimed at holding in place the side blocks of triangular section (the lions) by forging the hilt round them, to grip the corners of their bases. The fact that the junction line is obvious is evidence that the weld was not perfect. Indeed, no place can now be found where metal is continuous across the joint. It may be that the smith later found that his added pieces could be securely fixed even if not locked properly, and thus he discovered that he could weld metal to metal.

Owing to an accident one of the side pieces became loose and was carefully detached. There was a narrow cavity between the parts. Both adjacent surfaces were covered with oxide of various colours which incorporated black tubercles and blisters typical of rusting processes in the presence of certain bacteria. In addition there was a curious narrow ridge of bright red oxide whose origin is obscure. Both blisters and ridge required a certain amount of space between adjacent pieces of metal in which to form.

This side piece had been locked to the main mass of metal so well that it was only found possible eventually to refit it when the lion was cooled in a mixture of solid carbon dioxide and acetone.

It seems probable that this locking technique was a precursor of welding proper and that in this sword we have one of the last of its type, since all the other known weapons of this pattern appear to have been genuinely forge-welded.

B. TORONTO

The Toronto specimen was examined by Dr. O. W. Ellis, Director of the Department of Engineering and Metallurgy, Ontario Research Foundation, Toronto. He reports:

Microscopic Examination of Sample Removed from Pommel of a Luristan Sword (pl. 65, fig. 6)

Plate 67, fig. 8, shows a section of a small sample removed from the pommel of the sword at the position shown in pl. 67, fig. 7. This section includes a number of non-metallic inclusions which lie parallel to the upper and lower surfaces of the pommel. Numerous non-metallic inclusions of the same type were found throughout the centre of the section. The size of these non-metallic inclusions supports the view that the metal from which the pommel was made was manufactured by what are now out of date methods. The metal cannot be described as wrought iron, in view of the relatively high carbon content.

Plate 67, fig. 8, shows, at a magnification of 100 diameters, a section (etched in 3% nital) approximately 0.15″ from the rim of the pommel. Here can be seen a number of non-metallic inclusions. Most of these lie near the centre line of the section shown in this figure, which corresponds approximately in position to the centre line lying between the two roughly parallel circular surfaces of the pommel.

Microscopic examination of the etched sample as a whole brought out the interesting facts that the pommel, to judge by the structure of the sample, comprised (a) a case of low carbon steel, (b) a core of medium carbon steel (0.45-0.65% C.) which contained more non-metallic inclusions than the case.

It is probable that the pommel, and in all probability the haft, of the sword were fashioned out of steel having a content of from 0.45% to 0.65% of carbon, and that during the process of fashioning the pommel and haft, the steel was decarburized superficially to an appreciable depth while, concurrently, many of the non-metallic inclusions which were present near the surface of the original ingot of steel were extruded from it.

There are no evidences of cold work remaining in the structure. The possibility that the pommel and haft were cold worked cannot be entirely discounted, but it seems unlikely that, after cold working, the sword would have been reheated unless it were for the purpose of hardening the blade by quenching in water from above at least 735°C.—quenching would, in this case, be normally followed by drawing. It would be of considerable interest to check the structure of the blade, which would involve the removal of but a fragment of steel from the very tip of the blade—a very much smaller fragment than that removed from the pommel.

It seems most likely that the pommel, if not the haft and blade, were fashioned when hot, with a finishing temperature of very roughly 800° C., that during this process the steel, originally having a carbon content throughout of somewhere between 0.45% and 0.65%, was superficially decarburized and that concurrently the non-metallic inclusions which it contained were extruded, as a result of hot working, from the outer layers of the pommel.

Microscopic Examination of Further Samples from Luristan Sword

INTRODUCTION

Our previous report dealt with some of the characteristics of a small sample removed from the edge of the pommel of this sword. The question at issue was whether the pommel was cast or forged. It was shown by microscopic examination that at least that part of the pommel from which the small sample was removed had been forged. It seemed likely that the whole sword had been forged, but this could not be determined without seriously damaging the weapon.

However, permission was obtained for us to remove samples (1) from the free end of the beard on one of the heads with which the pommel was decorated and (2) from the tip of the blade. This report deals with the microscopic examination of these samples.

SAMPLE FROM FREE END OF BEARD

Plate 68, fig. 9 is a photostat copy of a very rough sketch of the section of the beard which was the subject of examination. It will be seen that the steel forming the beard is at this section divided into more or less three separate areas, these tending to lap over one another. It should be borne in mind that the parts which in this section seem to be almost separate from one another were joined securely to parts of the beard closer to the head.

The samples A, B, C and D in plate 68, figs. 9 and 10, refer to photomicrographs which are discussed below.

Figure 10 shows the structure of an almost complete cross section of the beard corresponding in position to the area in fig. 9 occupied by the samples A, B, C and D.

The structure of the steel in this part of the beard varies considerably as one passes from back to front. The structure towards the back of the beard suggests that the steel here is relatively high in carbon, 0.55 to 0.65% at a guess. The carbon falls off fairly uniformly as one passes from the back to the centre of the beard and then quite rapidly as one approaches the front of the beard. If it were assumed that the craftsman who made this sword started with a piece of steel having a uniform carbon content of 0.55 to 0.66%, which is probably rather unlikely, as the pommel took shape, its outer parts, the faces and the fronts of the beards became decarburized, so much so that the steel at the surface of the beard was in places rendered almost free from carbon (see pl. 70, fig. 10C).

It is not improbable, as suggested above, that whoever made the sword had at his command a piece of steel which varied considerably in carbon content within itself owing to the manner in which it was produced. It seems likely also that during the forging of the piece the slaggy matter which was present in the steel after it had been reduced from ore was, under the action of a hammer, squeezed out of the steel and concentrated near its surface. This would account for the relatively large amount of non-metallic material which can be seen in pl. 70, fig. 10C. It would also account for the apparent lapping of the metal over the non-metallic impurities in this part of the beard.

The fact that the sections shown in pl. 69, figs. 10A and 10B, are relatively free from non-metallic impurities seems to confirm the idea that forging resulted in the extrusion of non-metallic material from the centre of the forging as a result of hammering.

Towards the right of pl. 70, fig. 10D, can be seen the channel which separates the main body of the beard at this section from the wing of steel which forms the right hand side of the beard at this section (the left hand side of the section is shown in pl. 68, fig. 9). This wing was attached to the rest of the beard at this section by nothing more than a thread of steel, but must have been well secured to the beard elsewhere.

It will be observed that the stringers of non-metallic inclusions in pl. 70, fig. 10D, lie roughly parallel to the channel and to the root of the cavity at the back of the beard (see fig. 9). This suggests that the face and beard were formed from a piece of steel attached to the pommel having a T-shaped cross section.

Either by forcing the T-section piece into a die or hammering it with a countersunk punch engraved with the features of the face, the arms of the T were bent backwards. Before this was done the stringers of inclusions in all probability lay parallel to the arm of the T; afterwards they occupied the positions shown in figs. 10D and 9.

SAMPLE FROM TIP OF BLADE

The structure of this sample is shown at a magnification of 500 diameters in pl. 67, fig. 11. The structure resembles that of a modern razor blade. It is a structure which one associates with Damascus blades (see paper by N. Belaiew on "Damascene Steel," *Jour. Iron and Steel Inst.* 97, No. 1 [1918] 417-39). However, much to our surprise, we found that the steel had an average Vickers hardness number of 190 only, which means that the blade had not been quenched and drawn to give it the properties one generally associates with a Damascene blade. In technical terms the structure in pl. 67, fig. 11 consists of spheroids of cementite (iron carbide) in a matrix of ferrite (iron) rather than of spheroids of cementite in a matrix of martensite, which is the structure of steel when correctly hardened.

It seems probable that the craftsman who made this sword was aware of the means whereby such blades were made and hardened, but he did not harden the blade. It is not impossible that daggers were not always hardened, on the one hand because they were short and did not require the strength and flexibility of swords and, on the other hand, because they were not subjected to the conditions under which swords were used. The possibility exists that this sword might have been a ceremonial weapon. However, the unhardened blade of the one now in question would lose its edge quickly, particularly if it were employed as a weapon in combat. It would have been quite suitable, however, for the purpose which Ehud had in mind when he visited Eglon, the king of Moab (Judges 3: 21, 22).

C. PHILADELPHIA

The Philadelphia specimen was examined by Dr. R. M. Brick, of the University of Pennsylvania. He reported on the sword and on the bracelet of similar workmanship as follows: "Both specimens (U.M. 30-38-18 iron sword; U.M. 30-38-28 iron ring or bracelet) were of forged iron." (Pl. 71, figs. 12, 13.)

D. BRUSSELS

Report by Dr. R. Sneyers, Chef de Laboratoire, Musées Royaux d'Art et d'Histoire, Parc du Cinquantenaire, Bruxelles, to Monsieur G. Goossens, Attaché, Asie Antérieure, M.R.A.H., kindly supplied by Count Joseph de Borchgrave d'Altena, Conservateur en Chef.

Examen d'une épée en fer du Luristan, No. d'inventaire 0.982. Longueur totale 54 cm.
(pl. 71, fig. 14)

PAR MÉTALLOGRAPHIE:

Un polissage sur le disque de la poignée permet de constater que le métal est en fer carburé très hétérogène, à structure de ferrite + perlite avec impuretés. Certaines plages du même polissage présentent des quantités très variables de perlite. La teneur en carbone maximum évaluée par métallographie est de l'ordre de 0.4%. On ne voit aucune trace d'écrouissage. Il ne s'agit nullement d'une *fonte*, la teneur en carbone étant absolument trop faible.

E. KIEV

Dr. E. E. Herzfeld reports that a metallographic examination of an iron sword in the Khanenko Collection, Kiev, Russia, was made, and that the handle was found to be of wrought, not cast iron, as had been believed.

F. HAMBURG

The report on the Hamburg sword by Dr. F. K. Naumann, which follows, is of exceptional value. It throws much new light upon the structure of the weapon, and on the technical methods employed in the munition works of this early period. The original publication is too long to quote here in full, but the relevant portions of the report, which deal with the structure, the metallurgical and chemical composition of the weapon, are given below (Report from the Max Planck Institute for Iron Research Treatise 731. Report No. 19 of the

Historical Department of the Society of German Metallurgists):

Examination of an iron Luristan short sword, by Dr. Friedrich Karl Naumann in Dusseldorf

A Luristan short sword (pl. 72, fig. 15) which to outward appearance might have consisted of cast iron, was examined radiographically, metallographically and chemically. It is shown that the sword is not cast, but composed of a number of forged separate parts. The processes of examination, carried out with careful treatment of the find, are described. . . .

The sword was placed at our disposal by the Hamburg Museum for Arts and Craft. Its total length is 43 cm. The exceedingly rusty blade, of 30 mm. maximum width and 5 mm. thickness, seems to supply evidence for a thickened central ridge.

The broad faces at the lower part of the hilt are reinforced; the hilt being thickened on the wider faces of the handle, and ornamented on each of its narrower faces with a figure, perhaps a recumbent animal. At the line of transition between the figure and the hilt section, a narrow ridge runs down alongside the figure like a welded or soldered part. Perhaps it is an indication as to the method by which the figures were fixed.

Strangely enough the handle is placed at right angles to the blade. The handle is 26 mm. wide and 9 mm. thick, and is subdivided into three sections by two encircling rings. In the upper third the handle broadens at the transition to the pommel. The pommel consists of a circular plate of roughly 75 mm. in diameter and 8 mm. in thickness. It bears, on the narrow sides of the handle, two bearded male heads facing outwards which are laid upon the pommel plate, with their curly wigs bound by a headband, while their beards protrude downwards below the plate. According to H. Potratz these heads correspond to the male type common to the North Syrian sphere of art in the first millennium, B.C.

To produce an article of such complexity in cast-iron would no doubt require certain skill. The same, however, applies at least to the same extent if one considers the handle with hilt and pommel as being assembled from a number of wrought sections of iron.

In order to make visible any joints which might possibly exist that might support the assumption that the sword was an assembled structure, it was next examined by the magnetic powder process. By this method on the extremely rusty surface, a clear indication could nowhere be observed.

Better insight into the structure of the sword could be hoped for from a radiation process. The ray had to be sufficiently hard to penetrate the thick cross-section. X-rays could not have fulfilled this demand. Apart from this, interference through white radiation with its powerful long-wave content had to be anticipated. For this reason radiation from Iridium-Isotope Ir 192 was used. With this the sword was radiographed from different directions. The pictures revealed noteworthy discoveries concerning the structure of the weapon. The sword then, excepting the three binding rivets, consists of at least ten separate parts. (pl. 72, fig. 16)

On the broad faces of the blade below its entry into the hilt, two plates are attached by rivets, presumably to stem the blade against the hilt. Gaps between the plates and the blade are clearly recognizable in the radiograph (fig. 16). . . . The lower section of the handle is split to take the blade. . . . The blade is fastened in the split by a single rivet. From the radiographs the structure of the hilt is not ascertainable beyond dispute. It is probably an integral part of the handle which is more thickly formed in its lower part. Seams are recognizable between the lower part of the handle and the figures on the narrow faces. If the figures were attached directly on to the handle then they could have been fixed only superficially. The ridges which run laterally and at the top along the figures and appear as darker seams, could be interpreted as welded or soldered parts. The fixing of the figures to the handle could also have been achieved by means of a groove, forged or chased in the narrow faces, into which the bases of the figures were fitted, and whose edges were then hammered against the figures so that a dovetailed joint resulted. At the same time it is possible to imagine the hilt-section as a right-angled shell, and the figures as integral parts of this shell. The shell could have been expanded by heat and fastened by contraction. . . .

Both the ridges that subdivide the handle are clearly recognizable on the radiograph as wires that have been bent round it. Both the separating lines between handle and ridges, no less than the surface of contact in the wires, stand out clearly.

The joint structure of the pommel, and how it is fixed to the handle is again more difficult to discover. A radiograph taken from below at an angle . . . indicated a joint between handle and pommel-plate, from which may be deduced that the handle has been set into a slot in the plate. A radiograph of the pommel-plate along a diameter parallel to the round surfaces was impossible with Iridium 192. It was necessary for this to use a still more penetrating ray. For this purpose a Betatron with a radiographic strength of 15 MeV had to be used. . . . In a photograph taken from below at an angle, the width of the slot in the pommel-plate now became evident. It is less than the width of the handle at its upper end. The handle then is set into the plate as a tenon. . . . After it was established through the radiographs that the handle of the sword was composed of a multiplicity of parts, the conclusion drawn from the outward form that the sword had been made by casting had lost much of its probability. There still remained the question whether separate parts, particularly the ornamental figures, consisted of cast-iron. This was only possible to decide by an analytical, or surer still, by a metallographic examination. For such an examination the thick layer of rust had first to be removed from the part to be examined. By means of the customary method of sectioning it would not have been possible without considerable damage to its appearance. However, it was possible by means of a special method of grinding to restrict the necessary interference to a great extent.

The process consists of boring through the layers of rust with a fast rotating drill of obtuse conical shape, 1 mm. in diameter, as is used by micro-analysts, and then grinding the upper surface of the bore-hole with a wooden rod, adding elutriated emery and then polishing with argillaceous earth. The process had the disadvantage that the surface is difficult to grind evenly. Moreover, small particles of rust could not be prevented from breaking off from the surface and falling into the hole and producing scratches on the polished surface. Therefore, no very high demands could be made as to the condition of the bore-hole. However, it was sufficient for the practical elucidation of the questions that arise here. Moreover, the process could doubtless still be improved.

The first grinding carried out in this way was made on the flat face of the hilt, which in view of the above one can either imagine as a thickening of the handle or as an integral part of an expanded shell. If this last suggestion is accurate the substance of the figures of the hilt is at the same time determined with this grinding. Above all it was necessary to examine the figures, for if cast-iron had at all been used, they would most likely have been produced from it. After the process had been tried on this easily accessible place, one of the figures themselves was examined, namely, one of the male heads on the pommel-plate. The grinding was applied above on the head-band. . . . In the unetched ground surface one rough and several finer slag particles appear, such as are characteristic of wrought iron. The particles all extend in the same direction, which proves that the part has been forged.

Flakes of graphite, which would appear in an unetched section had the hilt been produced from cast iron, were not observable. The structure developed by etching consists of ferrite and a little pearlite. Consequently, lacking carbon, it is a specimen of wrought iron. A very similar structure was revealed by the grinding of the figure on the pommel. . . . The parts examined do not consist of cast-iron, but of forged wrought iron. If this applies to these parts which are so complex in formation, there are no grounds for assuming that parts of simpler form, such as the handle and pommel-plate, have been cast. The ridges on the handle have already been recognized in the radiograph as wires.

Further, it seemed worth knowing how the figures had been attached to the hilt and pommel. The presence of caterpillar-like ridges alongside the figures of the hilt and at the sides of the heads of the pommel could, as was remarked, indicate a fixing by means of welding or soldering. A metallographic examination of the ridges by boring in the way above described, showed that these consisted of the same substance as the above examined parts. A soldering with non-iron metal is therefore excluded. Also, by analysis, no other metal could be discovered in the collected bore-dust, apart from iron and traces of calcium, magnesium and copper.

It was obvious from the outset that the blade was not cast. With reference to the observed central fluting the idea had to be considered whether the blade was not assembled and ornamented by welding together different layers of iron and steel in a similarly skilful manner, as is the case with the well-known Roman swords from the Nydam Moor. . . . Such an examination, which would have to comprise the whole cross-section of the blade was indeed impossible by the non-destructive process already described. But, because of the significance of the expected result, it was considered that a representative specimen might be obtained by sawing a piece, roughly ½ cm. in size, out of the centre of the blade. This sample was thereupon ground along its width and length, and later broken up after the metallographic examination. In the polished planes from surface to surface the blade revealed the characteristic structure of wrought steel with layers of differing carbon content and numerous coarse slag particles. One surface layer corresponds to a steel of roughly 0.2%C. The ferrite is dispersed in the form of needles or sheets (Widmanstätten structure), which indicates that the blade had been highly heated and quickly cooled off in an earlier manufacturing stage. The pearlite is bunched together spherically.

The last stage of manufacture, or treatment, thereupon followed at a comparatively low temperature (below 700°C.). The other surface layer has a very low carbon content and consists of a coarse-grained re-crystallized ferrite with fine needle-shaped outcrops which in the etching with sodium picrate prove to be tertiary cementite and a little pearlite. This zone is especially rich in many coarse, heterogeneously compounded and much-broken particles of silicate welding slag. It may be concluded from the structure of both zones, that the blade was forged complete in the region of re-crystallization, that is, at a temperature under 700°C.

Noteworthy is the presence of twinning in the coarse-grained ferrite. Such twins are formed under multi-axial tension through treatment by striking. Their formation is assisted by low temperature and a coarse-grained structure.

Twinning is frequently observed in the structure of blades and edges of antique swords, knives and axes, and it may be concluded that they are a genuine mark of forging in those parts. As no grain-line is recognizable, the distortion that leads to the twin formation could have been produced, not by means of reforging when cold, but rather by single powerful straight blows. . . .

The analytical examination of the sample taken from the blade showed the following chemical composition: 0.067%C; 0.23%Si; <0.01%Mn; 0.04% P; 0.002% S. This thus shows an iron unusually deficient in sulphur and manganese. Silicon must be overwhelmingly present in the slag particles in silicate form. The carbon content represents a medium value in the different layers, some poorer, some richer in carbon. . . .

The above report by Herr Naumann tells how by the employment of radiation from Iridium-Isotope, Ir.192, and a yet more penetrating ray from a Betatron, with a radiographic strength of 15 MeV, it was possible to determine that the sword was built up from no less than eleven separate forgings, riveted together.

Such a revelation was perhaps not quite unexpected in view of the statement by M. Godard, who was Consul-General for France, in Persia, at the time when many of the weapons were being excavated from tombs in Luristan. He reported that he had seen hundreds of these weapons, but that they were in a very fragmentary and dilapidated condition.

It is evident that at the time when they were being manufactured some very efficient workshops must have been available, and that the separate parts of the weapons were mass produced. The sword may have been worn as a badge of honour, awarded perhaps to some distinguished company of warriors for a notable deed of valour. For the production of so remarkable a weapon in such numbers as M. Godard reports must surely imply that there had occurred an exceptional event which called for some unique award—if indeed that was its origin.

It would be difficult to overestimate the importance of the contribution that this study has made to our knowledge of the workshop practice of the armament workers of the time. The only comparable evidence is that provided by some bronze arrow-head moulds of the seventh or sixth century B.C., from Mosul and from Carchemish respectively, now in the British Museum. In the mould from Mosul, pl. 72, fig. 17, even the setting-out lines, incised in the separate pieces of the mould by the fitter who constructed it, which enabled him to make each part register accurately with its neighbours, are still visible. They show with what skill and care he drew out on each part lines which enabled him to produce a mould such as this, of which a modern tool-makers' workshop would not be ashamed.

It seems evident that, about the ninth-sixth centuries B.C., in the Near East, among workers in metal, there was a growing interest in technique.

We may note the great advances in the working and hardening of iron; the combination of decorative parts of iron with castings in bronze; and the production of door and furniture fittings of box-like, hollow bronze castings. A survey of the reliefs from Nimrud (Assyria), now in the British Museum, will demonstrate the immense variety, the skilful construction and great beauty of the ornaments and weapons borne by the Assyrian warriors of the time. The steel swords which we have been studying, wherever made, mark an important stage in the history of iron working.

I wish to express my thanks especially to Miss Winifred Needler, Curator of the Near Eastern Department, and to Miss Margaret Schmunk (now Mrs. Michael Spence), both of the Royal Ontario Museum of Archaeology, who were the first to draw my attention to these remarkable weapons, and by their careful survey of the evidence for origin and dating have made so important a contribution to their study; to my colleagues, Dr. R. D. Barnett, Keeper of the Department of Western Asiatic Antiquities, and Mr. R. M. Organ, Chief Experimental Officer, Research Laboratory, British Museum, for his valuable report printed above. And, in particular, I wish to thank Dr. F. K. Naumann in Dusseldorf, for permitting me to reproduce some of his photographs and notes on the fine example of these swords in the Museum at Hamburg.

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FIG. 2. Steel sword. British Museum

FIG. 6. Steel sword. Royal Ontario Museum of Archaeology, Toronto

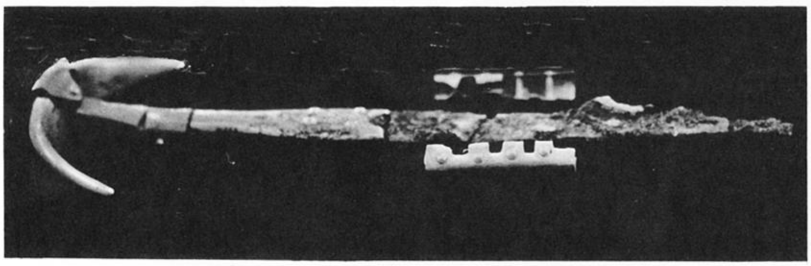

FIG. 1. Iron sword with gold pommel, grip, and scabbard ornaments. Alaca Hüyük, near Ankara, 2400-2100 B.C. Archaeological Museum, Ankara

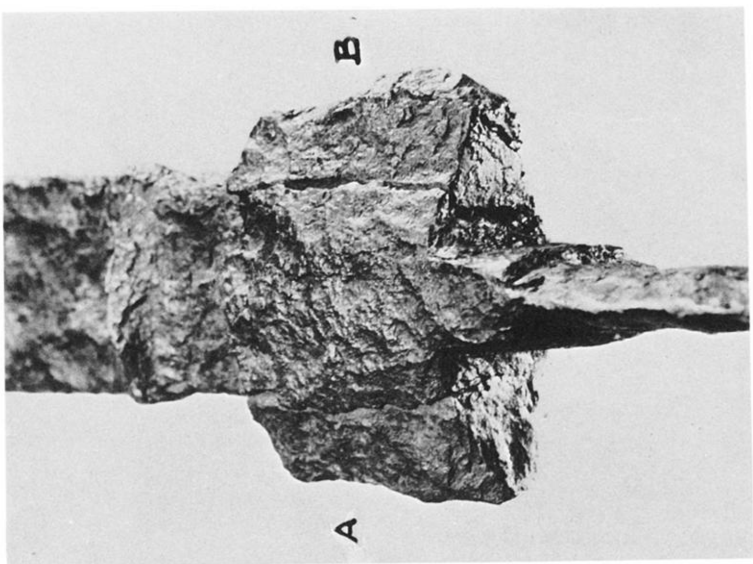

Fig. 3. Steel sword, detail. British Museum

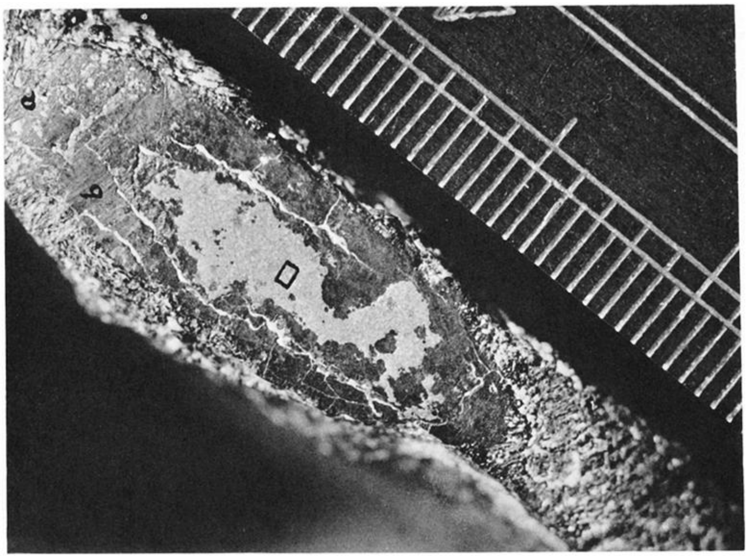

Fig. 4. General appearance of polished section of pommel edge x 5·4. Rectangle shows location of fig. 5. a) haematite, b) magnetite. British Museum

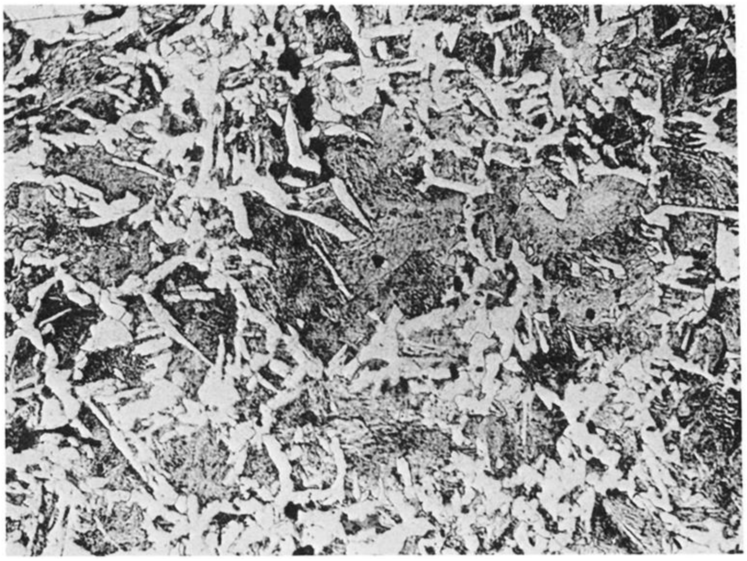

Fig. 5. Polished section of pommel disc x 200. Ferrite and pearlite in steel about 0·5% carbon. British Museum

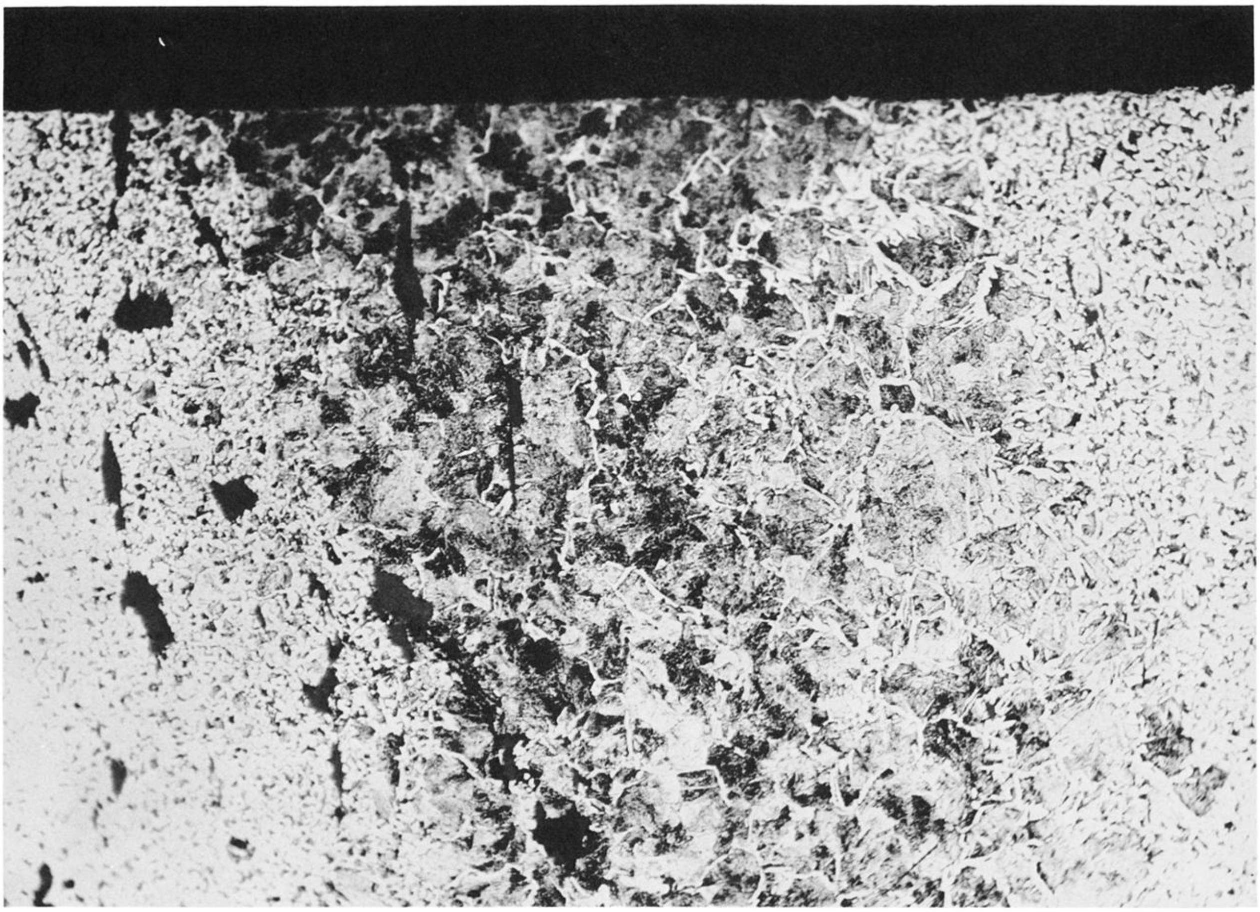

FIG. 8. Steel sword pommel section x 100. Toronto

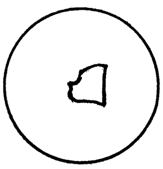

FIG. 7. Showing where test specimen was taken from pommel (wedge-shaped cut). Toronto

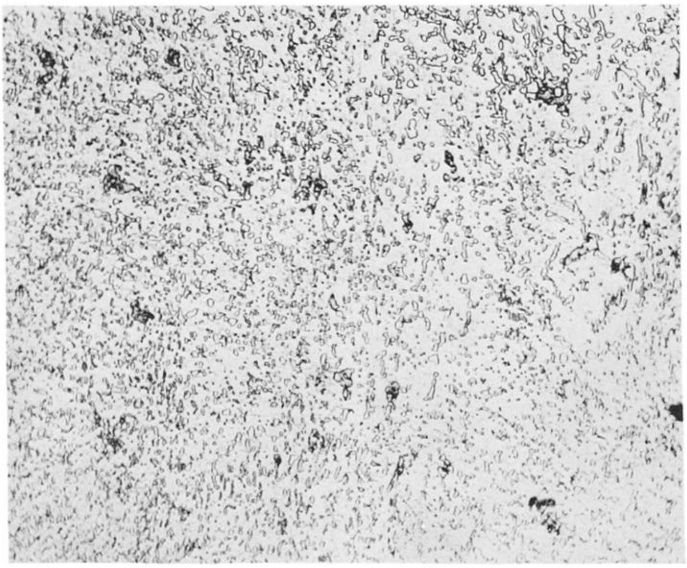

FIG. 11. Structure of steel near tip of sword x 500. Toronto

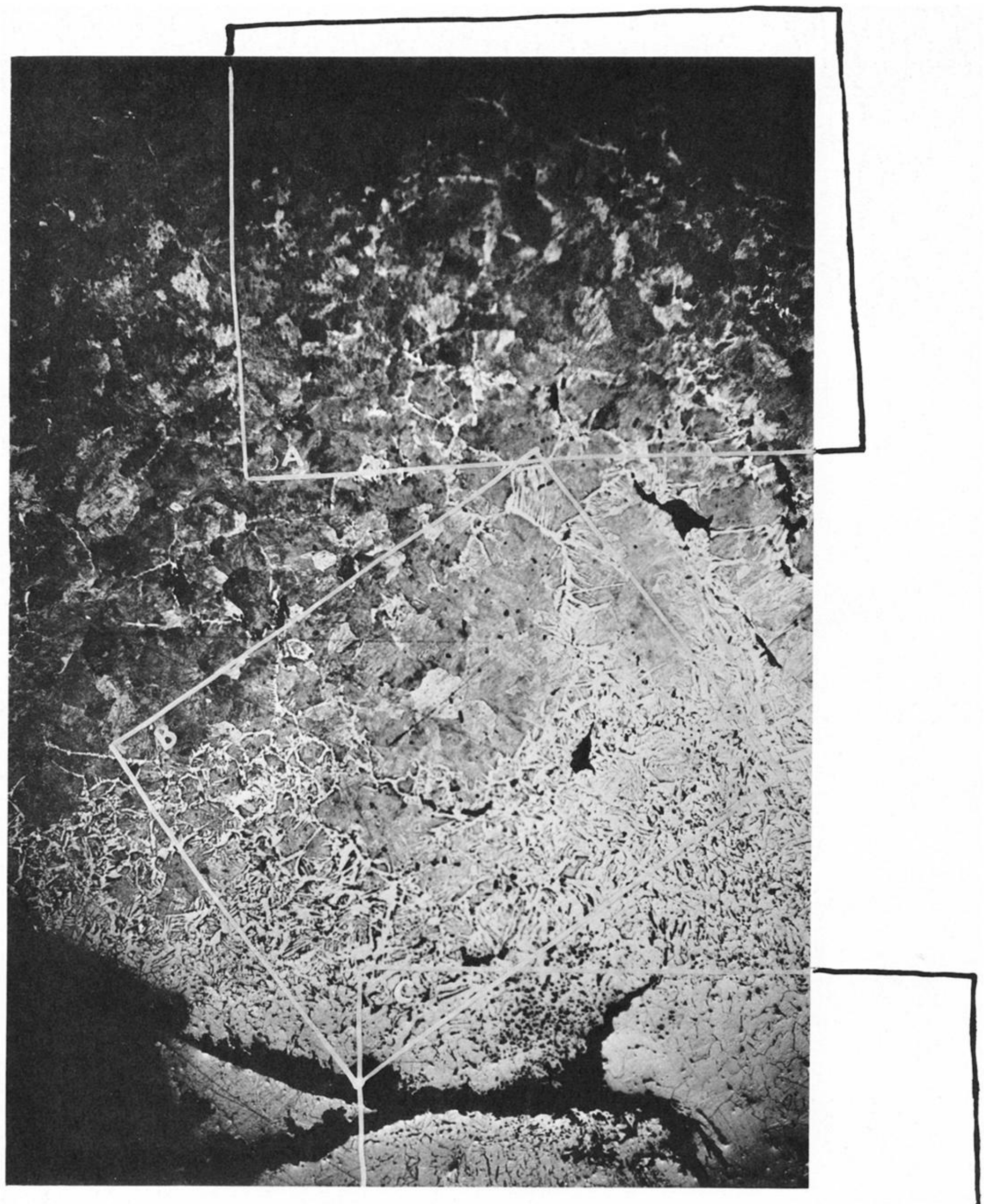

FIG. 10. Section through beard (see fig. 9 A, B, C) x 50, showing relative positions of structure shown in figs. 10 A, 10 B, 10 C. This is mirror image of structure shown in 10 A, 10 B, 10 C. Toronto

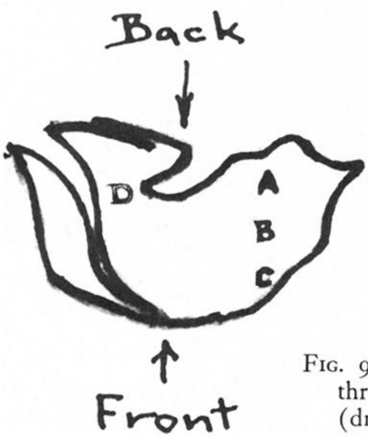

FIG. 9. Appearance of section through beard. Toronto (drawing by Dr. Ellis)

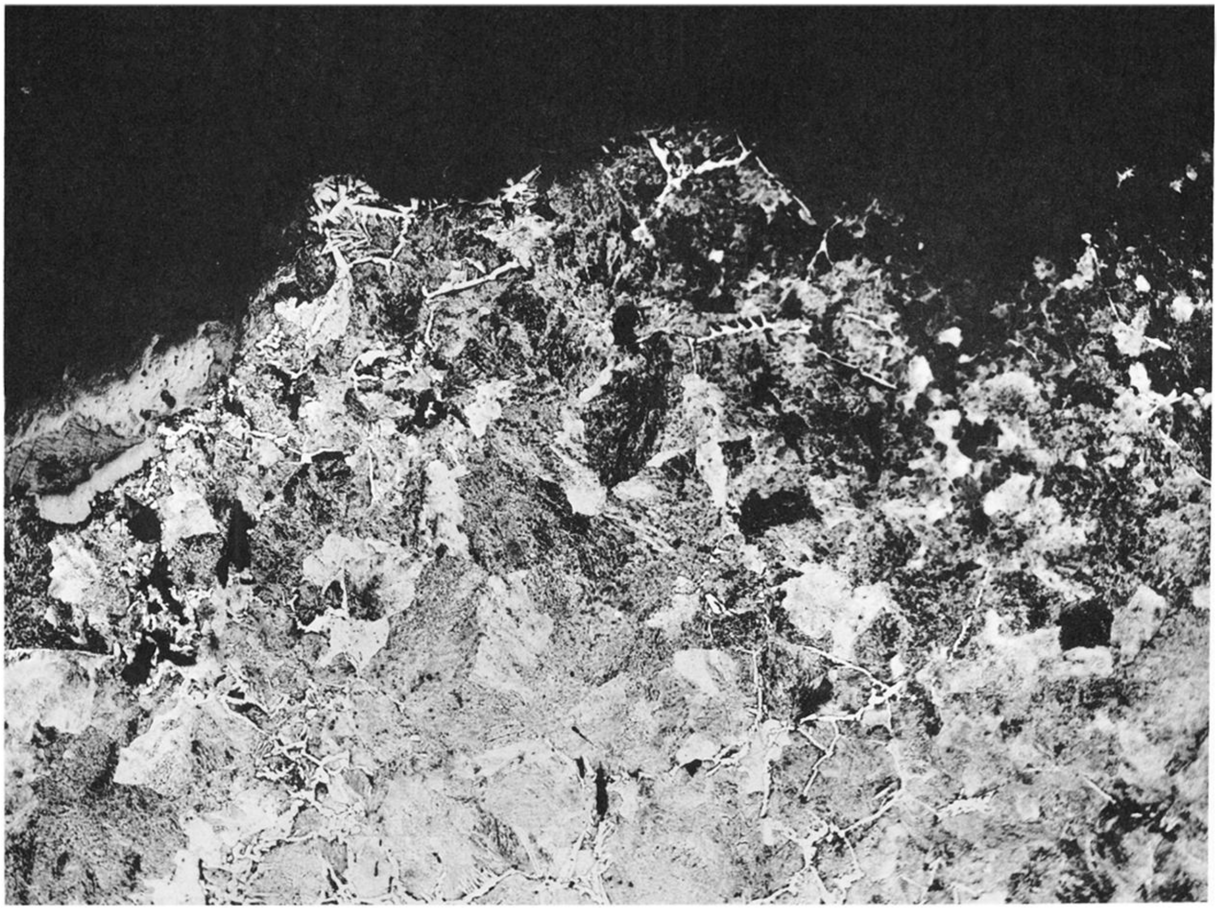

FIG. 10 A. Structure of steel, section adjacent to back of beard, x 100 (see A in fig. 9). Toronto

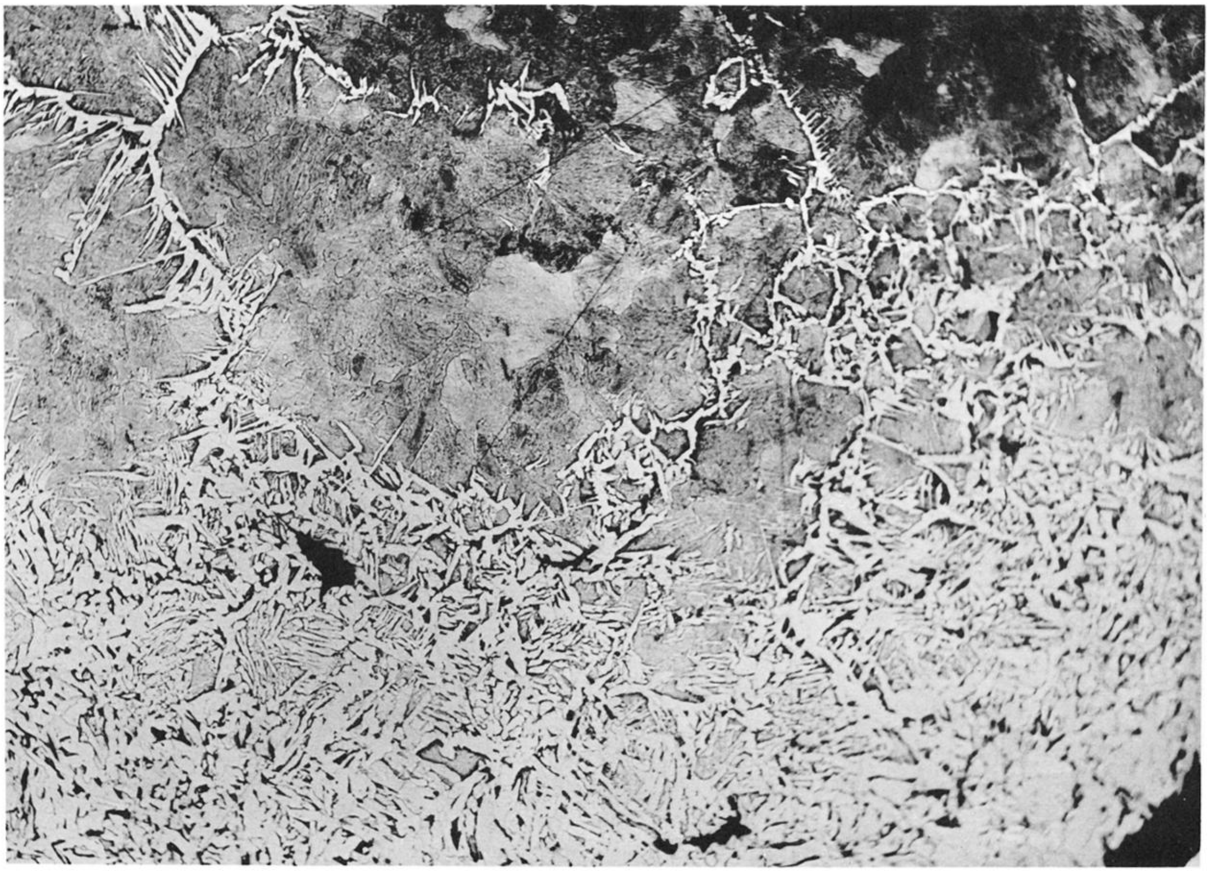

FIG. 10 B. Structure of steel, section near centre of beard, x 100 (see B in fig. 9). Toronto

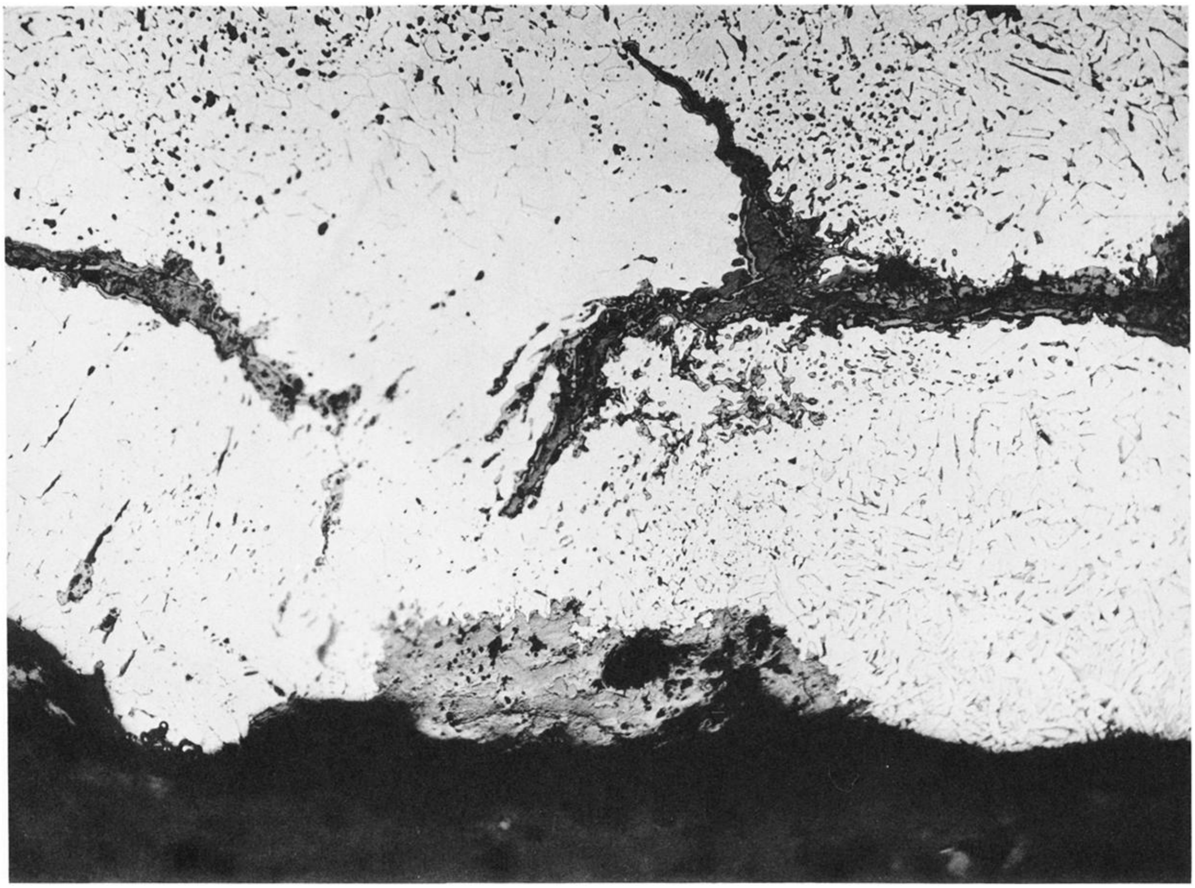

FIG. 10 C. Structure of steel, section adjacent to front of beard, x 100 (see C in fig. 9). Toronto

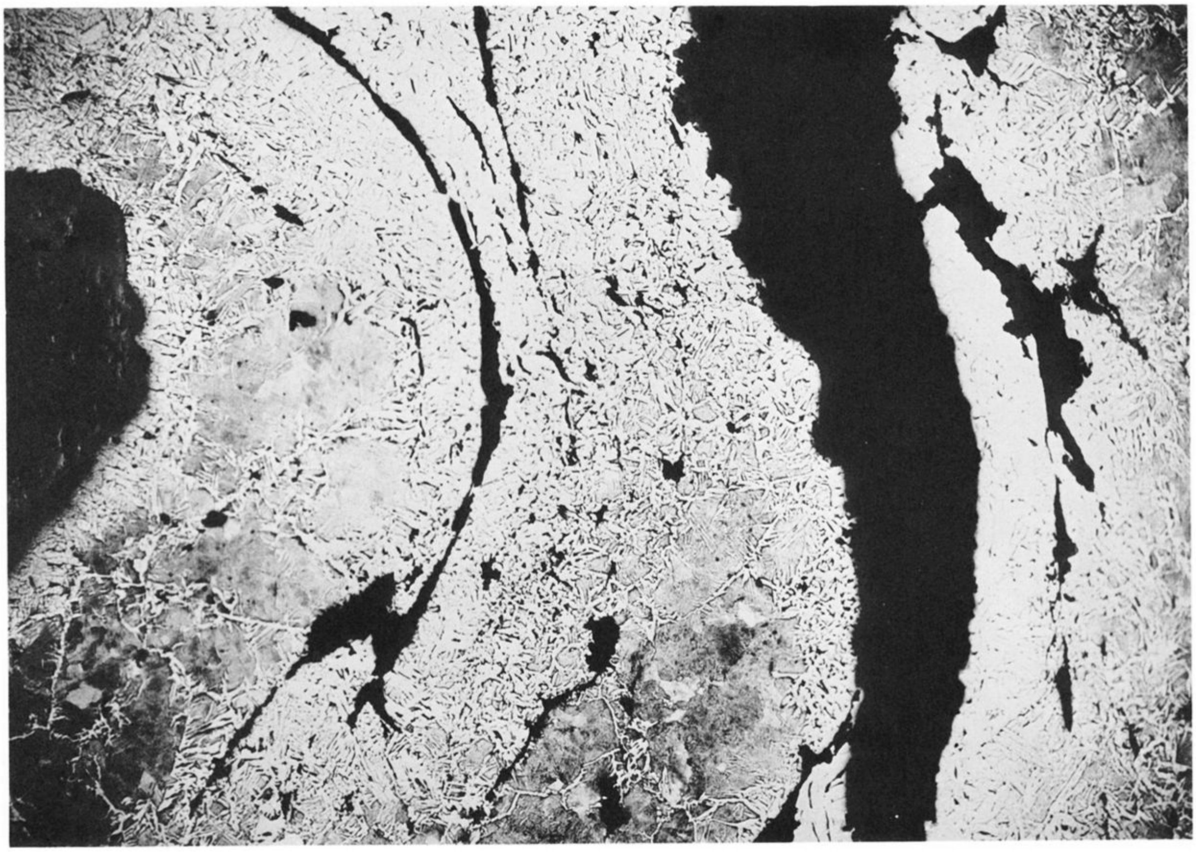

FIG. 10 D. Section through beard (see D in fig. 9) x 50. This is mirror image of structure shown in fig. 9. Toronto

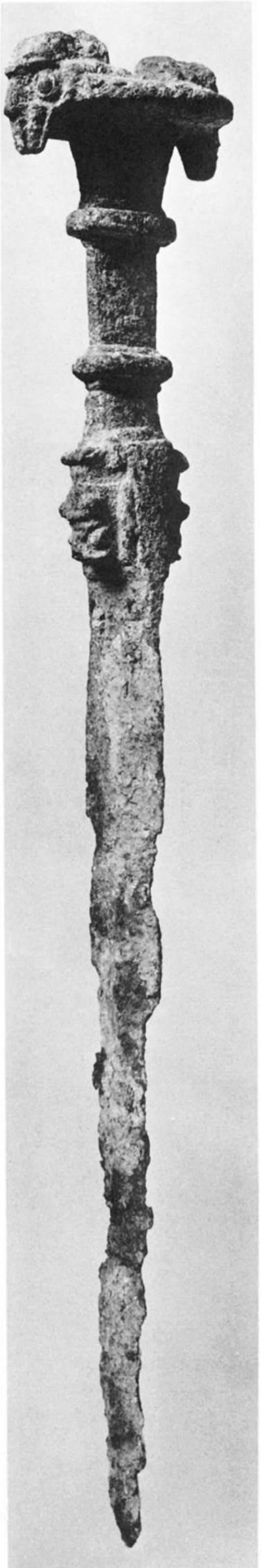

Fig. 12. Steel sword. Philadelphia

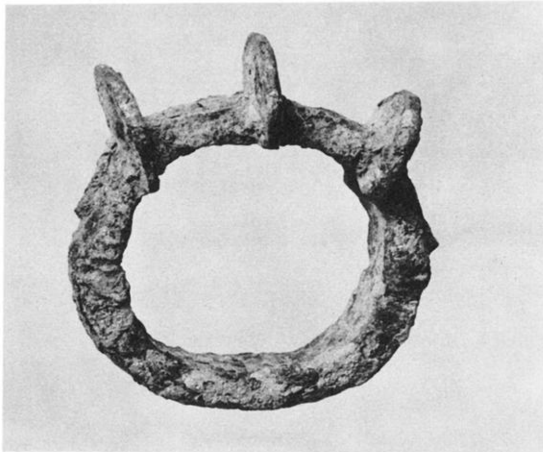

Fig. 13. Bracelet. Philadelphia

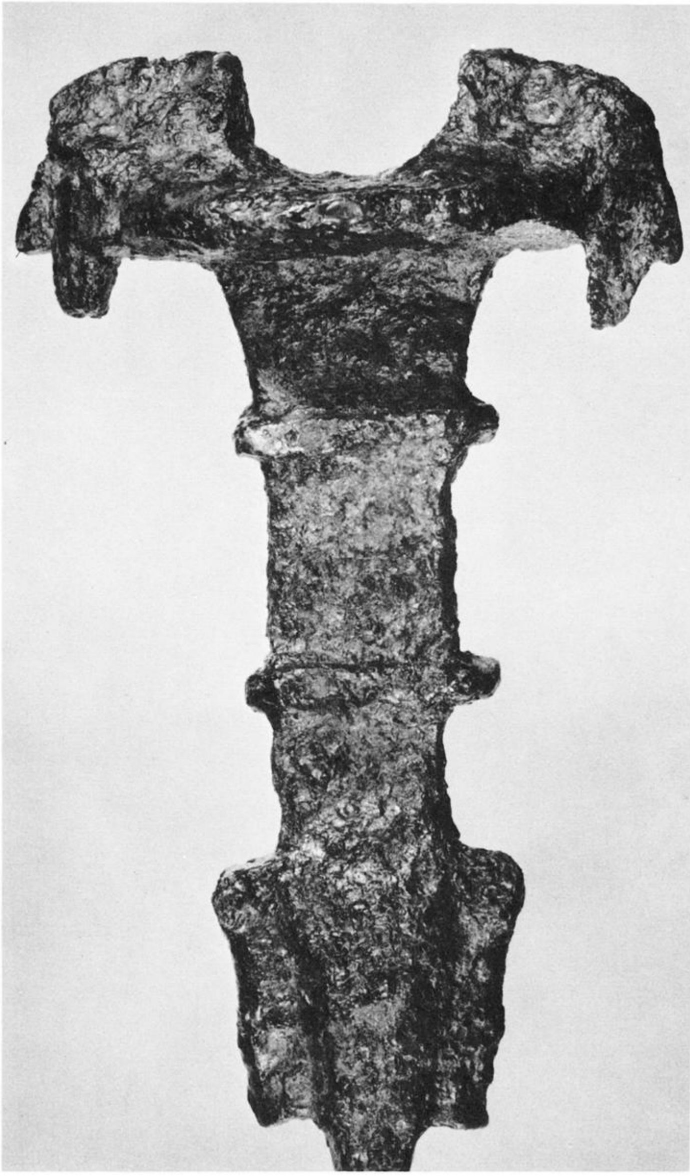

Fig. 14. Handle of sword. Brussels

FIG. 15. Handle of steel sword. Hamburg

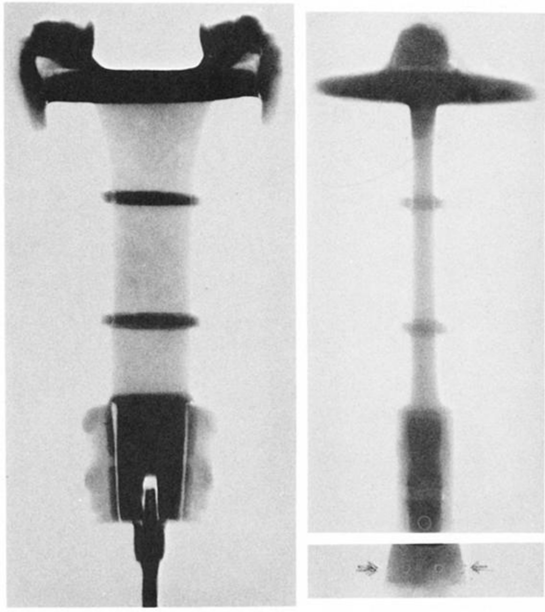

FIG. 16. Handle of steel sword at Hamburg. Radiographs by Dr. F. K. Naumann

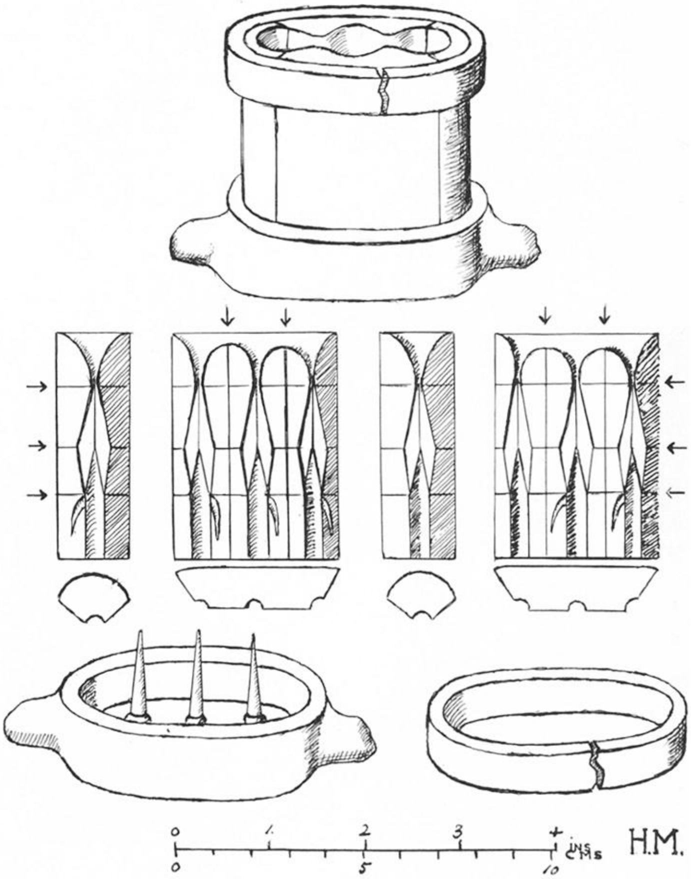

FIG. 17. Bronze six-piece arrowhead mould for three arrowheads at one pouring. From Mosul. British Museum