COPPER AND ITS ALLOYS IN EARLY TIMES.[1]

WITH the discovery of metals, and notably the application of copper and its alloys in Neolithic times, we have one of the great turning points, if not the greatest, in the history of human development, the first-birth of the germs of that civilisation and culture to which we have attained at the present day. The discoveries of the properties of steam and electricity and their applications to our industries and other practical purposes of life we are apt to regard as wonderful and epoch-making, yet when we compare them with the results which have followed the discovery of metals, they are but trifling and insignificant.

The order in which the metals were discovered was not the same for every region, as their ores are very capriciously distributed in the world, and it is extremely probable, if not absolutely certain, that the metals which occur native, *i.e.* those which occur as metals in nature, must have been first known to the men inhabiting the localities in which they occurred. The metals so occurring most frequently are gold and copper. The former is much more widely distributed than the latter, and must have been the first metal to be known in many regions.

It is, however, one of the most worthless metals for practical purposes, so that until the rise of Greek and Roman civilisation but little use was made of it. Copper, too, we only find in use to a very limited extent, as it was not well suited for the construction of weapons or useful implements. On the other hand, its alloy with tin afforded a metal which in many physical properties could only be surpassed by iron or steel. According to the views of several ancient writers, Lucretius and Poseidonius, so momentous a discovery as that of metals contained in ores must needs have been brought about by no uncommon cause.

According to them a conflagration consumed forests which covered the outcrop of metalliferous veins, reducing the metals and bringing them to the notice of man, but there are no grounds for such inference. The discovery of metals other than "native" had no such poetic origin, but was brought about in a more commonplace and more humble way. It had its origin in the domestic fires of the Neolithic age.

The extraction of the common metals from their ores does not require the elaborate furnaces and complicated processes of our own days, as pieces of ore, either copper carbonate or oxide, cassiterite, cerusite, or mixtures of these, and even iron oxides which by chance formed part of the ring of stones enclosing the domestic fire, and became accidentally embedded in its embers, would become reduced to metal. The camp fire was, in fact, the first metallurgical furnace, and from it, by successive modifications, the huge furnaces of the present day have been gradually evolved.

First, a shallow cavity would be formed in the hearth of the fire for the reception of the molten metal, and this would be made larger as time went on and larger quantities of metal were required by deepening it or by surrounding it with a higher wall of stones. Furnaces of precisely this primitive form survived in Derbyshire up to the seventeenth century. In Japan the furnace for smelting copper, tin, and lead ores, a mere hole in the ground, which was in universal use there up to 1858, and is still extensively employed, is as simple and rude as that of the men of the Bronze age.

The alloys of copper and tin during the early Metal age, and even somewhat later, were obtained not by melting together copper and metallic tin, but by the reduction of oxidised copper ores containing tin-stone, or of copper ores to which tin-stone was added. As it has been stated by several Continental archæologists that when a copper ore containing tin ore is smelted the tin does not enter into combination with the copper, but passes into the slag, I have made several experiments under the conditions which were available to prehistoric man, which completely disprove their statements.

A furnace of the simplest form, merely a hole in the ground, was constructed in my laboratory at the Royal School of Mines. The fuel used was charcoal. A mixture of copper ore (green carbonate) and tin-stone was smelted in it, and a copper-tin alloy, a bronze containing 22·0 per cent. of tin, was obtained. The experiment was repeated several times, and in every case copper-tin alloys were obtained. This experiment proves indisputably that when a copper ore containing tin ore was smelted by primitive man, a bronze consisting of copper and tin was the result.

The shape and structure of the lumps of copper which have been found in the founders' hoards[2] of the Bronze age afford valuable evidence as to the size of the rude smelting furnaces, the method of smelting, and the manner in which the metal was removed from the hearth. These lumps are always fragments of rudely disc-shaped cakes of about 8 in. to 10 in. in diameter, and 1½ in. in thickness, having the largely columnar fracture of copper when broken near its solidifying point. They show that the furnace was simply a small shallow hole or hearth scooped in the ground, about 10 or 12 in. in diameter, and that the operation of smelting must have been conducted as follows:—A small charcoal fire was first made in the hearth, and when this was burning freely a layer of ore was spread over it, and upon this a layer of charcoal, then alternate layers of ore and charcoal were added in sufficient quantity to yield a cake of copper. The fire was doubtless urged by the wind alone in the earliest times, but later by some kind of bellows.

When all the charge had melted, the unburnt charcoal and the slag were raked off. The metal was not laded out, but was allowed to solidify first, and at the moment of solidification was rapidly pulled out and the cake broken up at once on a large stone. In Korea, at the copper mine of Kapsan, this primitive method of removing the copper from the furnace still survived when I travelled through the country in 1884.

The method of smelting copper ores in the primitive furnace which has survived in Japan from prehistoric times closely resembles that of the Bronze age. The copper of the Bronze age resembles modern blister copper in composition, but, unlike it, it often contains only traces of sulphur. When sulphur is present in the crude metal only in traces it undoubtedly indicates that the metal had been obtained by smelting oxidised ores. The percentage of copper in several characteristic specimens ranges from about 97·0 to 99·0.

I will now ask for your attention to the earliest alloys of copper and tin, those of the Bronze age. In the production of these alloys in the earliest part of the age, copper ores containing cassiterite can alone have been used; it is obvious, therefore, that

[1] Abridged from the Presidential Address to the Institute of Metals by Prof. William Gowland, F.R.S.

[2] Founders' hoards, many of which have been unearthed in this country and in Europe, contain generally worn out or broken implements, waste castings, and rough lumps of copper apparently brought together for recasting. In some the objects are new and ready for use or are in an unfinished state. They appear to have been the stock-in-trade of itinerant founders. A flat axe made of the alloy is in the British Museum.

the percentage of tin they contain must have varied with the percentage of cassiterite in the ore and the regularity with which the smelting operations were performed. Even in the later period of the Bronze age, when the alloys were made by smelting the copper ore with cassiterite, alloys of definite composition can only have been accidentally obtained. Further, it is very questionable whether the metal tin was ever employed in making the alloys until the Iron age was well advanced, as this metal has never been found in the founders' hoards. Consequently the implements and weapons are of very varied composition, at first generally containing but little tin, less than 3 per cent., but later having that metal frequently in satisfactory proportions for the uses they were intended for.

A curious feature of the alloys of which the early weapons were made in Hungary is the presence of antimony as an important constituent instead of tin. This doubtless arose from the alloys having been prepared by smelting the antimonial copper ores which occur in that country. Axes made of these alloys would be fairly serviceable on account of the hardness produced by antimony in copper. We hence find them in use, with antimony largely replacing tin, until late in the Bronze age.

The difficulties the earliest men had to contend with were extremely great, for it is self-evident that alloys of definite composition could not be ensured by the early practice of smelting mixtures of ores. It would seem, therefore, that when we find weapons or implements of suitable composition for their intended use, some physical tests must have been applied to the furnace product before it had been used for their manufacture.

We will now pass to a brief consideration of the methods followed by prehistoric man for the manufacture of his weapons and implements. Practically all copper celts were cast in open moulds, as if cast in closed moulds they would be more or less vesicular and worthless, except when the copper contained arsenic, tin, antimony, zinc, or nickel in not less proportions than 1 per cent., or an excess of cuprous oxide. The remains of his appliances which have been found show clearly that the metal from the smelting operation was remelted in crucibles and poured from them into moulds of clay or stone, perhaps of sand, but of this there is no definite evidence. The metal was not laded from the smelting furnace, as the small crucibles with rude handles which have occasionally been found, and have been erroneously supposed to be ladles, show no signs of having been exposed to a high temperature both on the inside and outside, as would have been the case had they been so used; the interior and upper edges alone bear marks of such exposure. The reason for this will be seen later.

Implements and weapons of bronze, unlike those of copper, were always cast in closed moulds. The method of melting the metal in each case was as follows:—The furnace or hearth was merely a shallow depression in the ground. The crucibles were made of clay, which was sometimes mixed with finely cut straw or grass. They were embedded in the ashes at the bottom of the hearth in such a manner that their bases and sides were thoroughly protected from the intense heat of the fire, their upper edges and interior only being exposed. This method had been adopted owing to the fusible character of the clay of which they were made. The fuel used was wood and the charcoal which was produced during the process.

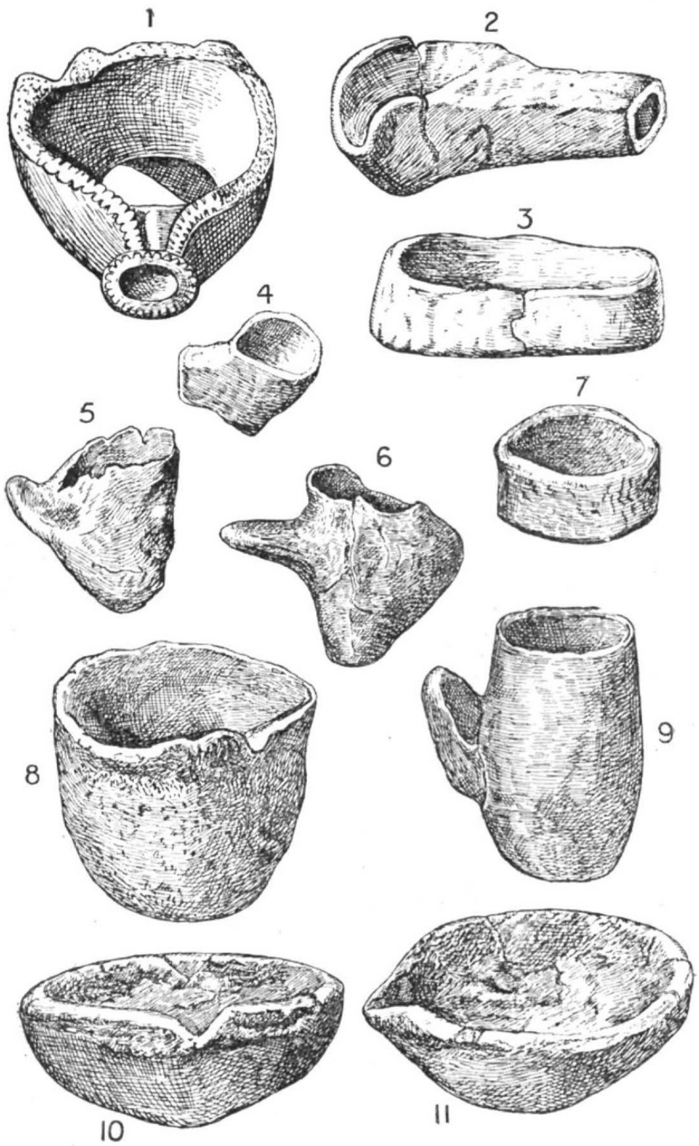

FIG. 1.—Prehistoric crucibles.—1. Clay vessel found among the débris of pile dwellings in Carniola. It is open to doubt whether this is a crucible or not. 2. A common form widely distributed in the remains representing the early Bronze age in the pile dwellings of Switzerland, the Danubian basin, and Ireland. It is furnished with a socket for the insertion of a stick, by which it was removed from the fire and its contents poured into a mould. 3. A shallow oval dish of somewhat rare occurrence, found in the Mond See. 4 Found in the remains of a crannog in Lough Mourne, Ireland. 5, 6, 7, 8, 9. Crucibles found at Dunadd, Argyll, together with iron spear-heads and other iron objects. 10 and 11 were found together with copper and bronze implements and stone moulds in Mercia and Almeria, in the south-east of Spain.

After a crucible had been thus placed and charged with copper, copper and tin-stone, or copper and tin, the fire was made up over it. A sufficiently high temperature for melting the metal could be obtained by the wind alone. When the contents of the crucible had melted, the crucible was removed from the furnace and the metal poured into a mould.

In consequence of this mode of heating, the lower parts of the crucible will, it is evident, bear but little traces of the action of a high temperature, whilst the upper edges and interior will exhibit a fused or semi-fused structure, and this is precisely what we find in all early crucibles.

Some of the most important types of crucibles are illustrated in Fig. 1.

The small capacity of by far the greater number of these crucibles which have been found is worthy of note. Few can have held more metal than would suffice for the casting of a single axe. This is, however, not surprising if we remember that they are the appliances of that remote time when metallic weapons were only beginning to replace those of stone.

The moulds used by primitive man are also of considerable interest. The earliest are of the class known as open moulds, and consist merely of cavities of the necessary form and size hollowed in the surface of a stone.

In casting swords and daggers of bronze the moulds must have been of clay and been heated to dull redness at the time when the metal was poured in—a method of casting which is still practised in Japan—as by no other means could such perfect castings of their thin blades have been obtained. The castings generally were hammered at the cutting edges, and it is to this hammering, and to it only, that the hardness of the cutting edges of both copper and bronze weapons is due, and not to any method of tempering. Much has been written about the so-called art of tempering bronze supposed to have been practised by the men of the Bronze age in the manufacture of their weapons; the hardness is also said to be greater than can be given to bronze at the present day. I should like to correct this error, as it can only have arisen owing to its authors never having made any comparative practical tests of the hardness of bronze. Had they done so, they would have found that the ordinary bronze of to-day can be made as hard as any, in fact, harder than most, of prehistoric times, by simple hammering alone.

We will now pass to the consideration of the copper alloys of Mycenæan, Babylonian, Greek, and Roman times. Until the introduction of iron, copper and bronze played an important part in the lives and struggles of the early races occupying the Greek peninsula and its islands, whilst in later times the alloy bronze afforded an imperishable material to the great sculptors of the golden age of Greece, by which many of their incomparable works have been preserved to us.

In Greek literature we have no records of metallurgical processes relating to copper or its alloys, such as are to be found in the writings of Roman authors, notably Pliny.

Strabo, the only Greek author who condescends to take any notice of metallurgy or metal working, confines his statements to gold, silver, and lead. But at Laurion the remains of ancient furnaces for smelting lead ores, which have been unearthed from time to time, indicate that low hearths resembling those of the Bronze age were extensively employed; and if we may reason from Japanese metallurgical procedure, similar furnaces would be used for copper. The island of Cyprus, once rich in copper ores, was doubtless the source whence the inhabitants of the Greek peninsula in early times obtained their copper.

Among the earliest specimens of the metal which have been found in Greece are some copper nails which were obtained by Dr. Schliemann at Orchomenos, a city in Bœotia, which was in a state of decay in the time of Homer. They belong to that remote period in Mediterranean civilisation to which the name Mycenæan has been applied.

They are interesting as showing that the men of that remote period were able to produce copper of tolerable purity, but this would not be difficult, as the ores which they worked would be oxidised ores, oxides, and carbonates from the outcrops of veins, viz. the parts which were exposed at the surface of the ground.

Bronze was also then in use for nails and cramps in building construction, but especially for weapons, and was of good quality.

There is abundant evidence to show that Egypt was the first in the field in artistic bronze casting. When it first began it is difficult to say, but objects of at least as early as 3000 B.C. are in existence.

Even in the early examples great technical skill is displayed. The most ancient Greek bronzes are solid castings, whereas in Egypt they are light and hollow, having been cast with a core of argillaceous sand, which still remains in many specimens.

The statuary bronze frequently contains considerable amounts of lead, sometimes with but little tin, and the question naturally suggests itself, whether this arose from scarcity of the latter metal. Only a few analyses have been made, and unfortunately few of the objects can have even approximate dates assigned to them.

Bronze was in extensive use in Nineveh about 1000 B.C. for vessels and utensils of many kinds, and curiously was sometimes employed for those which we should now make of more precious metals.

The Greek copper alloys of a later period, many examples of which are found in the coins of about the fourth century B.C., are true bronzes consisting of copper and tin, with lead or zinc only as impurities and not intentionally added.

A curious feature in them is the presence of nickel varying from traces up to 0·5 per cent. The percentage of tin is somewhat irregular, but in most examples ranges from about 8 to 11 per cent. The same is true of the Macedonian coinage alloys from the third to the second century B.C., but the percentage of tin in them is somewhat greater, generally being from about 10 to 12 per cent. These alloys were undoubtedly made by melting together the metals copper and tin, and not, as in the Bronze age, by smelting stanniferous copper ores, or by melting copper with tin ore.

The Macedonian alloys more particularly are the best of the ancient bronzes.

A little later in Greek coins we find lead as an intentional constituent in various proportions, ranging generally from about 6 to 10 per cent., or even more, with a proportionate reduction in the percentage of tin. The Macedonian coins, however, with few exceptions, preserve their character as true bronzes.

The alloys used for statues are frequently true bronze with 9 to 11 per cent. of tin, but in other examples about 5 per cent. of lead has been added, probably with the intention of increasing the fusibility of the alloy and its fluidity when molten.

The statements of Pliny as to the composition and mode of manufacture of the bronzes as imitated in Rome throw but little or no light on the subject; in fact, they are for the most part useless and misleading. As regards the Corinthian bronze, the beauty of which is so extolled by classical writers, he states that the alloy was discovered by the Romans at the sack of Corinth, when vessels of gold, silver, and bronze had been accidentally melted together during the burning of the city and produced a golden bronze.

The siege of Corinth, however, occurred in 146 B.C., but the excellence of Corinthian bronze had been recognised long before.

Whatever may have been the exact composition of this bronze, of which several statues are said to have been cast, I may say that no addition of gold or silver to any copper-tin alloy will cause it to resemble gold closely. Imagination must, I think, be responsible for the accounts given of this bronze by ancient authors, especially when we read also that its beauty was derived from being cooled in the water of the fountain of Peirene.

With the fall of Greece and the rise of the supremacy of Rome we enter an important period in the history of copper and its alloys. In Spain and in Britain we find copper-smelting being vigorously carried on by the Romans, and in Rome and the chief seats of the empire a further extension of the use of bronze, not only for statues and other objects of art, but for vessels of all kinds, furniture, and other articles of domestic life. Of special importance is the invention of a new alloy, brass, which comes into use for the first time in Europe.

Among the varied remains which are representative of the Roman occupation of Britain, few are of greater interest to the metallurgist than the cakes of copper found in North Wales and Anglesea. These cakes afford us, in their form and character, unmistakable evidence of their history. They had been obtained by smelting sulphide ores, or ores containing sulphides, in low hearths, in which they had almost certainly been allowed to solidify before removal. According to Pliny, who seems in this matter to have had access to fairly trustworthy sources of information, the copper obtained by smelting was brittle and useless, and in order to obtain malleable metal from it, it was mixed with lead and melted several times, and the oftener the operation was repeated the better was the quality of the copper. This brief account of copper-refining by a non-technical writer gives us an excellent *résumé* of the process as practised in Roman times. The operation was evidently conducted with free access of air, and the lead used would, by its oxidation, aid greatly in the removal of impurities from the copper.

The earliest Roman alloys which have come down to us are copper, lead, tin, alloys of the fifth century B.C. Their chief peculiarity is their very large content of lead, namely, from about 19 to 25 per cent., the tin being about 7 per cent. They were worthless for practical purposes, but formed the alloy of which the large coin of the republic—which weighed from 8 to 11 ozs.—the "As," was cast. These copper-lead-tin alloys continued in use as coinage alloys until 20 B.C., but from that date until two centuries later lead is seldom found in coins except as an accidental impurity.

The large percentages of lead were undoubtedly added in these cases on account of the cheapness of the metal as compared with copper and tin.

The copper-tin-lead bronzes appear also to have been used by the Romans for engineering and industrial purposes. An interesting example of this use is afforded by the broken shaft of a water-wheel which was found in the lower Roman workings of the north lode of the Rio Tinto mine. The water-wheel was probably built in the first century of our era, as coins of the time of Vespasian (70 to 81 A.D.) were found near it.

The bronze used for statues by the Romans also always contains lead in considerable proportions, as much as 6 to 12 per cent. being often present. In this they were doubtless influenced by Greek practice, the lead being added to the bronze to increase its fusibility and more especially its fluidity when molten, so that it might receive the sharpest possible impressions of the mould.

I may point out here that the addition of lead to bronze was and is largely practised by the Japanese, not only for the reasons stated above, but also to enable the objects cast of the alloy to receive a rich brown patina when suitably treated; and in this connection it is worthy of note that Pliny states that by the addition of lead to Cyprian copper, the purple tint is produced that we see in the drapery of statues.

The alloy used by the Romans for mirrors does not differ greatly from that in use in Europe for metallic mirrors in comparatively recent times, the percentage of tin ranging from 23 to 28 per cent., but lead is present in all from about 5 to 7 per cent.

Copper-zinc Alloys—the Brasses.

Zinc as a distinct metal was unknown in early times; in fact, as late as the sixteenth century it was not known in Europe; but there are strong reasons for the belief that the Chinese were acquainted with it as metal at least several centuries earlier. It is occasionally but rarely present in the implements and weapons of the Bronze age, and then only in small quantities as an accidental impurity, which has been derived from smelting copper ores containing it.

In somewhat later times it occurs in rings, armlets, and other personal ornaments found in the ancient burial mounds of Germany and Denmark, but these mounds are of post-Roman date, and the objects mentioned have really been made from Roman coins.

In Greek alloys zinc is never found as an intentional addition, but only as an impurity, about 1 to 2 per cent. or less; in fact, according to Gobel, all antique objects which contain zinc are not Greek; but this, in my opinion, is only true for those containing considerable proportions of the metal, and not for those with the small amounts just mentioned.

In Roman times it first appears in the coins of the republic as an impurity; as an intentional addition, however, it only begins in the time of Augustus (20 B.C. to 14 A.D.), when brass was made for the first time in the world's history.

One of the earliest examples is a coin of 20 B.C., which contains 17·31 per cent. of zinc.

The Romans were the first makers of brass. Although they were unacquainted with the essential constituent zinc, yet they had discovered that by melting copper together with a certain ore (calamine), a yellow alloy of a more golden colour than bronze could be obtained.

It was first employed for coins which appear to have had a higher value than those of bronze, even up to the time of Diocletian (286 to 305 A.D.), when six parts of brass are said to have been worth eight parts of copper. There is, too, a curious statement by Procopius in his *De Œdificiis* relating to its value in the fifth century A.D., in which he says that brass was then not very greatly inferior to silver.

The method employed by the Romans in making this alloy from copper and calamine was a very simple one.

It was conducted as follows:—The calamine was ground and mixed in suitable proportions with charcoal and copper in granules or small fragments. This mixture was placed in a crucible, and was very carefully heated for some time to a temperature sufficient to reduce the zinc in the ore to the metallic state, but not to melt the copper. The zinc being volatile, its vapour permeated the fragments of copper, converting them into brass. The temperature was then raised, when the brass melted, and was poured out of the crucible into moulds.

This process was so effective that, until a comparatively recent period, all brass was made in Europe by the ancient process, and even until a few years before 1861 it was thus made at Pemberton's Works in Birmingham. It was called "calamine brass," and was generally believed to be superior in mechanical properties to brass made by using metallic zinc.

The survival of this ancient process affords a striking example of the conservatism characteristic of British metallurgy, as brass had been made in England by Emerson, using metallic zinc, in 1781. This, so far as I have been able to ascertain, was the first to be made in Europe by melting copper and zinc together.

In Roman alloys the percentage of zinc was very variable, ranging from about 11 to 28 per cent. For ornamental purposes and scale armour they had an excellent alloy, of which the following are examples. Several rosettes and studs which had formed the mounts of a casket were unearthed in the excavations at the Roman city of Silchester in 1900.

Both the rosette and stud are of practically the same alloy. Now, of all the copper-zinc alloys, those which contain from 15 to 20 per cent. of zinc possess the greatest ductility.

This Roman brass is therefore one of the most ductile of the whole series of brasses. It is, besides, identical in composition with Tournay's alloy (copper, 82·5 per cent.; zinc, 17·5 per cent.), which, on account of this property and its rich colour, is used for the manufacture of all French jewellery made from thin sheets in imitation of gold. Hence the brass of which the rosettes are made is notably of the composition which is best fitted for making such ornaments, and is that which would be employed at the present day.

I have also examined the scales forming part of a suit of Roman scale armour dug up in the excavations of a Roman camp near Melrose, and found them to be of practically the same composition as the above.

The chief use of brass by the Romans, apart from the various coinages, appears to have been for fibulæ and other personal ornaments and for decorative metal-work, and for these, as we have already seen, they had invented a metal perfectly suitable, both as to its workable qualities and its beauty.

That they were the first inventors of brass is, I think, without doubt, as the alloy is not found in Greece or the Greek colonies or elsewhere until the time of the Roman Empire.

In the eleventh century great care was bestowed on the purification of the copper intended to be used in the manufacture of calamine brass for objects of art, more especially for the removal of lead, as it had been found that brass contaminated with that metal could not be satisfactorily gilt.

As regards the brass which was made in this country by the ancient method, *i.e.* "calamine brass," and that made with spelter, the former, according to Dr. Percy, was preferred for the manufacture of buttons and articles to be gilt, as it was said to take the gold better in "water-gilding." It was also preferred for other purposes. It is difficult to see why there should be any difference between the two brasses unless the spelter of those days was more impure than at present, possibly containing more lead and iron. Prejudice against the metal made by a new process may, however, have been one of the causes of the opposition which was raised to its use.

With the disappearance of the calamine brass, one of the last links in the chain connecting the modern metallurgy of copper and its alloys with antiquity is broken. An important link, however, still remains in the *cire perdu* process of casting bronze, a process in which it can scarcely be said that we are any further advanced than the Greek founders of some centuries before our era.

Further, it must not be overlooked that the principles on which copper-refining is based were carried out in practice in the time of Pliny.

The influence of copper, and particularly of bronze, from the age of Bronze to that of Imperial Rome, is an element which has played a greater part in the civilisation of Europe than that of any other metal. This is often lost sight of in this age of iron and steel. It hence seemed to me that it might be of interest and possibly of profit to present to the members of our Institute an account of the achievements which our fellow-workers in bygone ages were able to accomplish without the elaborate appliances and scientific knowledge of our own times.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

LONDON.—Further gifts to the University are announced in connection with the scheme for removing the headquarters to a site behind the British Museum, to which we referred last week. The Duke of Bedford has offered 25,000*l* and a reduction off the price of the site of 50,000*l*., and an anonymous friend of the University has offered 70,000*l*., making a total amount, with the gifts announced last week, of 305,000*l*. Although Lord Rosebery's name has been published as representing the University on the board of trustees which has been formed in connection with the scheme, the approval of the Senate has not been given to the proposals. Strong exception was taken to the Chancellor's action at the meeting of the Senate of March 20, when the Vice-Chancellor (Sir William Collins) tendered his resignation in view of what had taken place. At the unanimous wish of the Senate, he afterwards consented to remain in office. Lord Rosebery's explanatory letter was subsequently published, in which he states that by consenting to act as trustee he was committing no one, not even himself, to anything except to his being trustee for certain sums collected for the benefit of the University. From official correspondence which has been communicated to the Press, it appears that both the Prime Minister and the Chancellor of the Exchequer approved the proposed site.

Prof. F. G. Donnan, F.R.S., was appointed by the Senate to the University chair of general chemistry at University College, in succession to Sir William Ramsay, the appointment to take effect from the opening of next session, in October. The Senate elected Dr. L. N. G. Filon, F.R.S., to the Goldsmid chair of applied mathematics and mechanics, tenable at University College, such appointment to take effect from the beginning of next session, in October. Dr. Filon succeeds Prof. Karl Pearson, who resigned the chair in question on his appointment to the Galton chair of eugenics.

At the same meeting of the Senate, E. C. Snow, an internal student of University College, was granted the D.Sc. degree for a thesis entitled "The Intensity of Natural Selection in Man," and other papers.

Additional grants from the London County Council, amounting to 28,000*l*. during the sessions 1911–12 to 1913–14, were formally announced to the Senate.

IT is announced in *Science* that Prof. R. Ramsay Wright, vice-president of the University of Toronto and dean of the faculty of arts, will retire from active service on September 30. He has filled the chair of biology for the last thirty-eight years.