XVIII. *Observations on some ancient metallic Arms and Utensils; with Experiments to determine their Composition. By* George Pearson, *M. D. F. R. S.*

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THE opportunity of examining the ancient metal instruments, which are the subject of the present paper, was afforded me by Sir JOSEPH BANKS, Bart. K. B. P. R. S. whose zeal for science induced him to sacrifice them to chemical analysis.

I am further indebted to Sir JOSEPH for almost all the curious particulars relative to the history of these instruments; which he was so kind as to permit me to extract from his own notes.

Most of the articles were found in Lincolnshire, in the bed of the river Witham, between Kirksted and Lincoln. Several of them were discovered when that river was scoured out in 1787 and 1788.

The river Witham, between Lincoln and Tattersall, runs through a country almost level, abounding with moorish soil. Its current is slow, and had for ages been depositing gradually a mud, which possesses powers of preserving things lodged in it for a great length of time. The peat moss also of moorish soils has the same property. Inthe Philosophical Transactions, (Vol. XLIV.) an account is given of a body which was dug up in the isle of Axholme that was judged to be of great antiquity, from the structure of the sandals on the feet; and yet the skin, with hair upon it, was pliable and soft like doe-skin leather.

The workmen who found several of the articles which are the subject of this paper, and at the same time many other arms and utensils of our Roman, Saxon, and Danish ancestors, universally agreed, that most of them lay at the bottom of the river, on the hard soil, and below all the mud. From which observation it may be inferred, that our Saxon ancestors kept the river in much better condition than their successors have subsequently done; and indeed this conclusion receives a great degree of credit from the arms which, in the year 1788, were brought up by an eel-spear near Kirksted Wath; for in that place, and in some few others, the old bottom lay so low, that those who cleaned the river had not occasion to sink down to it, although they removed as thick a body of mud there as elsewhere.

The instruments of which I shall here give an account, were evidently made of what are commonly called brass, and iron. The brass instruments, as I shall show, were allays of copper by tin; and the supposed iron implements were found to be steel.

It will be proper in this place to observe, that brass is a term commonly used to denote any metallic composition the principal ingredient of which is copper; but the most accurate writers in chemistry use the term brass, with more precision, to denote only the compound of copper and zinc; and therefore I shall employ it in this latter sense.

SECTION I. Of the Copper Instruments.

§ 1. *Miscellaneous historical Observations.*

The articles belonging to this head were seven in number; namely, a Lituus, a Spear-head, a Sauce-pan, a Scabbard, and three Celts.

1. *The lituus:* its figure is shown by the drawing, Tab. XI. fig. 1. It is well known to have been a military musical instrument of the Romans. Several classical writers mention it, as Horace, in ode i.

> " Multos castra juvant, et *lituo* tubæ
> " Permistus sonitus."————

And Virgil mentions the lituus in celebrating Misenus, who served Hector in the Trojan war, and afterwards Æneas, in the office of trumpeter:

> ————" Illi Misenum in littore sicco,
> " Ut venére, vident indigna morte peremptum;
> " Misenum Æoliden, quo non præstantior alter
> " Ære ciere viros, martemque accendere cantu:
> " Hectoris hic magni fuerat comes; Hectora circum
> " Et *lituo* pugnas insignis obibat et hastâ."
>
> Æn. lib. vi. v. 162.

And again in the Georgics, lib. iii. v. 182.

> " Primus equi labor est, animos atque arma videre
> " Bellantum, *lituosque* pati, tractuque gementem
> " Ferre rotam, et stabulo frænos audire sonantes."

The lituus is supposed by judicious antiquaries to have been adopted from the barbarous nations; and that the figure of it was intended by the barbarians to resemble a snake, the principal object of their religious worship, and of the most sacred mysteries of the Druidical religion. If these remarks be true, they throw new light on the crooked staff of the augurs, which the lituus much resembles. It is accurately represented among the trophies which ornament the base of TRAJAN'S column at Rome, erected in memory of his conquest of the Dacians and Sarmatians, and covered with bas-reliefs, describing the events of that war. The lituus is also found on the reverses of some Roman coins: see fig. 2.

The specimen before us was found in the river Witham, near Tattersall ferry, in 1768. It is imperfect, a little of both ends being broken off; but notwithstanding these defects it is a very valuable relic, as there is little doubt that it is the only one known to be in any cabinet at this time in Europe. It has been neatly made. The parts which appear like joints are pieces which slide over the tube for ornament, or perhaps for holding the instrument more conveniently. It had the appearance of a brazen tube, from which a great part of a blackish coating had been rubbed off. It was evidently made of a plate of hammered metal of about one-twentieth of an inch thick. The juncture of the edges of the metal, the whole length of the tube, was preserved by means of a solder clumsily applied, by melting it withinside the tube. This solder, which was readily melted out by a red hot iron, was ascertained to be merely tin; for it afforded rapidly oxide of tin by applying nitric acid; the cold saturated solution in muriatic acid afforded CASSIUS' precipitate on dropping into it nitro-muriate of gold; and it afforded no acetite of lead on digesting it in acetous acid.

The black coating was easily scraped off with a knife, but the quantity of it was too small to enable me to determine whether it had been applied by art, or was the accidental effect of the mud or earth in which it had been buried for many ages. The ancients, as PLINY informs us, stained plates of one sort of copper, the *æs coronarium*, with ox gall to make it look like gold: and the crowns and chaplets of public actors were made of copper so coloured.* It, perhaps, will not appear very improbable, that the coating of the lituus was with this substance.

The performers on the lituus among the Romans, seem to have been persons of at least as high rank as the stage players, and with propriety might therefore use instruments as highly ornamented.

II. Tab. XII. represents a *Spear-head*. In Sir JOSEPH BANKS's collection there is a British spear-head of bone, a Norman one of iron, and a third, the article before us, of copper, which is believed with the greatest reason to be Roman workmanship.† This Roman spear-head is worthy of admiration and imitation, on account of its figure, weight, and size, as an offensive weapon. It is however made of cast metal, as appears from its rough surface, figure, texture, and grain. That it is made of bad metal will be made appear hereafter. It has not been hammered, but has been cast hollow to receive a wooden shaft, and in order to be light and save the expence of metal. It is evident from its figure, that it is of the very best conceivable form for piercing, and for inflicting the largest wound at the least expence of weight and bulk. This weapon was found in the river, with another, near Fiskerton, in the year 1788.

* "Coronarium tenuatur in laminas, taurorumque felle tinctum, speciem auri in co-"ronis histrionum præbet." PLINY, lib. xxxiv. cap. viii.

† An instrument is described and represented by a figure in the Archæologia, Vol. IX. fig. *c*, exactly like this spear-head, and it is deemed to be Roman.

III. The *Sauce-pan* is represented in Tab. XIII. From its form and the grain of its fracture, and its being one entire piece, it appears to have been made of cast metal. It is considered to be a piece of Roman workmanship. It is neatly and curiously grooved at the bottom, to admit the fire to penetrate to the contents more easily. On the handle is impressed, seemingly with a stamp, C ARAT; which letters may possibly signify CAIUS ARATUS, as the latter part of the stamp seems not to have made an impression.

It was found in the year 1768 in the river Witham, near Tattersall ferry. It appeared to have been tinned, but almost all the coating had been worn off. As it was said that it had been used by some boatmen, for some time after it had been found, it might have been tinned after it got into their possession. The art of tinning copper, however, was understood and practised by the Romans,* although it is commonly supposed to be a modern invention, therefore it is not very improbable that this utensil was originally covered with tin by that people.

IV. Tab. XI. fig. 3. represents the *Scabbard* with a sword of iron within it. This and another brass scabbard in Sir JOSEPH BANKS's collection were found in the river Witham in 1787, near the site of Bardney abbey. In the same place were found many other arms; from whence some conjecture respecting their antiquity may be formed. We may suppose that the destruction of that noble monastery was not effected without loss on the side of the Danes who attacked, and the Saxons who defended it. By the best accounts it was destroyed in the year 870.†

* "Stannum illitum æneis vasis, saporem gratiorem facit, et compescit æruginis "virus." PLINY, lib. xxxiv. cap. xvii.

† TANNER's *Notitia Monastica*, p. 248.

These swords are therefore prior to the conquest; but which are Danish and which are Saxon, is not easy to determine. Probably these people, who were always at war with each other, and consequently had frequent opportunities of possessing themselves of each other's weapons, adopted from each other whatever improvements were made by either; and thus in effect they might both use the same weapons. Swords like this are to be seen in illuminated manuscripts, and on painted glass. In STRUTT's Hoꞃða Ænȝel-cẏnnan, where he describes the customs of our Saxon and Danish ancestors, such swords frequently occur; especially in the lives of the two OFFAS. Similar swords are also in the hands of the Danes, who are killing the abbot of Croyland on the shrine, as delineated by Dr. STUKELEY, in the Philosophical Transactions, Vol. XLV. p. *597*.

The brass scabbard before us possesses some degree of elegance, and much accuracy of workmanship. It appears to have been originally covered with a bright blue varnish, but the quantity was much too small for ascertaining its nature. Exactly such a sword as this is represented at the side of a Danish soldier, in pl. 26, Vol. I. of STRUTT's work just quoted. The sword within this scabbard was destroyed by rusting, and could not be drawn out. The pommel and guard had been broken off. There was a plate of open work, about four inches long, laid over one side, and near the top of the scabbard; and at the bottom, on one side, was a sort of joint; and on the other and opposite side was a bas-relief figure. The scabbard was made of hammered metal, and was perhaps about one-thirtieth of an inch thick.

The next, and last three articles under the present head, are known to antiquaries by the name of *Celts.* They were, probably, instruments used by the ancient Britons, Gauls, or Celtæ. The learned do not agree whether the celts were Roman workmanship or not: nor to what particular uses they were applied. Accordingly some persons have supposed that they were the offensive weapons of our ancestors; and others have supposed that they were both offensive military weapons, and civil instruments; but the most probable opinion is, that they were merely domestic tools. Many of the celts are cast after the model of stone implements, which are confessedly ancient British or Celtic chopping instruments, and tools for making holes. Several of these stone implements, in Sir JOSEPH BANKS's collection, correspond exactly with the figure and size of the celts. Great quantities of these instruments have been at different times discovered in England, as well as in Ireland, and some few in France. Sometimes they have been found in heaps, as if the owner had, and probably did throw them away by basketfulls, as things of little value. It has been very ingeniously conjectured, that when the Romans came to Britain they found the inhabitants, especially to the northward, very nearly in the same state as that in which our late discoverers found the natives of the South Sea islands. The Britons parted with their valuable articles of food, rarities, and commerce, for metal tools made in imitation of their stone ones; but in time, finding themselves cheated by the Romans, who made these tools of bad metal, of the shape of the ancient British stone axe, as the inhabitants of Otaheite were by the use of base metals; they relinquished these tools when they became acquainted with those made of better metal, and according to the Roman patterns. Hence we see a reason for such great quantities of celts being found among the Celtic nations, and not among the Roman, excepting now and then a specimen, which may be looked upon as the tool, or spoil of barbarian auxiliaries.

v. Tab. XIV. fig. 1. represents a *Celt*, No. 1. found on the peninsula of Ballrichen, within the precincts of a Druidical grove, or dwelling, in Ireland. The same kind of celt is described in WRIGHT's Louthiana, b. 14. p. 7. pl. i. and also in the Archæologia, Vol. V. p. 113. by Dr. LORT. It weighed one pound and one quarter. Except at the edge it was nearly three-eighths of an inch in thickness. It was of a blackish colour, from oxide of the metal and dirt upon its surface.

vi. Fig. 2. represents the *Celt*, No. 2. It was found in a field, by ploughing, in Cumberland. The celt in Dr. LORT's collection which most resembles this article is delineated by fig. 11. pl. viii. p. 113. Vol. V. of the Archæologia. The celt before us differs from that just referred to, in being grooved on both sides to receive a shaft or handle, instead of having a socket. It weighed nearly three quarters of a pound, and was about five-eighths of an inch thick, except at the edge. Its external appearance was like that of the former celt.

vii. Fig. 3. represents the *Celt*, No. 3. It was much smaller than the two former, weighing only about five ounces, but it resembled in shape fig. 1.

§ 2. *External, or more obvious Properties.*

(*a*) These metallic instruments differed considerably from one another in their external appearance, with respect to colour. A little green or blackish oxide of copper adhered to their surfaces. The lituus, and the celts, No. 1. and No. 2. in the parts not covered with oxide or dirt, were yellow, like rather pale brass; the scabbard was somewhat less yellow; and the spear-head and sauce-pan were of a pale yellowish-brown colour. The celt, No. 3. was covered entirely with black oxide and other extraneous matter.

(*b*) A small part of the surface of each of the articles being filed or rubbed to remove the exterior matter, the colours of all of them were what I would call different shades of pale copper colour; not very different from gun metal and prince's metal, but not at all like brass. They all took a fine polish, which, when first produced, was pale coloured and whitish; but, by exposure to the air, it became deeper coloured and tarnished. On examination of the polished surfaces with a lens, the metallic matter appeared perfectly homogeneous, and of a close texture.

The articles being cut through with a chizzel, the same differences among the cut surfaces appeared, as among the polished surfaces just described. On fracturing the metallic bodies, the visible interior structure or texture did not appear similar in colour and grain.

The *spear-head* was open grained, almost as copper; and porous, as if made of bad metal, but of a blackish-brown, or dark grey colour.

The *sauce-pan* was also open grained or porous, although less so than the spear-head. The colour of the grain, like that of the spear, was dark brown or grey.

The *lituus* and the *scabbard* were close grained; lighter coloured than the former, but grey.

The *celts* were all open grained, but much less so than the pan and spear-head; and differed from them in being brown.

The celts when lacerated exhibited shining facets, and striæ or radii. The cut surface, and also the grain of the celt, No. 3. was much paler than the cut surface and grain of the other two celts.

An experienced observer can judge tolerably well concerning many metals, and metallic compositions, by inspecting fractured surfaces; but to judge accurately from these appearances, the metals to be compared with one another should be in the same state of aggregation.

I therefore melted the old implements, and cast them into the same ingot mould. In this state I could also judge better of their hardness, brittleness, strength, malleability, and other properties, but especially of their specific gravity.

Each of these ingots was fractured by a pretty smart stroke with a hammer. The fractures of all the metals were, in this state, close, or fine grained; and therefore denoted hardness. Their appearances were the following.

1. The *celt*, No. 1. Less close grained than the rest, and pale brown.

2. The *celt*, No. 2. Fine grained, and greyish brown.

3. The *celt*, No. 3. Still finer grained; bright greyish, and somewhat crystallized.

4. The *scabbard.* So like the celt, No. 2. that it was not easy to perceive a difference between them in grain and colour.

5. The *spear-head.* Close grained as any of the ingots; but of a dull pale slate colour.

6. The *sauce-pan.* Fine grained, but not so much so as the *lituus;* and of a somewhat slate-coloured hue, or dark grey; but less dull than the scabbard.

7. The *lituus*. Very close grained; of a bright slate and silvery hue, and partly crystallized.

(*c*) The trial with the drill, and with the hammer, showed the lituus to be the hardest of these old metals; almost as hard as bell metal: the next in hardness was the celt, No. 3: the next in order was the pan: and next the celts, No. 1, and No. 2, and the spear-head, which were nearly alike in this property.

They were all much harder than copper, or even than brass.

(*d*) The ingots of the lituus, sauce-pan, spear-head, scabbard, and the celt, No. 3, all broke readily enough with a smart stroke with the hammer, and more readily than the ingots of the celts No. 1. and No. 2. Plates of the spear-head and pan possessed little malleability and ductility; being very liable to be cracked in beating them, as if they had been made of impure metal. The lituus was very flexible, malleable, and elastic; so were plates of the celts, No. 1, and No. 2, and of the scabbard; but the celt, No. 3, although, apparently, made of the purest metal, possessed little malleability. They were all less malleable than brass. The celts, No. 1, and No. 2, possessed more strength and hardness conjointly than any metal in use, except iron and steel; and of course are the fittest metal for chopping instruments of any known metal, except iron and steel.

(*e*) The metallic implements before us were all rendered harder, and specifically heavier, by hammering: and they were again rendered softer, and specifically lighter, by annealing, that is, by ignition and gradually cooling.

(*f*) These ancient metals were very sonorous, particularly the sauce-pan, the lituus, and the celt No. 3.

§ 3. *Specific Gravities.*

These were ascertained by weighing the metallic instruments themselves, as well as after melting and casting each of them in the same ingot mould.

1.	The lituus, before melting — —	8,3
	Ditto, after melting — —	8,85
	Ditto, another piece, after melting	8,888
	Ditto, another piece, after melting	8,650
2.	The spear-head, before melting —	7,795
	Ditto, after melting —	8,805
	Ditto, another piece of ditto —	8,850
	Ditto, another piece of ditto —	8,830
	Ditto, another piece of ditto —	8,860
3.	The sauce-pan, before melting —	7,960
	Ditto, another piece — —	8,255
	Ditto, after melting — —	8,630
	Ditto, another piece of ditto —	8,769
	Ditto, another piece of ditto —	8,740
4.	The scabbard, before melting —	8,5
	Ditto, another piece — —	8,6
	Ditto, after melting — —	8,657
	Ditto, another piece of ditto —	8,875
5.	The celt, No. 1. before melting —	8,780
	Ditto, another piece — —	8,885
	Ditto, after melting — —	8,734
	Ditto, another piece of ditto —	8,771
6.	The celt, No. 2. before melting —	8,680
	Ditto, another piece — —	8,653
	Ditto, after melting — —	8,474
	Ditto, another piece of ditto —	8,600

7. The celt, No. 3. after melting	—		8,854
Ditto, another piece	—	—	8,600

§ 4. *Experiments with Fire.*

(*a*) These old instruments melted at a lower temperature than that at which copper, or even some kinds of brass melt.

Although I did not succeed in determining precisely the temperature at which each of them fuses; it may be useful to relate the experiment made with that view.

(*b*) 100 grains of each of the above seven ancient metallic instruments, and the same quantity of copper, of pure silver, of allay of copper with one-eighth of its weight of tin, of allay of copper with one-tenth of its weight of tin, of allay of copper with one-twentieth of its weight of tin, of allay of three parts of copper with one of zinc, and of gun-metal, were exposed each in separate coppels, under a muffle, to the greatest degree of fire which I could produce in the best assay furnace.

A pyrometer clay piece of WEDGWOOD's instrument was also put into each coppel.

During forty minutes exposure to fire, not one of the metals melted, except the pure silver,* and the allay with zinc: nor did any of them emit visible vapour, or inflame, except the allay with zinc; nor did any matter ooze out of any of the metals.

* In WEDGWOOD's scale it is stated, that pure silver melts at 28°, and Swedish copper at 27°. But every part of the furnace in the above experiments might not be of the same temperature for the same space of time: and perhaps the state of cohesion and figure of the metal exposed to fire may account for the difference in the degree noted by the pyrometer in my experiment, from that stated in the scale. For I am assured, by Mr. THOMAS WEDGWOOD, that the degree of contraction is uniform among a number of pyrometer pieces, exposed in the same part of the furnace at the same time.

On cooling, it was found that the figure of the metals which had not been melted in the coppels was not altered, but they were changed, either totally or externally, into scoria-like black matter. The copper allayed with zinc was found to contain a nucleus of copper within a large proportion of black scoria and white oxide of zinc. The celt metals were changed into scoriæ, including copper-like metal. The other old metals were changed entirely into scoriæ. The copper allayed with one-twentieth of its weight of tin was changed into scoria containing a little copper; but the copper allayed with one-eighth of tin was changed into scoria containing a little copper, seemingly allayed with a much smaller proportion of tin than before.

The pyrometer pieces indicated degrees of fire, which varied between 18° and 21°. The pyrometer piece in the coppel which contained the silver, and also that in the coppel which contained the copper, denoted 20° of WEDGWOOD's scale, or about 3800° of FAHRENHEIT's scale.

(*c*) A thin plate of each of the old metals being exposed to the flame of a candle with the blow-pipe, a blue and green flame appeared, which soon disappeared, although the fire of the candle was applied so as to keep the metal red hot.

The same kind of blue and green flame was emitted from plates of these metals when they were exposed to fire in open crucibles, before they were melted; but it disappeared in a few seconds of time, although the fire was continued to be applied to keep the metal red hot; nor was any such flame produced when the metal was melted in open vessels, or kept stirring when in a fluid state.

(*d*) Each of the ancient metals being melted in close vessels, was then exposed to the air, and stirred with an iron rod;

but none of them emitted any blue flame, or white vapour, as was the case when brass was so treated.

The following experiment, to determine whether the ancient metal instruments contained any gold or silver, was made, while I was present, by Mr. BINGLEY, Assay Master.

(*e*) 50 grains of each of these metals, and as much gun metal, and also the same quantity of brass, were put into separate coppels, together with 150 grains of lead, under the muffle of an assay furnace: 150 grains of lead were also put alone, by way of test, into a separate coppel.

The fire being kept up in the usual way, the brass emitted a blue flame, and began to melt, discharging at the same time white fumes; but soon after it was melted the flame, and white fumes, disappeared. The ancient metals, and also the gun metal, afterwards melted, and without sending forth any flame, but a slight fume was seen when they were in fusion; which was particularly evident from the coppel containing the spear-head metal. This fume was not seen to arise from the coppel which contained lead only; but the Assayers observe it from charges of lead with silver, or lead with gold and silver, when much air is admitted.

The process being finished, nothing was left in the coppels which contained lead only, and lead and brass, except a just visible particle of silver; but in the other coppels there remained about one-third of the original quantity of the ancient metals, and of the gun metal: and therefore into each of these coppels 150 grains of lead were again introduced. The process being performed a second time, every particle of metal was absorbed, excepting a just visible particle of silver in the coppels which contained the celt, No. 2, the metal of the scabbard, and the gun metal: but there was a much larger globule of silver in the coppel which contained the spear-head metal.

As the only metal which appeared to contain more silver than the test itself was the spear-head, and as it emitted more fume than the rest, I repeated the process on this metal.

The process of cupellation the second time, as before, caused the appearance of the white fume, and afforded a residue of silver, as before, in greater quantity than that of the test. The silver was determined in the most accurate way to amount to the proportion of fifteen grains in a Troy pound of the spear-head metal. There was no gold in this silver, for it dissolved totally in nitric acid.

§ 5. *Experiments with nitric Acid.*

(*a*) A polished piece of each of the ancient metals was just wetted with *nitric* acid. Fumes of *nitrous* acid arose, and the part wetted became *white* and corroded; as is the case when the nitric acid has been applied in this manner to the allay of copper by tin.

(*b*) On 300 grains of each of the above metals, in a small retort, were poured 1800 grain measures of nitric acid, purified by distillation from nitrate of silver, and of the specific gravity of 1,350. The hydro-pneumatic apparatus being affixed, generally from thirty to forty ounce-measures of nitrous gaz came over in the cold, in the course of two to three days. In this time the whole, or at least the greatest part of the metal, was oxidified and dissolved; there being a clear blue solution, with a copious white sediment, and sometimes a part of the undissolved metal.

By means of the fire of a lamp, more gaz came over, which had been absorbed by the solution, and which also was afforded by the dissolution of the remaining metal.

The whole quantity of nitrous gaz varied, with the same as well as with different metals, between 60 and 85 ounce-measures; but either from my own inability to observe, or from the circumstances on which this variety depended being unknown, I cannot explain the reason of such differences in the result.

(*c*) After the solution (*b*) had stood several days, the clear blue liquor was decanted, and filtrated, from the white sediment: and pure water was poured upon the filter repeatedly, till what passed through was colourless, and almost tasteless. The filtrated liquid was boiled to evaporate all but about six ounces; and it deposited, on standing, a small quantity of white sediment.

The white sediment, from the solution (*b*), being dried, amounted to the following different quantities, from 300 grains of each of the different metals, namely,

1. The sauce-pan, exclusive of a little dirty extraneous matter, - - 65 grains, or $21\frac{1}{2}$ *per cent.*

2. The spear-head, exclusive of a little dirty extraneous matter, - - - 63 grains, or 21 *per cent.*

3. The celt, No. 3. - 55 grains, or $18\frac{1}{2}$ *per cent.*

4. The lituus, - - 54 grains, or 18 *per cent.*

5. The scabbard, - 48 grains, or 16 *per cent.*

6. The celt, No. 1. - 42 grains, or 14 *per cent.*

7. The celt, No. 2. - 42 grains, or 14 *per cent.*

(*d*) The decanted and filtrated liquid (*c*) being duly evaporated to crystallization, was found to contain nothing but nitrate of copper, and sometimes a very minute portion of white sediment; for it threw down nothing but prussiate of copper, on adding prussiate of soda; nor was any silver deposited on immersing in it bright copper wire; nor was any precipitation occasioned by adding muriatic acid, or muriate of soda, to the concentrated blue solution.

(*e*). The white sediment (*c*) was a light impalpably fine powder: it had a little metallic taste: it could not be melted with borax by flame with the blow-pipe, but was diffused through that salt, and rendered it opaque.

This sediment dissolved totally, except a little mere dirt, by long digestion in muriatic acid, and immediately in this menstruum when caloric was applied to make it boil.

This solution in muriatic acid did not throw down CASSIUS' precipitate on adding to it nitro-muriate of gold, but afforded a white deposit exactly like that which is made on adding nitro-muriate of gold to muriate of tin, made either by boiling tin in a large proportion of muriatic acid, or by dissolving oxide of tin (made with nitric acid) in muriatic acid.

The muriatic solution of the white sediment (*c*), on adding prussiate of soda, afforded a precipitate exactly like that which appears on adding prussiate of soda to muriate of tin.

The white sediment (*c*) being mixed with tartar, upon charcoal, the flame of a candle by the blow-pipe was directed upon it; by which treatment small silver-like globules were made to appear. These globules being collected, were digested in the cold, in so small a proportion of muriatic acid as could not dissolve the whole of the globules supposing them to be tin. They were gradually almost all dissolved, and nitro-muriate of gold being added, CASSIUS' precipitate was immediately deposited. But the metallic globules being dissolved by boiling in a large proportion of muriatic acid, no CASSIUS' precipitate was produced on adding nitro-muriate of gold; nor on adding it to tin dissolved by boiling in a large quantity of muriatic acid.

The preceding analytical observations and experiments will, on examination, perhaps be found to contain sufficient evidence to demonstrate that each of the ancient metallic instruments contains copper and tin; and they will also perhaps be found to prove, that these metals contain no other kind of metal, or other species of matter. But, in order to ascertain the proportion of the tin to the copper more accurately than I was able to do by analysis, and also in order to confirm or invalidate the evidence of analysis, I made the following synthetical observations and experiments.

§ 6. *Synthetical Observations and Experiments.*

Experiment 1. 50 grains of tin were united by fusion with 1000 grains of copper. The ingot of this allay of twenty parts of copper by one of tin, when polished, differed from the celt metals in shade of the same colour; these being much paler than this allay. It was a good deal harder, and not so tough as copper, but it was not so hard, and was more tough than the celt metals. Its fracture shewed also a more open grain than the old metals, and more inclining to the peculiar red colour of copper, instead of the brown and grey, or slate colour of the ancient metals.

With nitric acid it afforded, like the ancient metals, a blue liquor, and white deposit of oxide of tin; but in much smaller proportion than any of them; not being more than seven *per cent.*

Experiment 2. 100 grains of tin were united by fusion with 1500 grains of copper. This allay of fifteen parts of copper with one of tin resembled the celt metals, No. 1 and No. 2, in colour, polished surface, grain of the fracture, and brown colour of the fracture: consequently the red colour of the copper was completely destroyed. It was not, however, so hard, and was stronger than these celt metals; but was harder than the spear and the sauce-pan.

The solution of this allay with nitric acid only differed from that in the former experiment in affording a more copious white deposit, namely, ten *per cent.* of it in its dried state.

Experiment 3. 100 grains of tin were melted with 1200 grains of copper. This allay of twelve parts of copper by one of tin could scarcely be distinguished from the last described allay in the colour of the polished surface, nor was it so much closer grained or lighter coloured in its fracture as might have been expected; nor could I by the hammer distinguish it from that allay in point of hardness and strength. On the trial with the drill, it however betrayed a good deal more hardness. It was almost as hard as the celts, No. 1 and No. 2.

With nitric acid it afforded a deposit of eleven *per cent.* of oxide of tin.

Experiment 4. 100 grains of tin were united by fusion with 1000 grains of copper. This allay of copper with one-tenth of its weight of tin was as pale coloured as the celts, No. 1 and No. 2, but not nearly so pale as the celt, No. 3. I could not distinguish this allay in the properties of hardness and strength from the two celts, No. 1 and No. 2, and the scabbard; but it was harder than the spear-head and sauce-pan, and not so brittle. Its fracture showed the same kind of rather open grain, and texture, as that of the celts, No. 1 and No. 2, before they were melted, but it was not so close grained as any of the ancient metals after fusion; and it differed from all of them in being of a lightish brown colour.

The solution in nitric acid differed only from the former in affording a greater proportion of white deposit, namely, thirteen grains and a half *per cent.*

Experiment 5. 900 grains of copper were melted with 100 grains of tin: which allay of nine parts of copper with one of tin differed very little from the former.

By means of nitric acid this allay gave seventeen grains *per cent.* of oxide of tin.

Experiment 6. 100 grains of tin were melted with 800 grains of copper. This allay of eight parts of copper with one of tin was also scarcely distinguishable from the two former allays, in colour, strength, appearance of fracture, texture, and polish.

With nitric acid this allay afforded eighteen grains and a half *per cent.* of oxide of tin.

Experiment 7. 100 grains of tin were melted with 700 grains of copper. This allay of seven parts of copper with one part of tin was evidently different from any of the former allays; being harder, more brittle, paler coloured, the fracture showing a much finer grain, and of a grey or somewhat slate-colour. The grain, therefore, of this allay resembles in colour that of the celt, No. 3, the lituus, the spear-head, and the scabbard. It was especially like the lituus and the celt, No. 3, in the rather bright and silvery appearance of the fracture, instead of the dull slate colour of the spear-head and sauce-pan. On trial with the hammer, and the drill, it resembled exactly the lituus in brittleness and hardness. It was a little harder and more brittle than the celt, No. 3, and of course much more so than the other ancient metals.

This allay, on solution in nitric acid, yielded twenty *per cent.* of oxide of tin.

Experiment 8. 100 grains of tin were melted with 600 grains of copper. This allay of six parts of copper with one of tin was harder than any of the above allays: and perhaps it was harder and more brittle than any of the ancient metals. Its fracture exhibited a still finer, brighter, silvery, and more crystallized grain than any of the preceding allays.

Nitric acid separated from this allay twenty-two *per cent.* of oxide of tin.

Experiment 9. 100 grains of tin were melted with 400 grains of copper. This allay of four parts of copper with one of tin was about as hard and brittle as some sorts of bell-metal. Its fracture was still paler, finer grained, and silvery, than any of the preceding allays.

Nitric acid separated from this allay twenty-seven *per cent.* of oxide of tin.

Experiment 10. 100 grains of tin were melted with 300 grains of copper. This allay of three parts of copper with one of tin, was much harder than any of the preceding ones. It was also much more brittle, the fractured surface was quite smooth, and without almost any grain at all. It was of a silvery hue, and resembled much an ingot of a melted bell; excepting that it was finer grained, and of a duller colour.

Experiment 11. 100 grains of tin were melted with 200 grains of copper. This allay of two parts of copper with one of tin, was as brittle almost as glass. The fracture showed no grain at all, being quite smooth. Its colour was more like that of silver than any other metal.

Experiment 12. The metal of which what are called *brass guns* are made, does not in general contain a grain of zinc. They are made of an allay of about ten to twelve or thirteen parts of copper, with one part of tin. I found that the shavings of one of these guns melted much more readily than copper. The ingot was not so hard, but tougher than any of the above ancient metals. It possessed nearly the same hardness and strength as the allay, in *Experiment* 3. of twelve parts of copper by one of tin. The colour of the polished surface, and the grain and colour of the fractured surface, resembled pretty exactly that allay. Of course this gun metal is only a little less hard and brittle than the celts, No. 1 and No. 2, but it resembles them very exactly in the colour and texture of the grain.

This gun metal afforded nearly thirteen *per cent.* of oxide of tin, by means of nitric acid.

Experiment 13. 20 grains of tin and 10 grains of zinc were melted with 800 grains of copper. This allay of eighty parts of copper with two parts of tin, and one part of zinc, was a metal which had a very different aspect when polished, as well as when fractured, from either copper, or any of the above allays, or any of the ancient metals. For it had a rich yellowish or golden hue, and was nearly as tough, but a little harder than copper.

Experiment 14. 20 grains of zinc were united by fusion with 800 grains of copper. This allay of forty parts of copper with one part of zinc, was of a yellowish golden hue, and of course was very different in its external appearance from the allays of copper by tin. Like the allay of *Experiments* 1st and 13th, it was too soft, and, as the artists term it, *clingy*, to receive the impression of lines, figures, and letters, or for instruments in which holes are to be drilled.

The solution of this allay in nitric acid was blue, like those of the preceding allays and old metals, but there was no white deposit.

Observation. This is the proper place for me to observe, that all the above allays, and the gun metal, melted at a lower temperature than copper does; and, as far as I could determine, the temperature of fusion decreases as the proportion of tin increases.

The next experiments were made not only to satisfy myself, that if *iron* had been an ingredient in the ancient metals, it must have been made appear by the test employed; but also to determine the question made by some chemists, whether copper can be allayed by iron; and to show, as others have asserted, the allays of copper by iron, which were employed by the ancients.

From the writings of many able chemists I was inclined to suppose, that a malleable uniform metal could not be composed of copper and iron, without the aid of an intermede. I therefore, in the first place, used tin as the intermede.

Perhaps some of these experiments next to be related may not be found immediately relative, but as they occurred in the course of investigation, and as I believe few experiments of the same kind have been published, perhaps they will be found useful.

Experiment 15. 2000 grains of tin were melted with 1000 grains of steel,* by keeping the two metals in a close crucible exposed to a pretty fierce fire of a melting furnace. An allay was produced of an uniform metallic mass, of the colour of pewter, of a very open grain, but uniform texture; which was as brittle, and not harder than certain kinds of old bad pewter.

Experiment 16. 1800 grains of tin were melted with 600 grains of steel. This allay of three parts of tin with one of steel was perfectly similar to the last allay of two parts of tin with one of steel, excepting that the allay of this experiment was not so hard, and was less brittle.

Having thus prepared the steel for union with copper, by the medium of tin, I added to it copper.

Experiment 17. 600 grains of the allay of *Experiment* 15. were melted with 2400 grains of copper. This allay of twelve parts of copper with two parts of tin, and one part of steel, resembled exactly the allay of six parts of copper with one of tin, in *Experiment* 8. in the colour and grain of the fracture; in its polish; hardness; and brittleness. Its fracture was of course of a slate-coloured hue, or dark grey, somewhat crystallized and silvery. The fracture being inspected with a lens, the grain appeared finer or shorter than that of the allay of six parts of copper with one of tin.

The solution of this metal in nitric acid produced nitrous gaz, a blue solution, and a white deposit; as occurred in the dissolution of the ancient metals, § 5. p. 411, and of the allays of copper with tin, p. 414—419; but the result of the examination of this blue solution and white deposit was different from

* The steel employed was part of a file. Steel was preferred to iron, because it is fusible, but iron is not.

that of the ancient metals, and satisfied my mind completely, that if those metals had contained iron it must have been detected.

(*a*) The blue solution of this experiment being boiled, to carry off redundant acid, and evaporate about three-fourths of its water, prussiate of soda was added. A reddish-brown precipitation ensued, which resembled exactly that produced by adding this test to nitrate of copper.

(*b*) The white deposit of this experiment having been well edulcorated by pure water, was wholly dissolved in muriatic acid. This solution differed from that of all the white deposits of the preceding experiments, in being of a reddish-brown colour, like dilute solution of muriate of iron, and especially in affording a copious precipitation of prussiate of iron by prussiate of soda. With nitro-muriate of gold, however, this solution only produced a slight grey precipitation, as in the former experiments.

Experiment 18. 1000 grains of the allay of *Experiment* 15. were melted with 2000 grains of copper. This allay of about seven parts of copper with two parts of tin, and one part of steel, was an extremely hard metal, much harder than that of the last experiment; and it was very strong, but scarcely malleable. It took a beautiful polish, of a silvery colour. It was of a perfectly homogeneous texture. The grain of its fracture was extremely fine and uniform, and of a grey colour.

Experiment 19. 2000 grains of copper were melted with 200 grains of steel, in a close vessel, by keeping them exposed to a fierce fire in a wind furnace for about twenty minutes. This allay of ten parts of copper with one part of steel, was of a copper colour. The grain of its fracture was coarse, like that of copper. It was harder than copper, and less tough, but quite malleable. It was about as hard as the allay of twenty parts of copper by one of tin, and consequently was not nearly so hard as the softest of the ancient metals.

Experiment 20. 1000 grains of copper with 500 grains of a small round steel file were exposed to fire, as stated in the last experiment. On opening the crucible, part of the steel only was found to have been melted and united to the copper; but the other part of the steel which retained its form, was thoroughly impregnated or penetrated by copper; so that on breaking the part which had not been melted, and which was very brittle and porous, it was in appearance imperfectly metallized copper. The part of the allay which had been melted was not, as far as I could perceive, different from the allay of the last experiment, except that it was a little harder; being thought to be about as hard as brass.

I have not hitherto set down the specific gravities of the above allays, because I thought it most useful to make the statement of them together in one column, with, at the same time, the specific gravities of different parcels of copper, tin, zinc, brass, and bell-metal.

Specific Gravities.

1.	Plate of copper, a little hammered - -	8,8
	Another specimen, a little hammered - -	8,904
	Copper ingot - - - -	8,418
	Another specimen of ditto - - -	8,414
	Shotted copper* - - -	8,08
2.	Tin - - - - - -	7,3

* By shotted copper is meant copper which has been poured when melted into cold water, by which it is divided into small globular pieces and grains.

	Another specimen of tin - - -	7,25
3.	Zinc - - - - -	7,171
	Ditto, another specimen - - -	7,150
4.	Allay of copper with $\frac{1}{20}$ its weight of tin; three different parts of the same ingot - -	8,764
		8,760
		8,611
5.	Allay of copper with $\frac{1}{15}$ its weight of tin, in the state of ingot - - - - -	8,760
6.	Allay of copper with $\frac{1}{12}$ its weight of tin -	8,700
	Ditto, another piece of the same ingot - -	8,677
7.	Allay of copper with $\frac{1}{10}$ its weight of tin; two specimens of the same ingot - - -	8,658
		8,671
8.	Allay of copper with $\frac{1}{9}$ its weight of tin; two specimens of the same ingot - - -	8,510
		8,6
9.	Allay of copper with $\frac{1}{8}$ its weight of tin; two specimens of the same ingot - - -	8,790
		8,711
10.	Allay of copper with $\frac{1}{7}$ its weight of tin; two specimens of the same ingot - - -	8,766
		8,530
11.	Allay of copper with $\frac{1}{6}$ its weight of tin, in one large piece, as it cooled in the crucible -	8,635
12.	Allay of copper with $\frac{1}{4}$ of its weight of tin; two different parts of the same ingot - -	8,966
		8,928
13.	Allay of copper with $\frac{1}{3}$ of its weight of tin; two different parts of the same ingot - -	8,944
		8,909

14.	Copper allayed with $\frac{1}{4}$ of its weight of zinc -	8,400
15.	Common brass ingot - - -	8,300
16.	Common brass, hammered - - -	8,500
17.	Piece of an old small bell, probably compounded of copper with $\frac{1}{4}$ its weight tin - -	9,
18.	Two different parts of the ingot of gun metal of *Exp*. 12. p. 418 - - -	8,5
19.	Allay of 80 parts of copper with two of tin, and one of zinc - - - -	8,560
20.	Allay of 40 parts of copper with one of zinc -	8,450
21.	Allay of 2 parts copper with one of steel -	7,370
22.	Allay of 3 parts of tin with one of steel -	7,214
23.	Allay of 12 parts of copper with two tin, and one of steel; different parts of the same ingot -	8,534
		8,666
		8,633
		8,720
24.	Allay of 7 parts of copper with two of tin, and one of steel - - - - -	8,633
25.	Allay of 10 parts of copper with one of steel; two different parts - - - -	8,655
		8,600

§ 7. *Conclusions and Remarks.*

1. The first conclusion from the preceding observations and experiments is, that the ancient metal instruments examined consist principally of copper, as appears; 1st, from their external and obvious properties; particularly their colour, taste, malleability, and specific gravity: 2dly, from the whole of the metals, except a small deposit, yielding nitrate of copper with nitric acid: 3dly, from the synthetic experiments.

II. I conclude that these metal instruments contain tin; which metal was made appear, by the experiments on the white deposit afforded on dissolution in nitric acid, § 5: and which also was made appear by the synthetic experiments, § 6.

III. The third conclusion is, that these metallic instruments consist of metal only, or at least of nothing else which can be detected by ordinary known modes of analysis: for they are all malleable, and uniform in their texture; which properties metals do not possess when they are mixed by fusion with extraneous substances hitherto discovered by analysis; except carbon in several metals, and siderite in iron only.

IV. The fourth conclusion is, that these ancient instruments contain none of the metals but copper and tin: for,

1. They do not contain *gold*, *silver*, or *platina*, excepting silver in the spear-head, as appears from the experiment of cupellation, § 4. (*e*).

2. They do not contain lead, for that would have oozed out in the experiments of fusion and oxidation; and would have appeared in the grain of the fractures; as well as on adding muriate of soda, and muriatic acid, to the concentrated nitrate solution, § 5. (*d*).

3. They do not contain *iron*, for that would have been shown by the prussiate of soda, § 5. (*d*); as was proved by the synthetical experiment, § 6. *Exper*. 17. (*b*).

4. They do not contain *zinc*, for that would have been shown by the blue flame and white flowers in *Exper*. § 4. (*c*) (*d*); as well as by the yellow colour of the grain of the fracture, which was shown by the synthetical experiments, § 6. *Exper*. 13, and 14.

5. *Bismuth* would have appeared on diluting the nitrate solution, § 5. (*d*).

6. *Manganese* would have been seen on concentrating by evaporation the nitrate solution, § 5. (*c*) (*d*).

7. *Arsenic* would have manifested itself by the brittleness and whiteness of the metals; by the smell and visible vapour on exposure to fire and air; and on examining the solution, § 5. (*d*), and the white deposit, § 5. (*e*).

8. *Antimony* would have produced more brittleness than these ancient metals possessed: a white vapour would have appeared on examining the white sediment with the blow-pipe, § 5. (*e*): as well as in the experiments in the assay furnace, § 4. (*b*) (*e*); and a white precipitate would have fallen on diluting the muriatic solution of the white deposit from the nitrate solution, § 5. (*e*).

9. *Cobalt* would have been detected by the prussiate of soda; and by the colour of the oxide, in the experiment in the assay furnace, § 4. (*b*); and it would have given brittleness to the ancient metal instruments.

10. It is not at all probable that *nickel* was present; but if it had been an ingredient, it most likely would have been betrayed by its greenish oxide in the experiment, § 4. (*b*).

11. *Molybdæna*, and *quicksilver* may be mentioned for the sake of order, but it is utterly unreasonable to suppose them to be present, either naturally or by art; and evident appearances, or at least traces of them, must have occurred in the preceding experiments. As for the substances called *tungsten*, *uranite*, *menackanite*, and *titanite*,* we have not yet had sufficient evidence to prove their being peculiar metals; but from the properties which have been observed to belong to them, it is quite inconsistent with the preceding experiments and obser-

* A new metal, named *Titanium*, lately announced in the German Journals.

vations to suppose them to exist in the ancient metal instruments. It will be proper also to remark, that the only species of metals known till within the last two or three centuries, were gold, silver, quicksilver, iron, copper, lead, and tin. The oxides of several of the brittle metals were known indeed to the Hebrews, Greeks, and Romans, and perhaps to several barbarous nations of great antiquity; but not one of them was used as an allay, except the oxide of zinc to compose artificial orichalcum.

It appears that the metal of the spear-head contained silver; but although the presence of it was proved by a repeated decisive experiment, § 4. (*e*), the proportion of it was too small to alter sensibly the properties of the allay of copper with tin, and could not answer any useful purpose in such a compound. I therefore believe that the silver in this instance was not purposely added; but was an accidental or natural ingredient of the copper, used for the making the metal of this spear-head. The Bishop of LLANDAFF made a few experiments on a celt, from which his lordship concludes that it seemed to contain zinc: for it emitted a blue flame, and a thick white smoke, on the first exposure of a piece to fire; but no such appearances were seen on the second exposure of the same piece to fire. Every person will readily give credit for the observations being accurately made; nor would I even refuse to admit the conclusion, that the celt examined by his lordship did contain zinc; but it is also just to observe, that a piece of copper, or of allay of copper, with tin, being exposed to fire in an open vessel, emits frequently a blue flame on a first, but not on a second exposure to fire soon after the first, § 4. (*c*); and if much air be admitted to the allay of copper with tin in fusion, a white smoke will also sometimes be seen; as was observed in the preceding experiment, § 4. (*e*).

I suspect that the blue flame from copper when first ignited, and which ceases on fusion, is produced by the inflammation of a little of the copper already combined with oxygen; for some oxides of copper are so combustible, that if a small part of a given mass of them be ignited, the ignition will spread rapidly throughout the whole mass. Most probably celts were originally chopping tools, as we have shown in a former part of this paper, and therefore the addition of zinc to the allay of copper with tin would answer no useful purpose.

v. The fifth conclusion relates to *the proportion of the copper and the tin* to each other, in the ancient metals. I endeavoured to estimate the proportion of tin, by comparing the quantities of oxide of tin obtained from the ancient metals, with the quantities of oxide of tin obtained by the same means from allays of copper with known proportions of tin.

It appears from the analysis of the allays of copper by tin, that the oxide of tin afforded by the nitric acid solution is in the proportion of about 150 parts from every 100 parts of the metal tin, § 6. *Exper.* 1st—9th. According to this *datum* the proportion of tin in the old metals is in the following proportions, or nearly so.

1. The sauce-pan contains of tin a little more than 14 *per cent.*; that is about one part of tin and six of copper.

2. The spear-head contains 14 *per cent.* of tin; that is, somewhat less than one part of tin and six of copper.

3. The celt, No. 3; a little more than 12 *per cent.* of tin; that is, about one part of tin, and seven and a half parts of copper.

4. The lituus; nearly the same proportions of tin and copper as the celt, No. 3.

5. The scabbard; a little more than 10 *per cent.* of tin; that is, about one of tin and nine parts of copper.

6. The celt, No. 1;* a little more of tin than 9 *per cent.*; that is, about one of tin and ten parts of copper.

7. The celt, No. 2; the same proportions of tin and copper, as in the celt, No. 1.

VI. The two last conclusions are confirmed by the exact correspondence, between the ancient metals and the allays of copper by tin, in external and obvious properties, § 2. and § 6; in specific gravities, § 3. and p. 422, l. 21; and in chemical properties, § 5. and § 6. Allays of five to eighteen parts of copper with one part of tin can generally be distinguished from such allays with the addition of a very small proportion of the other metals; by the colour of their polish, the colour and texture of their grain, their strength, their hardness, their malleability, and specific gravities; without the aid of chemical analysis. It is worthy of remark, that these allays of copper with tin are evidently different, in their colour and grain, from such allays with the addition of even one-fortieth of their weight of zinc, *Exper.* 13th; and also from copper allayed by one-fortieth of its weight of zinc, *Exper.* 14th.

The similarity of the properties of the ancient metals, and of the allays of six to twelve parts of copper with one of tin, is very evident. But with smaller proportions of tin we find the allays are softer, and the grain of their fractures more open

* Mr. CAVALLO made a few experiments on a very small quantity of this celt before it came into my possession; from which he conjectured that it consisted of one part of tin, and six parts of copper.

than the ancient metals, *Exper.* 1—4.; and with larger proportions of tin we find the allays harder, more brittle, paler, and closer in texture than the ancient metals, *Exper.* 8.—11.

It is right, however, to remark, that the property of hardness of the allays of copper by tin is, *cæt. par.* as the proportion of tin, or nearly so; which is not the case with some of the ancient metals; for the spear-head and sauce-pan contain rather more tin than an equal quantity of the lituus, § 5. (*c*), which is much harder than them, § 2. (*c*); and the spear-head and sauce-pan are nearly as soft as the celts, No. 1 and No. 2, § 2. (*c*), which contain the smallest proportion of tin of any of the old metals, § 5. (*c*).

The grain also of the fractures of the spear-head and sauce-pan, before melting, is much coarser, or open, than those of the other ancient metals which contain a smaller proportion of tin, § 2. (*b*), p. 404, l. 21: but it appears from the synthetic experiments that the grain becomes finer as the proportion of tin is increased, § 6. *Exper.* 1.— 12. To account for these inconsistencies I must remark, that a minute quantity of extraneous unmetallic matter may be contained in metals; so minute indeed as to elude the most rigorous analysis, or at least not to be discoverable by the ordinary modes of examination; and which also may not render the metal at all unfit for most of the uses to which it is applied. For instance, good malleable iron may contain carbon, and even phosphate of iron or siderite; and metals in general may contain a very small proportion of oxygen, and yet be as useful as the purest metals. The best English copper is accounted less tough and ductile than Swedish copper. The purest English tin crackles when it is bent or chewed, but pure Malacca tin has not this property. These differences of properties most probably depend upon some extraneous matter; but in so small a proportion as to have hitherto eluded the research of analysis.

In the case before us, it is probable that a very minute proportion of extraneous matter was present in the spear-head and sauce-pan, especially as they were made of cast metal; which might be less hard, and less compact in texture, than an allay of pure metals containing a smaller proportion of tin to the copper, and yet the allay might be less brittle than the cast metal. This extraneous matter may be oxygen, or sulphur, or earth, although in an imperceptible quantity, introduced during the fusion. The lituus is harder, and not more brittle than the spear-head and sauce-pan; although it contains less tin. It was made of a plate of metal which had been much hammered, and must therefore either originally have been made of purer metal than the spear-head and sauce-pan, or have been rendered purer by hammering. Perhaps metals in general are rendered purer, more uniform in texture, and more dense, by remelting, than they were immediately after casting from the ore; or in the case of steel immediately after cementation; or in the case of allays after the fusion by which the union was effected. Accordingly, cast iron is rendered less brittle by repeated fusion; Mr. HUNTSMAN's cast steel is made by merely remelting steel which had been manufactured by cementation; and Mr. MUDGE's speculum metal, an allay of copper by tin, was not uniform and sufficiently compact till it was remelted. The specific gravity of the sauce-pan, and spear-head, was particularly increased by fusion, § 3. 2. 3; and their texture was rendered more uniform and compact, § 2.

The specific gravities of the ancient metals correspond, as nearly as should be expected, with their composition found by analysis; and agree sufficiently with the synthetic experiments, § 3. and § 6. p. 422.

I did not find that the specific gravity of the same metal, under known circumstances alike, was so nearly the same in all cases as is stated by most writers. In the preceding experiments, different parts of the same ingot varied more than is commonly supposed in point of specific gravity.

The specific gravities of the ancient metals, after melting, varied between 8,5 and 8,8, or nearly so, § 3; and the specific gravities of the allays of three to twenty parts of copper with one of tin varied between about 8,5 and 8,9, § 6. p. 422. These great specific gravities seem surprising, because that of tin is only about 7,2, and of copper ingot about 8,420, § 6. p. 422. But of all metallic combinations that of copper with tin produces perhaps the greatest increase of density. ARISTOTLE made this observation long ago,* and the fact is familiarly known to manufacturers of bell-metal. But it does not appear that the increase of specific gravity is so great as it is stated by GLAUBER. According to him, if two balls of copper and two balls of tin of the same dimensions be melted together, the compound will afford scarcely three balls of the same dimensions as each of the four balls; and yet the three balls will weigh as much as the four balls.—" Funde prædictos globulos in unum . . . .
" iterum effunde mixturam liquefactam in typum globulorum

* Ταῦτα γαρ μείζω δὴ και πλείω ποιεῖ μόνον τὸν ὄγκον. Ο῞ταν δ᾽ ἢ θάτερον μόνον παθητικὸν, ἢ σφόδρα, τὸ δέ πάμπαν ἠρέμα, ἢ ἐδὲν πλεῖον τὸ μιχθὲν εἶναι ἀμφοῖν, ὅπερ συμβαίνει περι τὸν κατΊτερον και τὸ χαλκόν.——————Ο᾿ γαρ κατΊτερος ὡς πάθος τι ὢν, ἄνευ ὕλης τῦ χαλκῦ, σχεδὸν αφανίζεται, και μιχθεὶς ἄπεισι, χρωματίσας μόνον.—ARISTOTLE, ΠΕΡΙ ΓΕΝΕΣΕΩΣ ΚΑΙ ΦΘΟΡΑΣ ΤΟ Α. Κεφ. ι. Ὅτι ἔςι μῖξις.

"primorum, et non prodibunt quatuor sed vix tres numero "globuli, pondere quatuor globulorum reservato."—GLAUBER, *de Furnis, pars* iv. p. 67. 8vo. 1651.

The specific gravity of the allays of copper by tin, and the following experiment, show that the contraction in the dimensions of these two metals on combination, cannot be so great as stated by GLAUBER.

I made two ingots of tin and two of copper, of nearly the same figure and dimensions. The specific gravity of the tin was 7,233, and that of the copper was 8,594. The absolute weight of these four ingots was 1730 grains. On combination by fusion, the compound afforded three ingots, and one-third of an ingot, of the same dimensions as the original ones; but those weighed only 1640 grains; 90 grains being wasted and adhered to the melting pot. The specific gravity of one ingot of this metallic combination was 8,340; and of another, 8,4. Consequently, after making the most reasonable allowance for the errors of the experiment, the contraction could not be one-fourth of the sum of the bulks of the metals previously to fusion, according to GLAUBER; but it might be about one-eighth.

VII. I next observe, that the proportions of tin found in the ancient metals consist with the uses for which they were made.

The principal uses of the allay of copper by tin are, to render copper less oxidable by water, or atmospheric air; to give hardness; to render it sonorous; to render it more fusible; to produce a close texture and whiteness for reflecting light; and to render copper less tough and clingy.*

Copper allayed with one of the smaller proportions of tin by manufacturers, is metal of which guns or cannon, improperly called *brass guns,* are made. Different proportions

* The workmen say, *claggy.*

of these two metals are used at different manufactories; but I believe that this gun metal seldom contains less than one part of tin to twelve of copper, nor more than one part of tin to nine of copper. Here as much strength, as is consistent with the preservation of the figure of the instrument during its use, is required: and if more tin were added, the gun would be liable to be fractured by the explosion; and if less were added, it would be liable to be bent.

Copper allayed with a somewhat larger proportion of tin than in gun metal in general, affords a metal sufficiently hard and strong for chopping tools, for many useful purposes. Of such proportions, namely, about eight or nine parts of copper and one part of tin, there is very little doubt all the ancient nations, who were acquainted with the allays of copper by tin, generally made their axes, hatchets, spades, chizzels, anvils, hammers, &c. These metals, united in these proportions, would, I believe, afford the best substitute known at this day for the instruments just mentioned, now commonly made of steel or iron. Accordingly, before the art of manufacturing malleable iron from cast iron was known at all, or at least practised extensively, that is, till within these last four or five hundred years, the allays of copper by tin must have been very generally employed. The celts may be considered as specimens of the kind of metal tools in general use before the art of manufacturing iron in the manner just mentioned was discovered: for, as hath been remarked in a former part of this paper, the celts seem to have been generally neither more nor less than metal heads of hatchets, and axes, or other chopping tools. And it is no small confirmation of this opinion, that by analysis and synthesis we have found those metals to contain, in perhaps most instances, the proportion of tin which renders them most fit for the uses to which they were applied. This proportion being considered to be about one part of tin to nine parts of copper.

Copper allayed with a larger proportion of tin than is generally contained in celt metal; that is, with one-sixth or one-seventh of its weight of tin, is fitter for cutting instruments, and piercing, boring, and drilling tools than celt metal; because it is harder, takes a finer edge, and yet is sufficiently strong on most occasions; nor do we possess at this day any metal, that I know, which is so fit for knives, swords, daggers, spears, drills, &c. as this allay, except iron and steel.

The spear-head contains tin in the very proportion here mentioned; and if the metals had been pure, it would not have been possible, perhaps, to have made this instrument of any other metals, which were so proper, and at so small an expence.

The sauce-pan also was made of allay of copper by tin in the proportions last mentioned, § 7. p. 428; but as this instrument is sufficiently hard with less or without any tin, there seems to be no use from the addition of it. We may conjecture, indeed, that as the sauce-pan was made of cast metal, the tin was added for the purpose of rendering the copper more fusible, and thereby also for more easily casting forms of it. Perhaps also the tin was added to render the copper less readily oxidable, and for the colour of this composition.

Copper united with the proportions of tin last mentioned is very sonorous; but it is rendered much more so by still larger proportions of tin. I apprehend the sonorous property increases as the proportion of tin is increased, within certain limits; provided the allay possess sufficient strength not to be fractured by the necessary impulse. But as the brittleness increases with the increased proportion of tin, I believe not more than one part of tin is added to three parts of copper to compose the most sonorous metal which is manufactured, namely, bell-metal.* But this allay is too brittle to be beat out into a plate for making a trumpet; and accordingly the lituus, which has been made of hammered metal, contains only about one part of tin and seven parts and a half of copper, § 7. p. 429.

Copper is united with tin for the purpose merely of becoming more fusible, and of continuing longer fluid, or cooling more slowly while passing from the melted, or fluid state, to the solid state. Such metal is used for making statues, and casts of figures in general, and is called statuary metal,† and sometimes bronze. The proportions of the two metals are various; probably according to the colour proposed, and the size and figure of the cast; as well as on account of the price of the metals.

A small proportion of zinc is sometimes added to allays of copper by tin; on some occasions, on account of colour, on others, perhaps, to render the copper still less oxidable and more fusible; and on other occasions, as I have found on inquiry, it is added from erroneous theory, or mere caprice. No one could tell me the use of zinc, which in some manufactories is added, in making gun metal.

Tin might be used also to render copper less clingy, or

* The proportion of tin varies in bell-metal from one-third to one-fifth of the weight of the copper; according to the sound required, the size of the bell, and the impulse to be given.

† The Greeks and Romans consumed vast quantities of copper in casts of figures. They added not only tin but lead to the copper. The proportions given by PLINY are one part of a mixture of equal quantities of lead and tin to fifteen parts of copper. The use of the lead I do not understand, if it was not to save expence.

more brittle, for the purpose of writing upon it, or marking it with lines and figures, as on mathematical instruments: but the allay with zinc is now preferred for these purposes, as I suppose on account of its being less hard than allays with tin, and yet sufficiently brittle; on account also of its golden colour; and also on account of its being still more difficultly oxidable by air and water.

The scabbard metal contained a rather larger proportion of tin than the celts, No. 1. and No. 2.; namely, being one-tenth of its weight, § 7. p. 429. Copper allayed by zinc would have been sufficiently hard and strong, and on other accounts preferable to the allay of copper with tin. This is, however, one proof of the extensive use of this last composition among the ancients.

The art of allaying copper with an earth-like substance; which, within a little more than these fifty years only, we have learned was an ore of a metal, namely, zinc; was known perhaps in the time of ARISTOTLE, and certainly of PLINY; for the latter informs us, that this composition *resembles orichalcum;* and *after his time* it was called orichalcum. Thus the *native* and *factitious* orichalcum were confounded. The ancients do not appear to have used the allay of copper by zinc, except for mere ornaments, to resemble gold. It is much more extensively employed by the moderns, and the allay of copper with tin is less extensively used: 1st, because the former is cheaper than the allay of copper with tin; 2dly, because it is now generally understood that it preserves its colour longer; 3dly, because it is easier to work it into various forms, and especially for philosophical instruments; few of which were probably made by the ancients.

The composition in common use, which contains the greatest proportion of tin, is called speculum metal. The requisites of this metal are compactness, uniformity of texture, whiteness, sufficient strength to prevent its cracking in cooling, and to bear polishing without breaking. Mr. MUDGE found the whole of these properties attainable in the greatest degree, by a little less than one part of tin with two parts of copper. But for very large instruments; such as the 40-feet telescope of Dr. HERSCHEL; the proportion of tin must be less than in small instruments, on account of the property of brittleness.

The compound of equal weights of copper and tin is so brittle, that it is not easy to conceive to what useful purpose it can be applied.

The allays of tin with copper, by which I mean those compounds of copper and tin in which the tin is in greater quantity than the copper, I believe, have not been examined. It is said, indeed, that tin allayed with a very small proportion of copper has been employed for tinning, to save much of the expence of tin; for a much thinner coat of this compound can be spread than of tin.

VIII. The next conclusion is founded on the experiments of the allays of copper with steel.

It appears that copper may be united to steel without the intermede of any other metal; for a perfectly homogeneous compound was produced by melting ten parts of copper with one of steel, § 6. *Exper.* 19. As this allay was not harder than that of copper with one-twentieth of its weight of tin, and as it did not appear that a compact and uniform malleable metal could be composed of one part of steel with two partsof copper, § 6. *Exper.* 20. I thought it unnecessary to make any more experiments with different proportions of copper and steel. For, 1st, granting that the allays of copper by steel are as hard, strong, and malleable as those of copper by tin, it is utterly improbable that the ancients should have used steel to harden copper; on account of the great scarcity and high price of steel comparatively with tin; and also on account of the difficulty of uniting copper with steel, but facility of uniting copper with tin.

2dly. It appears that no allays of copper by steel can be made, which possess the hardness, strength, and malleability required; but which required properties we obtain by combinations of copper with tin, and with which most indubitably the ancients were well acquainted. Count CAYLUS has indeed told us, that the ancients had two methods of hardening copper; namely, by cementation, and by allaying it with iron. The first method he has not explained; nor is any method known of hardening copper without addition, except by hammering it; which it is well understood cannot produce the required hardness. As to the other method by allaying with iron, I think myself warranted in refusing the Count's single vague evidence; and in admitting the evidence of other plainly decisive experiments; which consist also with reasoning and analogy.

Philological, and antiquarian writers in giving an account of the copper arms and utensils of the ancients: as they found them much harder than copper, and that they were used for purposes to which copper would have been quite unfit; and as they saw that the ancients commonly used copper on most of those occasions in which we now use iron, or steel; were led to imagine, that in ancient times there was an art understood of tempering copper, which had been subsequently lost.* If, instead of feigning such an hypothesis, these writers had examined by analysis the ancient implements which fell under their observation, I cannot doubt that they would have unravelled the mystery. Count CAYLUS himself had a glorious opportunity of ascertaining the composition of ancient copper instruments, when the seven swords, and hollow wheel were found at Genzac in 1751. If he had made but two adequate experiments, one to detect iron, and the other to detect tin, he would have had a much better foundation for reasoning than that of a mere hypothesis, however ingenious and learned.†

* "It appears, says Dr. LORT," in his paper upon celts, "that the ancients had "an art of tempering and hardening brass to a greater degree than is done at present, or perhaps than is necessary to be done." Archæol. Vol. V. p. 187.

With reluctance I must observe, that such an experienced inquirer as Dr. PRIESTLEY falls into the error of antiquaries, in asserting, that the ancients had a method, with which we are not well acquainted, of giving copper a considerable degree of hardness, so that a sword might be made of it with a pretty good edge. But PAUW tells us, that the Americans were in possession of the secret of giving a temper to copper equal to steel.

† At the desire of Count CAYLUS, the old metal instruments found at Genzac were examined by GEOFFROY, the younger. To prevent all suspicion of this celebrated chemist being defrauded of the honour due to him by mistaking his meaning, I shall cite his own words.

"Je cherchai à m'assurer s'il y avoit dans ces armes antiques une portion d'étain "sensible et aussi considérable que dans le métal que j'alliois. Pour cet effet je mis "dans un bain de plomb sur une coupelle un petit morceau de mon alliage, qui "aussi-tôt qu'il commença à se fondre, végéta, à cause de l'étain qu'il contenoit. J'ai "repété cette expérience, sur le métal des armes antiques, et ce métal n'ayant point végété, mais étant plus difficile à fondre que le mien, je fus convaincu que ce n'étoit "point l'étain qui durcissoit le cuivre, qui est le métal principal des armes."

This was the experiment for detecting tin; and the following is the account of the methods employed to determine the presence of iron.

There is not the least reason to suppose that the ancients added iron or steel to increase the hardness, or strength of the allay of copper by tin; nor does it appear from the experi-

" La difficulté que j'avois trouvée à fondre ce métal, me fit soupçonner qu'il conte- " noit du fer, et mon soupçon se changea presqu'en certitude lorsque je comparai le " grain de ce métal avec celui de quelques essais de cuivre alliés de fer, que mon père " avoit fait dans le temps qu'il donna à l'Académie des Sciences un mémoire sur le " tombac. Pour m'assurer s'il y avoit du fer dans ce métal j'en reduisis un petit mor- " ceau en limaille, et la plus grande partie de cette limaille étoit attirable à l'aimant: " mais il me restoit encore un doute sur cette preuve de l'existence du fer dans les " armes anciennes. *Le métal dont elles sont faites étant plus dur que l'acier*, eût usé " quelques petites parties de la lime par le frottement; ce que n'auroit point fait le " cuivre rouge qui est beaucoup plus tendre. Ainsi pour avoir une preuve qui ne " laissât aucun scruple, j'ai fait user à cette même meule avivée un morceau de métal " des armes anciennes, et en lavant la boue qu'il m'a fourni pour séparer les parties " terreuses de la meule des parties métalliques, j'ai eu une espèce de limaille extrème- " ment fine, qui étoit attirable à l'aimant; et je ne pouvois plus craindre alors de m'être " trompé moi-même par trop peu de défiance. Etant bien convaincu que le cuivre " des armes anciennes étoit allié avec du fer, j'ai fait préparer plusieurs essais d'un " métal que j'ai cru à peu près pareil, en fondant du cuivre rouge, dans lequel je faisois " entrer du fer dans différentes proportions, et tous ces essais m'ont fourni un métal " durci; mais si aigre qu'il étoit impossible de le forger. Cet obstacle qui m'arrêtoit " a été bientot levé lorsque en examinant ces armes avec plus de soin, et en consultant " à ce sujet des ouvriers connoisseurs, j'ai été assuré qu'elles étoient jettées en moule, et " ensuite réparées à la main. J'ai cherché à imiter pour la dureté et pour le tranchant " une épée Romaine, et je crois n'y avoir pas mal réussi dans celle que j'ai remise à " M. le Comte de CAYLUS. Elle est faite avec un mêlange de cinque parties de cuivre " rouge et d'une partie de fer fondues ensemble, puis jettées en moule."

I cannot persuade myself that it is necessary to comment upon the above passages, which Count CAYLUS considers as showing *decisively* that the ancient metals were hardened by iron, and not by tin. As to this learned antiquary's other method of hardening copper, which he says was employed by the ancients, it is falsified by daily experience: for it is well known that this metal is not susceptible of temper like steel, either by plunging it in any cold medium whatever, or by cementing it with salts, and carbonaceous matter. See the *Recueil d'Antiquités Egyptiennes, Etrusques, Greques, et Romaines. Tome premier*, 4to, 1761.

ments with this mixture, *Exper.* 17, and 18, that any advantage is to be expected from this addition; at least not for cutting instruments.

I cannot confirm the opinion above delivered, that the common metal of the ancients for cutting instruments was the allay of copper with tin, by the experiments of other persons, excepting those of Mr. DIZÉ, in the *Journal de Physique* for 1790, p. 272. He had only twenty-five grains of an ancient dagger to operate upon. This small quantity, however, afforded tin and copper, as appeared on dissolution in nitric acid. But Mr. DIZÉ made several analytical experiments on eight different sorts of coins, Greek, Roman, and Gallic. It appears from these experiments that these coins contained from $\frac{5}{12}$ of a grain to $24\frac{1}{3}$ grains of tin in 100 grains of each of the old metals. And it appears that these coins contained no other metals but copper and tin.

From the preceding experiments and observations we learn that tin was infinitely more valuable to the ancients than it is to the moderns: without this metal, it is not easy to conceive how they could have carried on the practice, and invented the greater part of the useful arts. Tin was even of more importance to the ancients, than steel and iron are to the moderns; because allays of copper by tin would afford better substitutes for steel and iron, than any substitutes which the ancients, in all probability, could procure for allays of copper by tin.

We see also the importance of Britain in times more remote, probably, than those of which we have any record, or tradition; being, in all probability, the only country which furnished the metal so necessary to the progress of civilization. If Mr.

LOCKE had been acquainted with the properties of the allays of copper by tin, and of their extensive use in highly advanced states of civilization among the ancients; he would have known that iron was not the only metal by the use of which we are in possession of the useful arts, nor consequently is it "past "doubt, that were the use of iron lost among us, we should in a "few ages be unavoidably reduced to the wants and ignorance "of the ancient savage Americans." In the barbarous state of its inhabitants, this island was known to the civilized nations of Europe, Asia, and Africa; and denominated in two of the most ancient languages, namely, the Phœnician and Greek, by terms which denote, *the land of tin;* for such, according to BOCHART, is the import of Britain, a corruption of *Barat-Anac*, or *Bratanac;* and there is no doubt of the meaning of the Greek word *Cassiterides.*

I do not mean by these observations to represent, as authors in general have done, that the ancients were not acquainted with the art of manufacturing iron, or steel, till long after the common use of copper, or that they did not know the superior properties of iron and steel; on the contrary, if this were the proper place, I could show that iron, or at least steel, was manufactured, and its useful properties understood, as early as copper was known. But steel was got anciently from those ores only which yield it in a malleable state; as it is, probably, obtained at this day in India, and called *wootz;* and as it is also obtained in the northern Circars, and likewise by the Hottentots. As steel was the only state of iron anciently manufactured, it was too scarce, and much too dear for general use; and hence the extensive use of allays of copper by tin, the best substitutes for the malleable state of iron and steel.

SECTION II. OF THE STEEL ARMS.

§ 1. *A few miscellaneous Observations.*

Of the ancient steel or iron arms and utensils in Sir JOSEPH BANKS'S collection, four articles only were selected for examination.

One of these was the Steel Sword within the copper scabbard, described in Sect. I. § 1. IV. and represented by fig. 3. Tab. XI.

I. *A Sword,* fig. 1. Tab. XV. Of a number of these weapons in the collection this was the smallest. The great difference in their size and weight, it is observed, was probably intended to give every man, according to his strength and mode of fighting, an opportunity of suiting himself. The figure of the blade is particular, and seems very well contrived.

The hollow in the middle of each side does not extend more than two-thirds from the guard to the point; and terminates in a ridge, which must give great support and strength to the cutting part.

The pommel and guard had been tinned, and part of the tin coating still remains upon them. This weapon, therefore, affords a specimen of the mode of tinning iron practised by the ancients. The blade seems to have been varnished by black matter, which remains very brilliant and smooth. On one side is the inscription + BENVENUTUS +, and on the other + ME FECIT +, perfectly legible.

From the crosses, we may conclude that the maker was a Christian; and from the name, that he was an Italian. The writing is in mixed characters, but it is probable that the artist exercised his trade of a sword cutler in the northern parts of Europe. We cannot however determine whether it be Danish, or Saxon. It was found in the river Witham, with a large quantity of other arms, in the neighbourhood of the site of Bardney abbey; and was brought up by an eel-spear, by a man who was fishing in that river, near Kirksted Wath, in 1788.

II. *An Axe.* Its form is evident from the fig. 2. Tab. XV. It was snipt a good deal, and several holes were worn in the middle, otherwise it was in a state of good preservation. It was found, with other axes, chopping instruments, and carpenters' tools, in the river Witham, in 1787, and 1788.

This axe perfectly resembles that carried by the lictors in their fasces, in basso-relievos. Its form induces one to suppose, or indeed to believe, that it was made for parade rather than use; its edge being very thin, and immediately above it the blade being thicker; but behind the thick part, exactly where the strength of an axe ought to be placed, it is thinner than in any other part. It was therefore not well calculated for chopping. The weight of this axe was one pound, and somewhat more than a quarter. Its length from eye to edge was seven inches, and the breadth was about six inches.

III. *A Dagger:* its form is represented by fig. 4. Tab. XV. It was made with great ingenuity and skill for answering the main purpose of it, that of piercing armour. It was found, together with another dagger, in Barling's Eau, near Short Ferry, in 1788.

IV. *A Sword in its Scabbard,* fig. 3. Tab. XI. I could not by any force draw it out of the scabbard. On breaking the scabbard, I found the sword destroyed by rust; but the guard, and hilt were still in a metallic state, and the pommel had been broken off. I have already described this instrument in the account of the brass arms.

§ 2. *Chemical Properties.*

I. *The Sword*, fig. 1. Tab. XV.

(*a*) Being filed and polished, it was of the colour of steel.

The blade was bent considerably before it was broken; and could not be broken without considerable force.—Comparatively with soft steel, or malleable iron, it possessed little malleability.—Under the hammer, file, and drill, it felt as hard as hardened steel. The snipt edges were hard, and strong enough to saw asunder the celts, described in this paper. Its fractured surfaces showed a silvery kind of open grain, like steel which has been hardened by plunging it, when white hot, in cold water.

The pommel and guard were much more malleable, and much less hard than the blade.

(*b*) The blade, when red hot, was malleable, but much less so than our common steel. On cooling gradually it became less hard than before; but it was not so soft as our common annealed, or distempered steel. By plunging the distempered piece of the blade, when white hot, in cold water, it was restored to its original hardness. By plunging the pommel and guard when white hot in cold water, they were rendered much harder; and by again igniting them, and letting them part with their fire gradually, they became as soft as they were originally.

(*c*) The specific gravity of the middle part of the blade, after filing off the coating, was 7,476.

(*d*) The dissolution of 300 grains of the blade in sulphuric acid and water, yielded nearly the same quantity of hydrogen gaz as an equal quantity of our steel affords. During the dissolution the mixture became black, and a black froth appeared on its surface; and, after repose, there was a deposit of black matter. The solution, made boiling hot, was poured upon a paper filter; and being filtrated, the filter was edulcorated, by repeatedly pouring upon it pure water. The paper filter was stained black by the solution, and there was a small deposit of black matter in the apex of the cone of the filter. This black matter was carbon, in about the same proportion as our steel affords by the same treatment. The filtrated solution, on evaporation, was found to contain nothing but sulphate of iron.

(*e*) A little nitric acid being dropped upon the polished surface of the blade; and also on the pommel and guard; a black spot was produced on the parts wetted.

(*f*) The tinned part of the pommel being just wetted with nitric acid, it became white.

11. *The Axe*, fig. 2. Tab. XV. (*a*) Being polished, it appeared of almost a silvery whiteness.—It was harder than malleable iron, but was not so hard as hard steel, for it was easily filed, and bored through with the drill. It was also cut through, and the cut surface was smooth and uniform, and close, as if made of the purest metal. It bent a little, notwithstanding its form and thickness; and required a very smart stroke with a heavy hammer to break it. The grain of the fractured part was like that of close-grained steel.—It was malleable both in its cold and ignited state.—It was almost as sonorous as bell-metal.

(*b*) By quenching in cold water when ignited to whiteness, it became harder, more brittle, and open-grained; but it could not be made so hard as the sword, fig. 1. By igniting the piece so hardened, and letting it part with its fire gradually, it was rendered much less hard than it was originally.

The artist who assisted me in examining this tool, observed that it was only made of steel for about an inch from the edge; but that the rest was iron; for he conceived it to be impossible to be all steel, on account of the eye for the wooden shaft. However, on filing different parts, and cutting the instrument, no seam could be discovered, where iron had been welded to steel; and every part appeared susceptible of induration and emollition, by the usual treatment of steel to produce these changes.

(*c*) The specific gravity, before hammering, was 7,802, and after hammering the same piece, it was 7,880. After ignition to whiteness and sudden quenching, the specific gravity was 7,384.

(*d*) 300 grains of this metal dissolved in sulphuric acid and water, and afforded black matter and sulphate of iron; with the same phænomena as the dissolution of the sword, fig. 1. afforded. The black matter was carbon, in apparently the same proportion as was obtained from the dissolution of the sword, fig. 1.

(*e*) Several parts of this axe being just wetted with nitric acid, they became black spots, as is the case on so applying this acid to steel.

III. *The Dagger*, fig. 4. Tab. XV. (*a*) Being polished, it had the appearance of steel.—It was not so hard as the sword, fig. 1. but it was so very strong and tough, that it was with difficulty broken, and could be bent very considerably.—Its fractured, or rather torn surface was open-grained, and crystallized.—It was more malleable when cold, than hardened steel usually is.

(*b*) In its ignited state it was very malleable. It was susceptible of induration and emollition, by the ordinary treatment to produce these changes in steel.

(*c*) The specific gravity of this dagger was 7,413.

(*d*) The dissolution in sulphuric acid and water afforded nothing but carbon and sulphate of iron, in about the same proportions as the dissolution of the sword, fig. 1.

(*e*) A black spot was produced by wetting this instrument with nitric acid.

IV. *The Sword*, fig. 3. Tab. XI. (*a*) The hilt being polished, it appeared like steel. It was almost as hard as common hardened steel, and as malleable.

(*b*) The hilt was very malleable in its ignited state. It was hardened, but not considerably, by quenching in cold water when white hot. It was rendered softer, after being hardened, by ignition and gradually cooling.

(*c*) The specific gravity of the hilt was 7,647: and after ignition and quenching, it was 7,427.

(*d*) The nitric acid produced black spots when applied to the polished surfaces of this metal.

(*e*) The dissolution in sulphuric acid and water afforded nothing but carbon, and sulphate of iron. The carbon was in smaller quantity from this hilt, than from the sword, fig. 1. and not more than from common steel.

§ 3. *Conclusions and Remarks.*

1. It appears that all these instruments are of steel; because they consist of carbon and iron, § 2. I. (*d*) (*e*); II. (*d*) (*e*); III. (*d*) (*e*); IV. (*d*) (*e*); because they are capable of induration by plunging them when ignited in a cold medium, § 2. I. (*b*); II. (*b*); III. (*b*); IV. (*b*); and they are softened by ignition and gradual cooling *(ibid.)*—they have the colour, texture, hardness, brittleness, § 2. I. (*a*); II. (*a*); III. (*a*); IV. (*a*); malleability when ignited, § 2. I. (*b*); II. (*a*) (*b*); III. (*b*); IV. (*b*); and specific gravity of many sorts of steel, § 2. I. (*c*); II. (*c*); III. (*c*); IV. (*c*).

2. The sword, fig. 1. appears to be the hardest, § 2. I. (*a*), and the dagger, fig. 4. the softest steel of the above instruments, § 2. III. (*a*).

3. These steel instruments appear to have been tempered, at least in the parts destined for cutting, and piercing.

4. The axe, fig. 2. being all steel, affords a proof that the ancients were not acquainted with the art of manufacturing soft malleable iron; nor consequently of welding it with steel; and that the only state of iron which they used, and could manufacture, was steel.

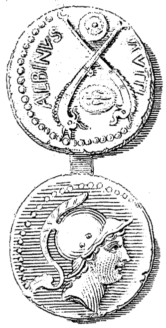
5. Although, it is most probable, that these steel instruments were made of steel got directly from the ore, they show that the ancients could render such steel very malleable in its ignited state, § 2. I. (*b*); II. (*a*) (*b*); III. (*b*); IV. (*b*); and free from extraneous matters, and particularly from oxygen.

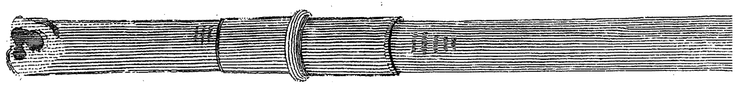
6. The different degrees of hardness and brittleness of these instruments may reasonably be imputed to the different proportions of carbon which they contain; and to the different degrees of cold applied in tempering them; although the experiments, § 2. I. (*d*); II. (*d*); III. (*d*); IV. (*e*), were not made with such precision as to demonstrate the reality of these assigned causes.

7. It seems probable that the axe was tempered at a low temperature, and had been much hammered: hence its great specific gravity before hammering, § 2. II. (*c*), and the little increase of its specific gravity by further hammering; and hence the great diminution of its specific gravity by quenching in its state of ignition to whiteness, § 2. II. (*c*).

8. Iron and steel instruments are destroyed, commonly, by the oxygen of water, or oxygen of atmospherical air. The destruction of iron instruments is prevented by whatever prevents

Fig. 2.





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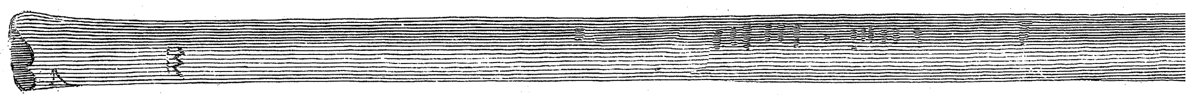

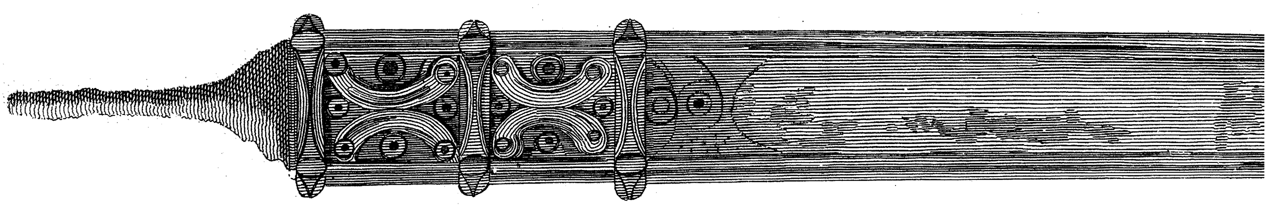

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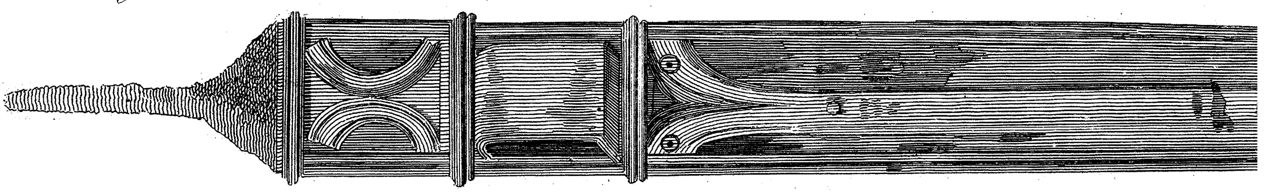

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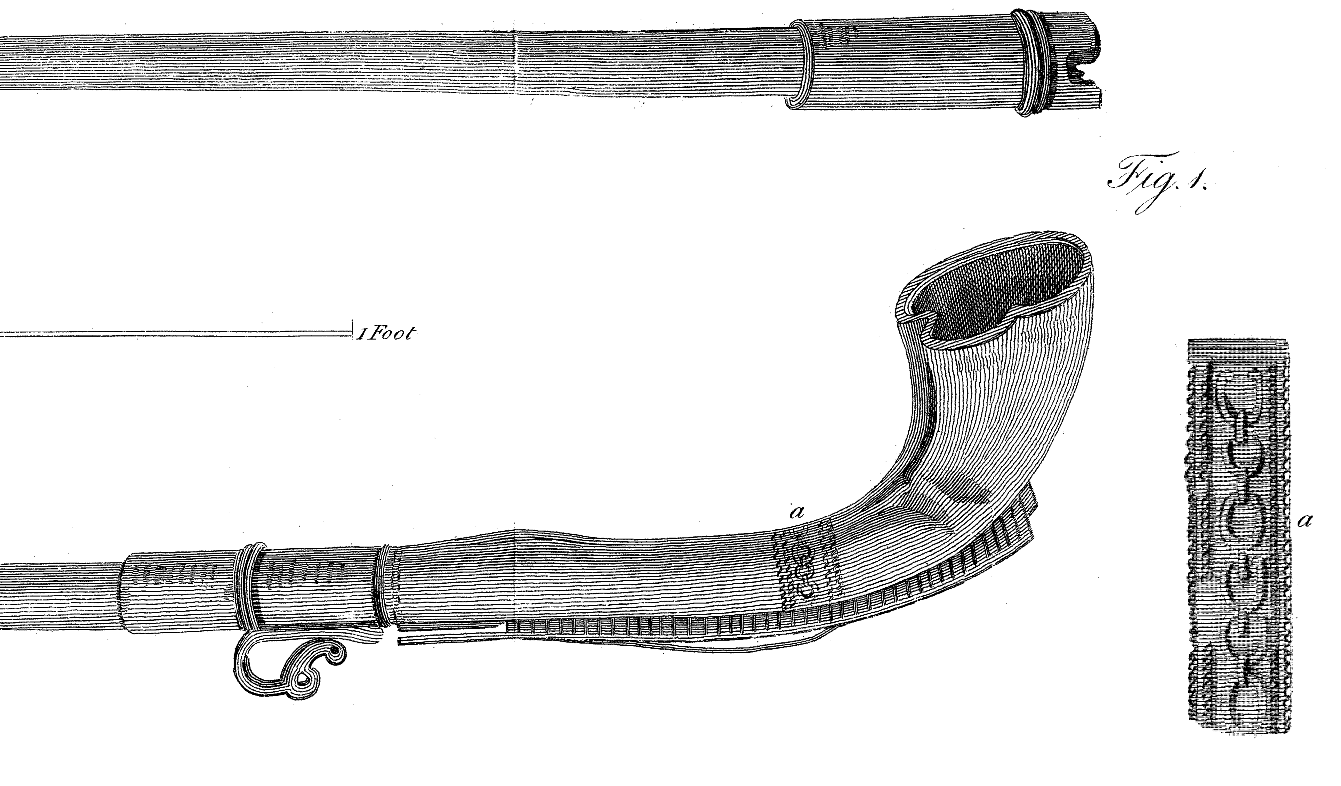
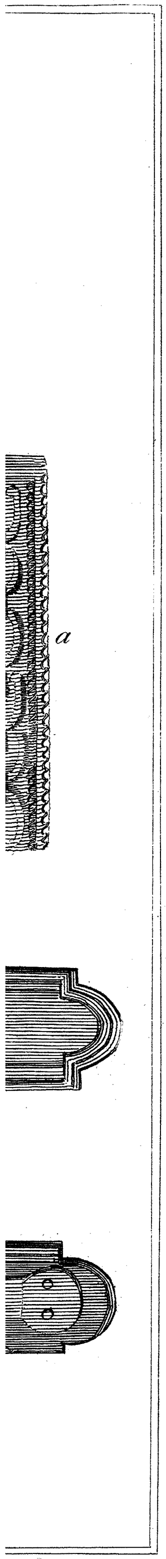


Fig. 1.



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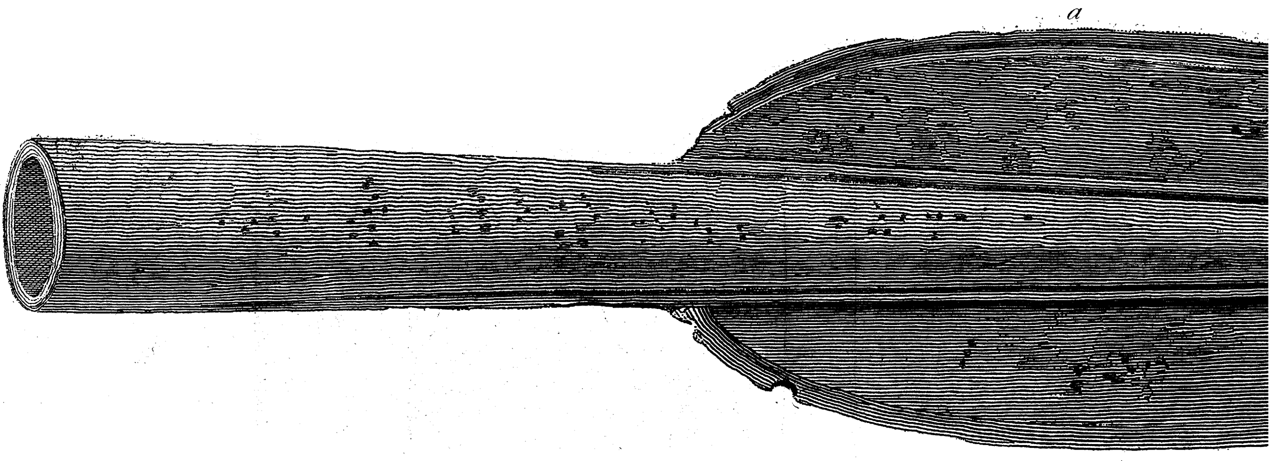
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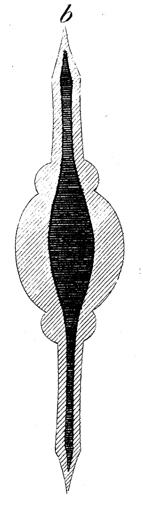
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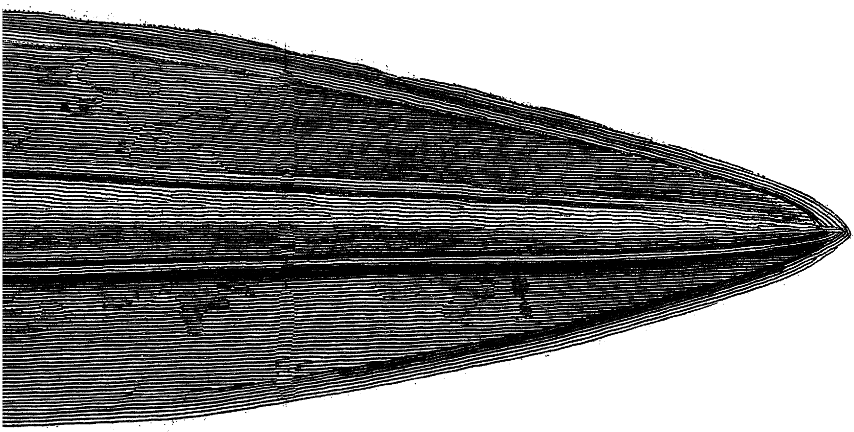


Basire sc.

a

b

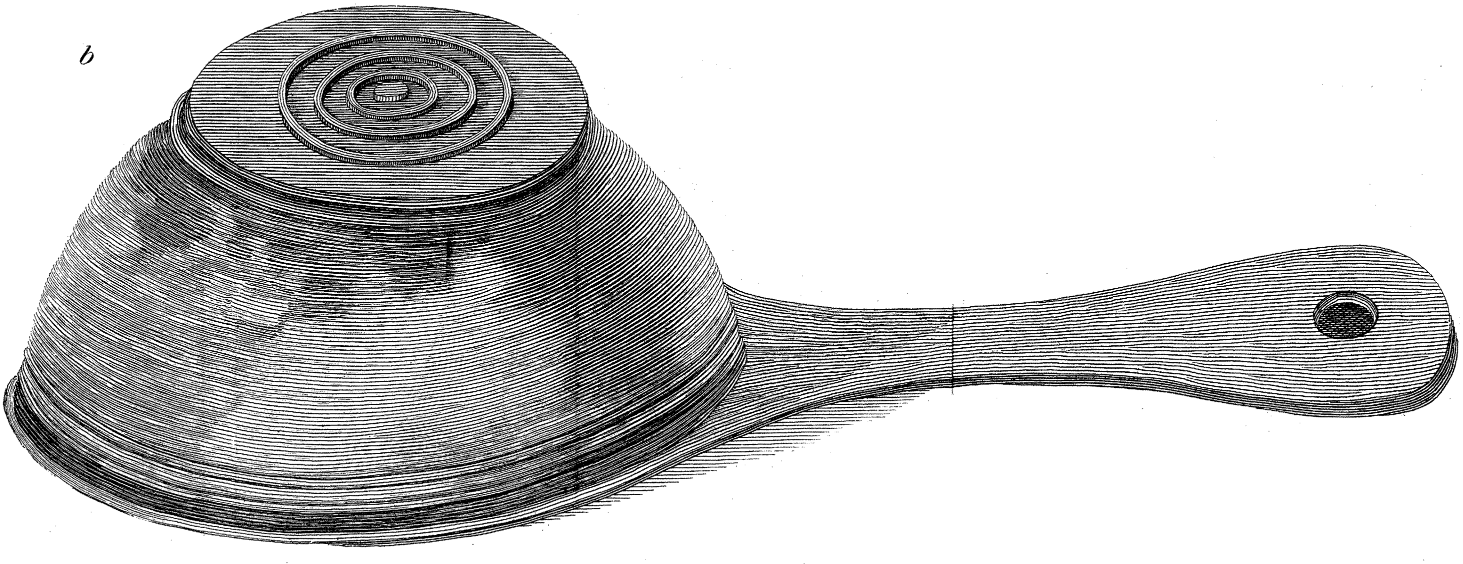
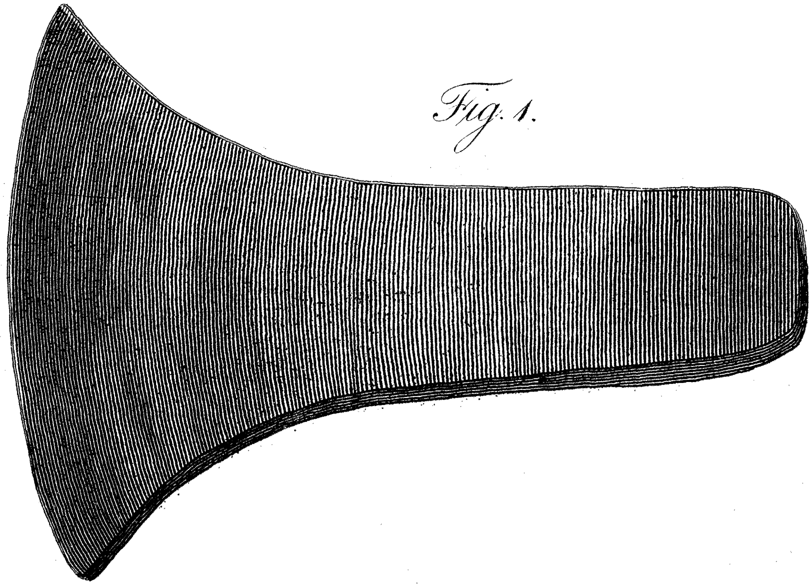


Fig. 1.



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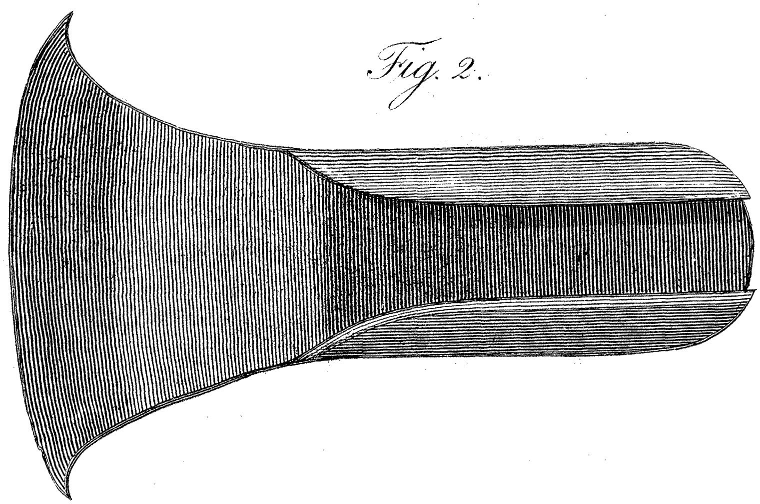

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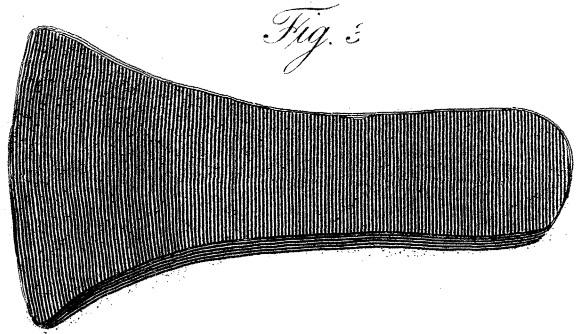
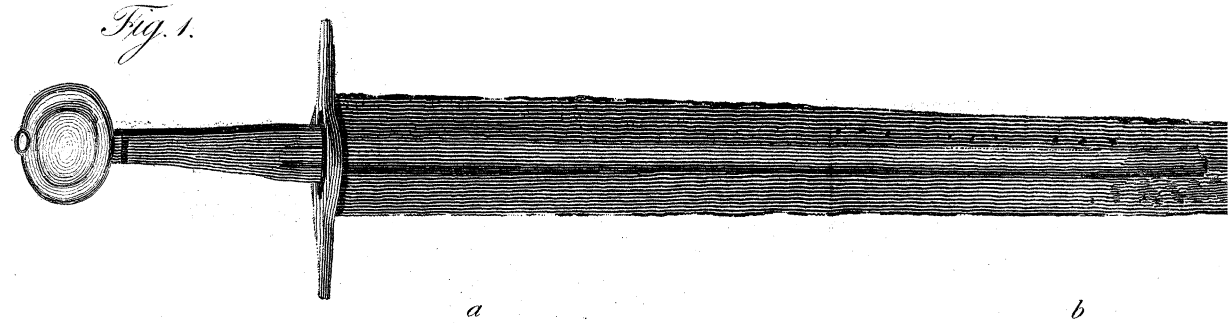


Fig. 1.



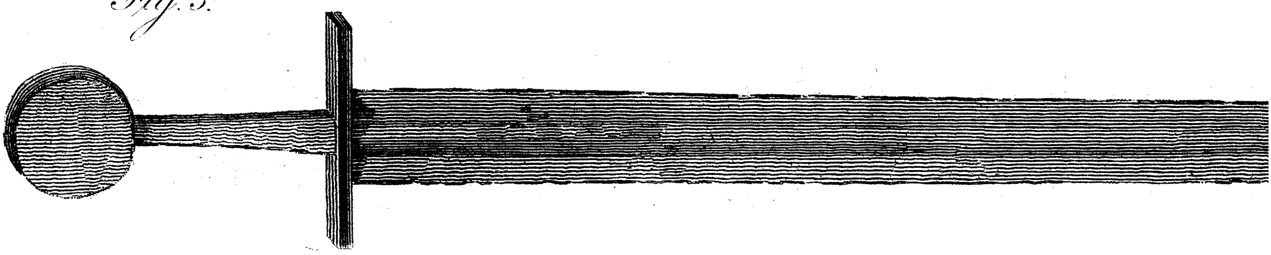
a

+BENVEHVTVS+

b

+ME FECIT

Fig. 3.



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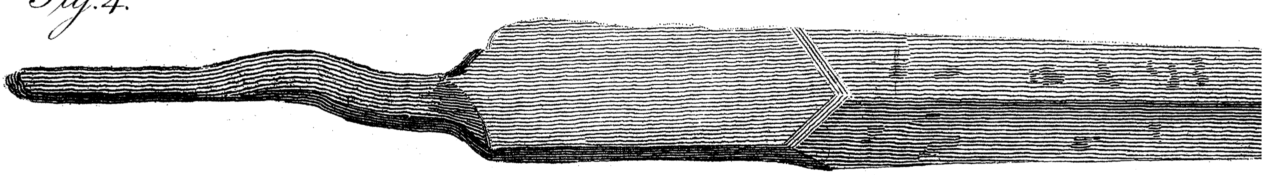
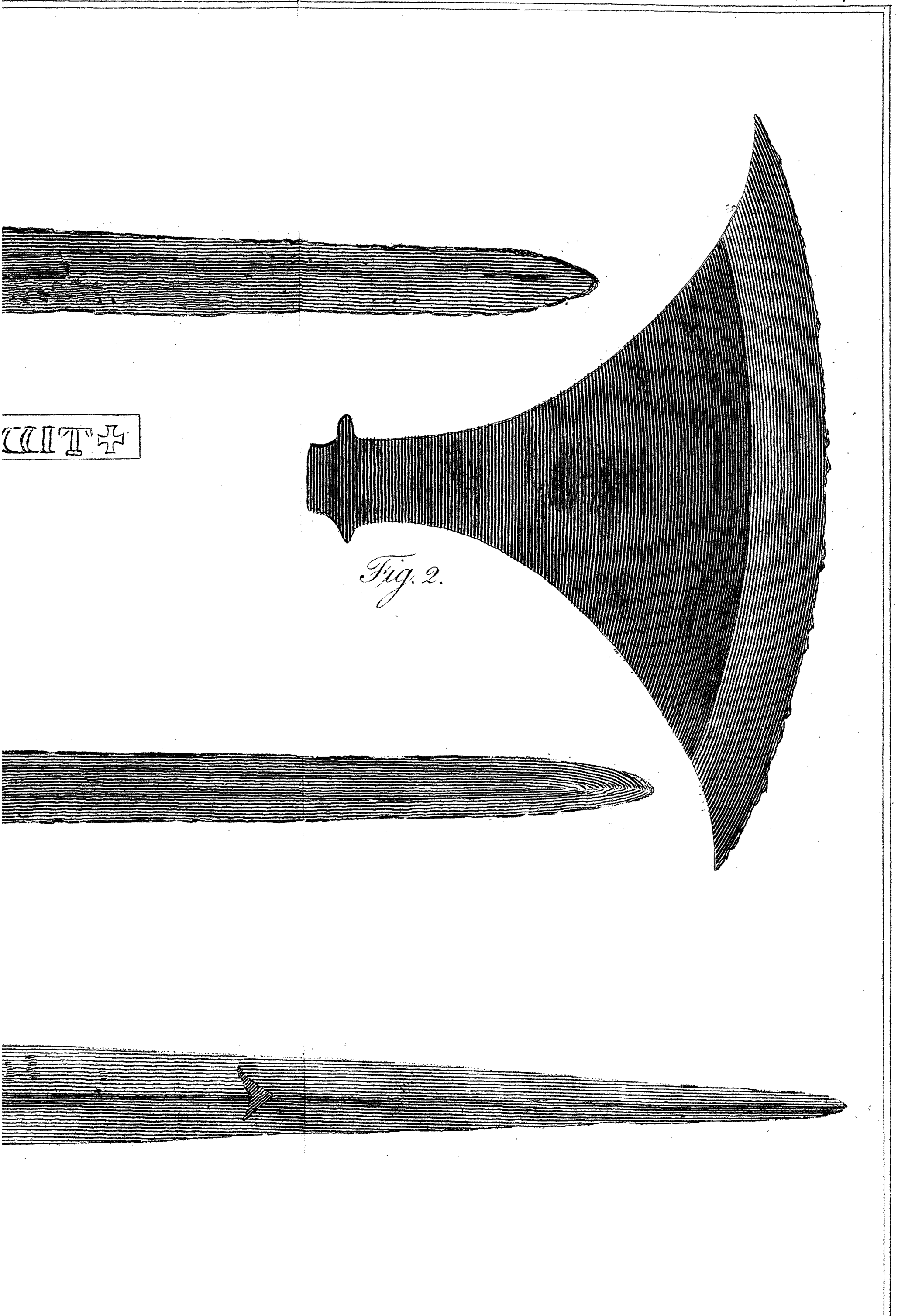




Basire sc.

the union of the oxygen of these substances. Upon this principle the sword, fig. 1. was preserved by its varnish; but the other tools must have owed their preservation to their having been accidentally coated with earthy matter; which perhaps contained principally clay.

9. The destruction of the iron sword by oxygen within the copper scabbard; and the preservation of the part of it not in contact with the copper, is a good example of the action of copper and water united in destroying iron, the copper remaining entire, Sect. I. § 1. IV. This effect of copper upon the iron bolts and nails, in copper-bottomed ships, is a loss of the greatest magnitude.

EXPLANATION OF THE PLATES.

Tab. XI. fig. 1. Two pieces of the Lituus which had been broken.

a. The ornament of chain-work round one end of the Lituus.

Fig. 2. An ancient medal, on which the Lituus is represented.

Fig. 3. Two views of a Danish or Saxon steel Sword in its copper scabbard.

Tab. XII. *a.* The Spear-head, of the same size as the original.

b. A section of its blade, to show what proportion of it is hollow.

Tab. XIII. *a* and *b*. Two views of the Sauce-pan. The diameter of the bowl five inches, and length of the handle five inches.

Tab. XIV. fig. 1, 2, 3, the three Celts, No. 1, 2, 3.

Tab. XV. fig. 1. A steel Sword, the pommel and guard of which were tinned.

a and *b*. The writing in mixed characters on the two sides of the Sword.

Fig. 2. A steel axe.

Fig. 3. Another sword of the same kind, as fig. 1. in Sir JOSEPH BANKS's collection.

Fig. 4. A steel dagger.

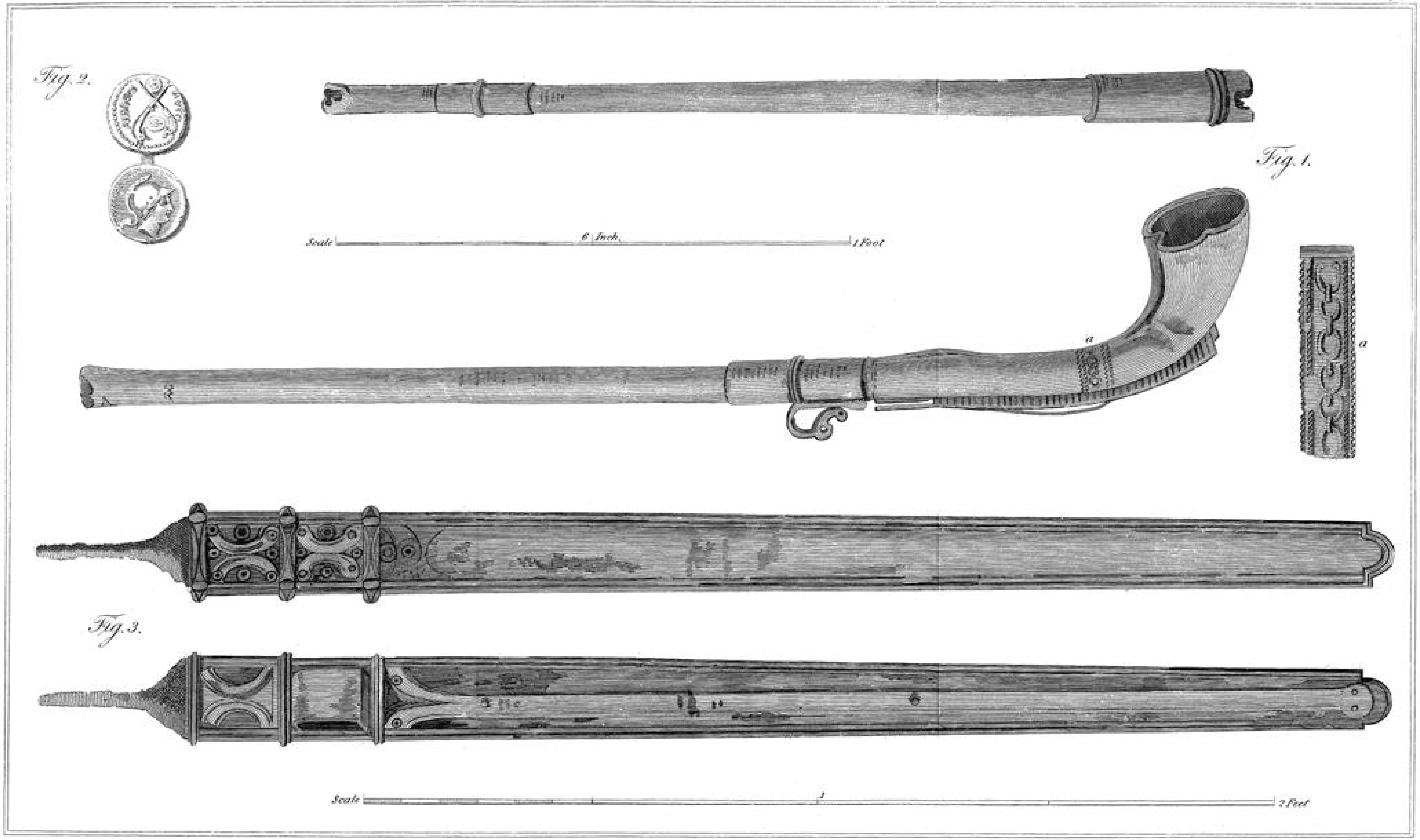
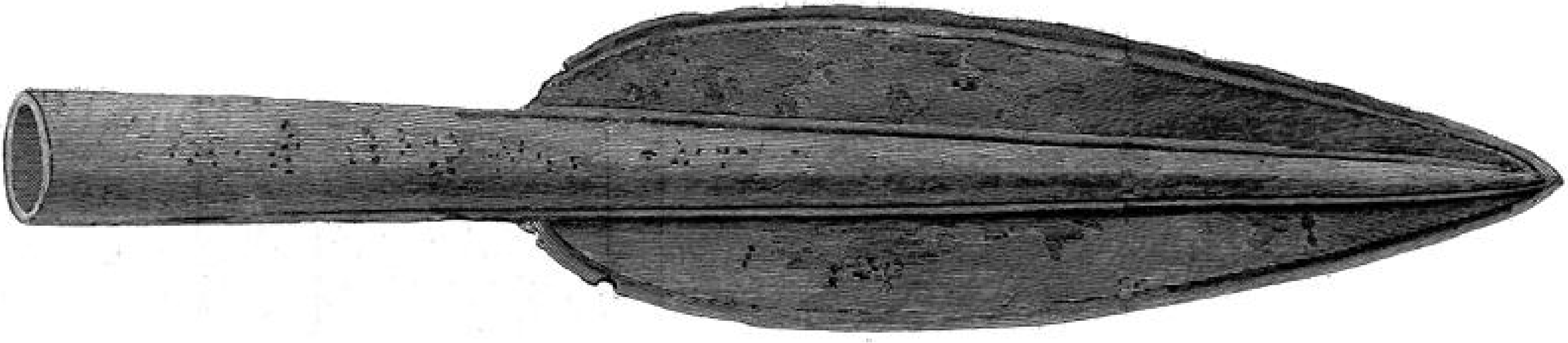


Fig. 2.
Fig. 1.
Scale
6 Inch.
1 Foot
a
a
Fig. 3.
Scale
1
2 Feet

a



b

Fig. 1.

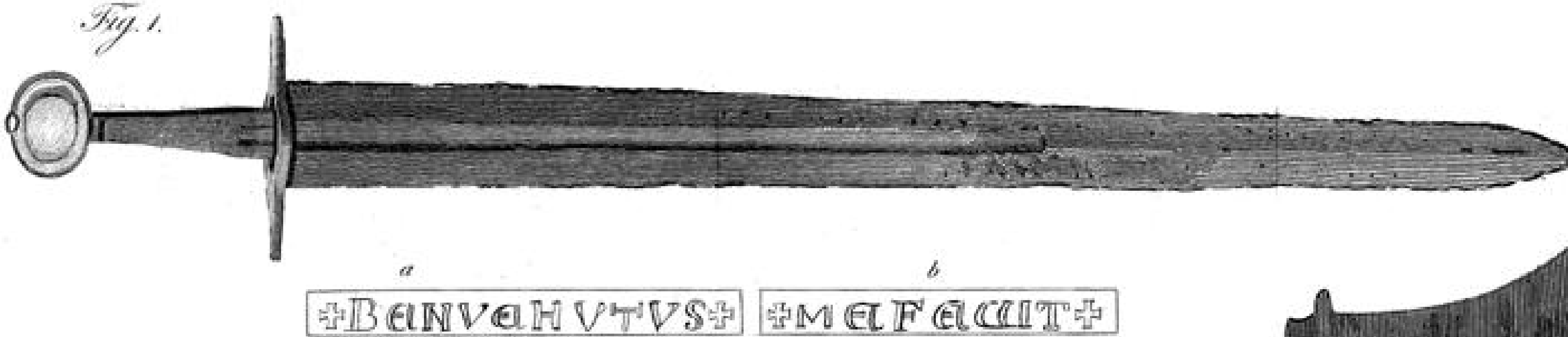
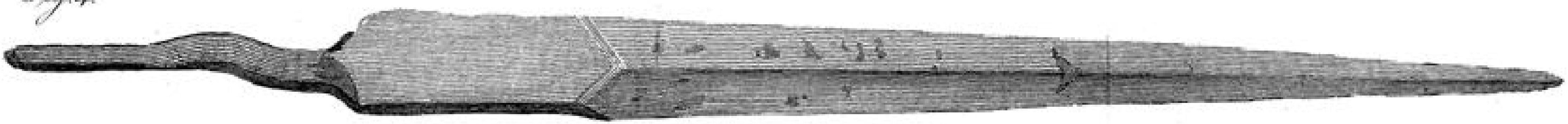


Fig. 2.

Fig. 3.

Fig. 4.



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