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Ancient Metallurgy

The Extraction of Metals from Ores as practised by the Ancients; Some Forgotten and Existing Methods of Ancient Man.

By ARTHUR E. ROBINSON, F.R.A.Inst.

MOST readers are aware of the fact that the scientific study of the various documents upon which the cultures previously known as the Ages of Stone, Bronze and Iron were based is of comparatively recent date.[1] A considerable period of time elapsed in most countries between the date upon which metal first appeared in use and the earliest recorded date at which the inhabitants produced metal from ore in the same areas. Some people never learnt how to produce metals, and in the fifteenth century many natives in the continents of America, Africa, Australia and in the Polynesian islands were neolithic. There is no evidence that metals were found within the ancient boundaries of Sumer, Ur and other sites in the Mesopotamian delta, or riverain area. It was considered that the metal used at Ur was imported from *ore* obtained in Oman which was exported thence to Mesopotamia.[2]

[1] The " chalco-lithic period " is the transition period between the neolithic and that at which smelting metals from ore began. During the chalcolithic period man used native metal found in nuggets, etc. J. A. Rickard (*Man and Metals,* pp. 171-2) estimated this at two or three millenia but considers that copper (or bronze) was reduced by a " bloom " process (probably some thousand years) by the Egyptians prior to the invention of smelting and casting.

2 Sir Leonard Woolley *{Abraham,* pp. 119-121). A bill of lading (2040 **B.C.)** for a ship's cargo has been found in support of this view. Rickard *(op. cit.)* gives the smelting era for Egypt as the First Dynasty, i.e. 3400-2980 **B.C.** He has illustrated a rock drawing of King Smerkhet (found at Wadi Maghara, Sinai) smiting the natives (Bedawi) there (fig. 27). A. Lucas (*Ancient Egyptian Materials and Industries,* pp. 153 *et seq.*) gives the Egyptian copper smelting era as Third Dynasty (2980-2900 B.C.). The aboriginal inhabitants of Sinai are described as Monitu and they traded turquoises in pre-dynastic times. The Omanese mines have been worked from an unknown period. Tin is unknown in Egypt or Cyprus, but it is found near Byblos. The general use of bronze in Egypt dates from the Xllth Dynasty (Lucas, *op. cit.,* p. 404), and the earliest known is dated to the IVth Dynasty. There are extensive ancient copper slags in Sinai. Rickard estimated that they had produced 5,500 tons of copper through the ages as compared with about the same quantity used annually in the world at the beginning of the last century. During the XVIIIth and XlXth dynasties Egypt imported copper. The Kubban mine (Nubia) was worked

It is an open question whether the nomadic cattle and camel herders in what are now almost desert areas of the Nile basin have produced metal from ore or have in the course of time forgotten the process and relapsed to a neolithic stage or purchased manufactured articles. During the late Ptolemaic period the Nilotic peoples south of Wadi Haifa apparently produced iron from ore or obtained it from some outside source such as Palestine.[3] During the Roman period the Blemmyes worked deposits of iron to a small extent but the industry was an ephemeral one, as the lack of fuel and the nomadic existence of the people militated against its permanency. Since then sporadic traces of metal working at later periods by the Romans and Arabs have been found. By the fifteenth century, however, all the metal required in Egypt was imported from abroad, and Cairo became one of the great metal distributing centres in Africa. Other places were Alexandria, Tripoli, Algiers and the Moroccan ports. It was not until the beginning of the nineteenth century that efforts were made to resuscitate the Egyptian mining industries. Muhamad Ali Pasha engaged European experts who travelled far and wide. Some have published books,[4] but their reports have not been disclosed outside the Egyptian royal family. Until a comparatively recent date considerable secrecy has been exercised regarding mineral deposits in the Sudan and Egypt. From verbal information and the

in the Xllth dynasty. Charcoal has been found in a tomb of the First dynasty period. A yield of one-third of the weight of wood (cut billets) is regarded as a fair average in the manufacture of charcoal under medieval conditions of production. Layard (*Nineveh,* vol. 1, pp. 222-3). described an ancient abandoned copper mine which was galleried and of considerable extent in the Tiyari Mts. He stated that in the Berwari valley there were mines of iron, lead and copper in abundance. The Kurds and Chaldeans however, produced metals from metalliferous boulders and pebbles washed down into the valleys by torrents.

3 See Sir Wallis Budge, *The Egyptian Sudan,* who cites long extracts from Diodorus, Strabo and Pliny (vol. i, cap X, pp. 153-165). Much of this is incredible. Sir Flinders Petrie estimated the date of some iron slag found at Meroe as not earlier than the Persian period, i.e. *circ.* 700 **B.C.** The iron articles found in the Meroitic tombs by Dr. Reisner or his predecessors have been dated to periods subsequent to the Christian era, i.e. Arab (Moslems possibly).

4 Dr. Russegger; Mr. Petherick, a Cornish engineer and a British Consul. The earliest date given for iron slags found in the Eastern deserts was after the Roman occupation, but it is possible that the Jewish colonies on the Nile manufactured and traded iron prior to that period. Some of these are believed to be 5th century **B.C**. date.

information published by the Egyptian Survey Department it is clear that there are extensive supplies of iron, but the absence of fuel, cost of transport and plant required make the industry under present conditions a speculative and unprofitable enterprise.[5] A British company is now working mines in Sinai; they are not mining or re-treating the vast quantity of ancient slags there. The late Sir John Evans merely fixed tentative periods which could be regarded as the bases for future research. Science is progressive, and since 1900 considerable field research by highly qualified and specially trained experts has necessitated many more subdivisions of the three primary cultures mentioned above. Some of these are quite local; others appear to be found in various areas but are not necessarily contemporary. Among some peoples and on some sites there are no traces of a copper or bronze culture.[6] The Tasmanians and the Australian bush blacks have never used any metals until the advent of the white man. In Nigeria the alleged antiquity of local metal production from copper and iron ores is based upon local tribal traditions and generally attributed to some eponymous ancestor from the East (Egypt or Mecca).[7]

5 Dr. Gsell considers that in North Africa there was possibly a reversion from bronze to neolithic *prior* to the Iron Age (see *Histoire de* l'*Afrique du Nord,* pp. 212, etc.). Iron bars were used as currency in Sparta during the 8-7th centuries **B.C.** (see Smith, *Hist, of Greece,* p. 23). Dechelette gives tables of the Iron Ages for Europe on pp. 540, etc., of his *Manuel d'Archaeologie.* Barth (*Travels,* vol. ii, p. 580) found that 40 trade hoes *(akika)* were the price of a slave. As an example of the diffusion of culture Theodore Bent found a double bell of the Congo type among the ruins of Zimbabwe. J. Roscoe (*The Bakitara,* pp. 5, etc.) describes the mining and manufacture of iron in detail and has illustrated a royal spear (plate 16). The bellows used are the pot type but the present writer considers that iron manufacture has been introduced into East Africa from Asia and is not a Nilotic (ancient Egyptian) culture.

6 Professor Gowland considered that in Southern India, South Africa and Central Africa there was no bronze age between Copper and Iron. The antiquity of the bronze age in Nigeria is not supported by any historical evidence as some of the Benin bronzes represent European soldiers and traders.

7 Most of the hereditary all-metal spears (copper or iron) found in Africa are heirlooms of sanctity. Professor Naville suggested that the first metal workers in Africa were the Chamites *(Rev. Arch.,* vol. xix, 1924, p. 24). These people crossed from Arabia and conquered the inhabitants. They used copper and flints and settled in the Lower Nile valley. Another opinion is that the " Seric " iron of the Romans was produced near Shiraz (Persia) where there are great heaps of slag. The tribe who gave this name to the iron moved to Southern Arabia in Roman times and traded with the Romans. (Dr. Beck, *Geschicte des Eisens,* cited by Professor Gowland in *Metals in Antiquity* in *J. R. A.* I., vol. xlii, 1912).

M. Dechelette, a famous war ace and archaeologist, was among those who drew attention in their published works to the variations in chronology regarding cultures in Asia, Africa and individual European countries. Professor Fleure has dealt with the question from the point of view of human geography. The result is that the study and research regarding the dates and sites at which metal has been produced from ore in various parts of the world is receiving more attention than the mere discovery of ancient specimens of manufacture. From the earliest period culture diffusion and development have been largely a matter of climate. Man, the hunter, had to follow the animals upon which he depended for food. The enormous quantities of animals necessary for each adult to kill so as to live has caused some anthropologists to consider that the lower types of man existed under much the same conditions as the monogamistic carnivora in respect to domestic conditions.[8] The herding or family instinct was developed later and probably, as among the Australian aborigines, severely controlled. In any case the nomadic existence is detrimental to all acquired art or culture. Practically all the recognised arts and sciences are traceable to sedentary peoples. The processes of making fire, the elementary use of weapons or tools of wood, or stone and wood; the use of rafts, etc., are probably sporadic in their origin. The extraction of metals from ores is however an entirely different question and the metal ages really represent a very small period in our history of man. There is no reason to think that the art of metallurgy was discovered by one particular race and that this knowledge was passed on around the world.

The domestic hearth[9] and violent thunder storms which have destroyed forests are not unknown in most

8 The practical extinction of the wild bison in N. America was caused by shooting down the herds with rifles by contractors for beef supplies to the workers on the trans-continental railways. The destruction of herbivorous animals has had much to do with migration of population and the creation of desert.

9 Modern scientists consider that the first step in metallurgy was the result of an accidental discovery of metal in the ashes of a domestic hearth. The ancients were extremely careful to conserve fire and the sunk hearth or fireplace is considered to be the early form. Two types have been found. One at Lobositz on the Elbe and the other at Platkow on the Oder are illustrated

of the sites where traces of ancient metallurgy have been found.

Metallurgy originally meant the art of extracting metals from ores. In this paper the original interpretation is adhered to arbitrarily, although the word has now a wider significance.

The purpose of this paper is to interest those who may be in a position to find traces of ancient metal production, which at the time when the original County Histories were written was dealt with in a somewhat perfunctory manner. It is not my intention to present to readers a history or chronology of metallurgy throughout the ages. I have an excellent publication before me now, " Copper Through the Ages," and a number of books and articles on the subject have been published. Among these is a notable paper[10] and notes by Mr. Hawkes of the British Museum in "Antiquity." Mr. Rickard, who has reproduced a photograph I gave him of a washing table found at an ancient mine in the Sudan (re-opened by former residents of St. Albans), is probably the most reliable authority on ancient metallurgy. The work however omits many technical details necessary to the layman. For these I have consulted Professor Gowland's and Dr. King's publications.

It must be noted that I have restricted the use of the word " smelt" to processes in which the metal is heated to such an extent that it is fluid.

It is a great aid to field work if the student or others engaged have some idea of what to look for. I am not satisfied that either Verulam (the British site) or Verulamium (the later Roman-British site) were en-

by Albert Neuberger (*The Technical Arts of the Ancients,* p. 249, figs. 327 and 328). The surface hearth is believed to be of a much later period, and it has been suggested as the earliest evidence of house construction, which developed around it, in a more or less permanent form (see figs. 329-333 and text, *op. cit.).* The legendary discovery of iron was that the forests of Mount Ida were ignited during a violent thunderstorm during the 15th century **B.C.** The iron was found among the roots of the charred trees where it had been produced by the intense heat from the burning wood.

10 G. A. Wainwright *(The Coming of Iron* in *Antiquity,* March, 1936), who mentions a dagger-blade of smelted (?) iron dated 2800 **B.C.,** from Tel Asmar, Iraq, etc. Recently, ancient copper workings have been discovered in Somerset. This was probably the source of supply for the cast copper-plated coins now in the Taunton Museum (see my *False and Imitation Roman Coins).* The coins at York must have been made from some similar (still undiscovered) site.

tirely dependent for their supplies of metal (manufactured or as ore) to sites as remote as Sussex or the Forest of Dean, etc. The general standard of craftsmanship for the working of wrought iron in this district has always been very high. It is to the priesthood of the Christian church that Europe owes her incomplete instead of total relapse to barbarism. Arts and crafts were fostered as many of us have seen demonstrated in the great cathedrals of which so many have now been destroyed. These arts and crafts have lingered through the ages. At Jerusalem there are families, both Christian and Jewish,[11] who claim to have carried on glass-making, polishing gems, making glazed earthenware of distinctive types, metal working and weaving in their families for many centuries. For many centuries the Falasha (black Jews) were the principal craftsmen in Abyssinia. Since the great Roman dispersions many of the Jews (at that time settled in Spain) fled to Salonica, Constantinople, Alexandria and other places from the Inquisition. They took the knowledge of their arts with them. These people guarded the secrets of their trades just as closely as their descendants do now, and their genealogical tables for hundreds of years are kept so that marriage always takes place between members of the same tribe of unquestionable lineage. It is the old story of the trade guilds and the industrious (and with capital) apprentice. This guild or clan system for

11 The Philistines disarmed the Hebrews (I Samuel xiii. 19-23). The Romans adopted the same practice, but allowed their slaves (captives) to use iron agricultural implements. It is believed that the great revolt in Britain under Boadicea was caused by the disarmament of the Britons who were allowed to retain their iron agricultural implements. When the crops failed and their grain, etc., were seized they rebelled. There were parallel cases in Egypt and North Africa. The Hebrews rendered tribute to the Romans in iron (? currency bars). The metal was so bad (? cast iron and not wrought) that the Romans rejected it and the Hebrews armed themselves secretly and revolted. Julius Severus, then governor of Britain, was sent to Palestine to quell the revolt (Dio. Cassius, LXIX, 13, etc.). The prolonged resistance of Caractacus and the Brigantes was due to the fact that they controlled metal supplies. It was a penal offence punishable by death under Roman law for any person to sell iron or iron weapons to non-Romans or export them to the barbarians on the Roman frontiers. The Moslems when they occupied Egypt enforced this law. It is possible that the raids from Caledonia were actuated by a desire for weapons, etc. Metallurgy does not seem to have been developed in Scotland in ancient times to the same extent it was in Ireland, Wales or England (see T. Davies Pryce, *Roman Occupation of Britain (Antiquaries Journal,* Jan., 1938, pp. 29, etc.).

metal workers is found all over the world.[12] Some are despised and others honoured. It is generally the smiths who are esteemed and the miners and furnace-tenders servile classes.

This paper has not been submitted to any experts, but I desire to express my thanks to Mr. Green (Public Library, St. Albans), the late Professor Bone, F.R.S., Mr. Minty, O.B.E., Mr. Hawkes, Mr. Digby and others of the British Museum staff, and Mr. H. Wilson, M.C. (County Librarian, Lewes). I have not had the time nor is there the space to publish the details (when fully worked out) of the consumption of fuel, deforestation and possible climatic changes caused by the manufacture of metals by using wood or charcoal without replanting the devastated areas. In Sussex the great slag heaps of the Romans have disappeared, as the materials were used extensively for road making. The Sussex and other British forests were consumed for fuel. In the U.S.A. agriculture and metallurgy have created desert conditions. The Irish forests were consumed by 1702; after that date ore was sent to England (Rickard, *op. cit.,* vol. ii, p. 891).

4* 4*

NATURAL METALS. This term is applied to metals found in an almost pure state either as nuggets, boulders, outcrops or as dust in alluvial soils. All of these have been used at various periods by man, now considered as the Neolithic. Those most employed are copper, gold, silver and possibly zinc in the U.S.A. where it is found at Tennessee in a natural state. Zinc has been found in Tasmania in a natural state, but there is no evidence that the neolithic (almost paleolithic) Tasmanians of the last century used the metal. Platinum is found in alluvial deposits in the Urals, etc. A mass of pure silver weighing 697 kilos. (about three-quarters of a ton) was found at Kongsberg in Norway. No native lead has been found and man did not use the metal, as it was too

12 There is an inscription, found at Caerwent (Venta Silurum) dated, *vide* records, 152 a.d. Prof. Gowland states that the Romans admitted women to the plumbers' guilds. They do not appear to have discovered the sterilising effects of using leaden vessels, water pipes, etc. (from recent researches by a German scientist).

soft for tools, etc., very much until a comparatively late period. The evidence regarding natural tin is conflicting. African natives are reported to have made articles from alluvial tin, but this is since the metal was imported from abroad and the production of copper and iron were well established industries in touch with tinsmiths, and native traders.

Only one instance of the occurrence of non-meteoric iron in a natural state is known. It is found at Ovifak (Greenland), where weather-worn boulders of the metal are found eroded from the parent basalt.

METEORIC IRON. This metal is almost pure.[13] It is, however, invariably alloyed with a small percentage of pure nickel. It has been used from a remote period by wandering nomads (Esquimaux) and the various other inhabitants of the districts in which it has been found. It was found first in use by the Esquimaux when the Ross Polar Expedition met some of these people. At that time it was not recognised as of meteoric origin. The Mbosi meteor, discovered by Mr. Nott when surveying in Tanganyika during 1930, weighs about 12-15 tons and measures 13 feet 6 inches by 4 feet by 4 feet. The largest meteor known is at Grootfontein (S.W. Africa) and weighs about 60 tons.

The Mbosi meteor shows marks of ancient tools, but it was due to the reluctance of natives visiting its site that it was discovered. It took ten hours' continuous work with a hacksaw to detach a specimen for analysis and museum purposes.[14]

NATURAL ALLOYS. This term might be regarded as a misnomer perhaps. It is applied to metallic ores (reduced by heat) in which two metals occur, or by smelting ores of different metals in combination. The

13 Meteoric iron was found in the Mississippi valley and found (contrary to archaeological opinion) to be malleable. The Egyptians called it Bia-en-pet during the VIth dynasty, and during the XIIIth dynasty iron appeared in their script as Bia-en-tabol (foreign iron). Terrestrial iron appeared during the Roman period as Bia-nu-ta (at Denderah, in script of period) i.e. Iron-of-the-earth. The " swords from heaven " of Timur and Attila are supposed to have been forged from meteoric iron. Peary collected tools of meteoric iron which had been shaped by beating with stone hammers. The Aztecs made knives from meteoric iron which were considered to be more valuable than those of gold, when Cortes arrived in Mexico. The An-bar of the Sumerians was believed to be meteoric iron.

14 See Frank Oates, pp. 44-49, *The Meteoric Iron at Mbosi* (illust.) in *Tanganyika Notes and Records,* vol. 1, no. 2 for further details regarding this and other siderites.

early forms of bronze (copper and tin) and brass (copper and zinc) or copper and antimony were produced probably from single ores, as tin and antimony vapourise[15] and unite with the copper in the furnace.

One of these natural alloys used extensively by the Romans was oricholcum, frequently described as brass.[16] Electrum is an alloy (probably natural at first) much used by the ancient Egyptians, who called it " Tcham." There are some very fine specimens in the Louvre of manufactures in this alloy. It is interesting to note that the copper-cored coins found in this country dated to the Roman period and cast in moulds are as a rule cased with base silver and not like the earlier issues, *i.e.* cased in pure silver. The corrosion of many plated coins found at Verulamium may be the result of galvanic action caused by the presence of zinc. The corrosion of the coins found within the walls of Verulamium is one of their most remarkable characteristics.[17]

German silver is an alloy of about **78%** copper and 20% nickel. It has been found in China. The coins of Euthydemos of Bactria **(235 B.C.)** were made of this alloy.

A curious find of small " struck " copper coins copied from Tetrician types was made in an abandoned copper mine in Cornwall, *circ.* **1853.** Native copper was found in Cornwall, but I have not seen any analysis of these coins, the weight of which varied from four to eight grains each. Native copper was common in Cornwall and Ireland.

Vespucci found the natives of La Plata made arrow heads of meteoric iron when he arrived in that country.[18]

15 Tin melts at 231.8° Cent, and lead at 327° Cent., i.e. 442° Fahr. and 612° Fahr. respectively Zinc melts at 736° Fahr. and copper at 1,950° Fahr. Gold requires 2,100° Fahr. and iron 2,786° Fahr. to reach melting point. The melting point of antimony is 810° Fahr. The boiling points of these metals are much higher and will be found in the Encyclopaedia Britannica or the usual text-books on metallurgy.

16 The generic term " brass " applied by early numismatists to all Roman coins is inaccurate; 96% copper is regarded as copper.

17 From verbal information by Mr. Mattingly of the British Museum. Roman iron articles at Verulamium were produced by the Bloom process. Their preservation is due to the purity of the iron.

18 The famous sword of Jehangir Khan was formed from a meteor which fell in India. It was regarded with great veneration and is perhaps one of

EARLIEST USE OF METALS. Practically every tribe or nation which possesses any folk-lore ascribes the manufacture or possession of their first metal weapon (sword or spear-head) to some more or less eponymous ancestor. It is not my purpose to deal with the history or chronology of the use of metals. Statements regarding the early manufacture by the Chinese[19] should be regarded with considerable caution as the chronologies are based upon mythical histories. In 1885 Dr. John Percy, the eminent metallurgist, in an address to the Iron and Steel Institute, stated it was an open question whether iron preceded bronze. Based upon the use of the metal, and not upon its production from ore, this statement is not so absurd as it was considered by archaeologists then. The discovery of iron in very ancient sites has certainly given rise to much thought.

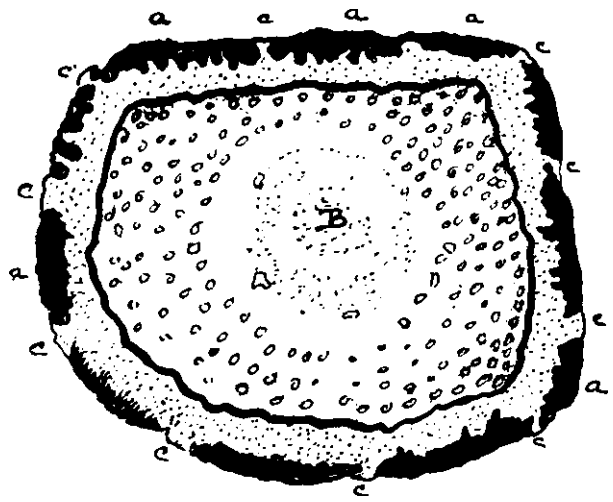
The use of metal had become so general that by the fifteenth century the manufacture of flint arrow heads and the beautiful polished axes (hammers of Thor) had been generally forgotten by most of the population of this country. Flint arrow heads were regarded as supernatural, and until the middle of the last century were worn as charms in Ireland. Specimens mounted in silver or gold may be seen in some museums. The Berbers of North Africa had until quite recently a similar belief, possibly based upon the prehistoric cult of the cornelian heart.

Primitive man probably used native metal in much the same way that he did stone, but of course it was not so plentiful and endurable and was unknown in

the earliest specimens of nickel steel that has been recorded. The invention of steel is said to have been made in India and from thence it travelled to Damascus and Spain after the Moslem era. Steel was known to the Romans, who obtained it from India probably. Roman weapons were made of forged wrought iron, after cast iron weapons (if the classical authors are correct) had been condemned as useless. The meteor from which the sword of Jehangir was made fell in India during 1620.

19 Rickard *(op. cit.,* vol. ii, p. 842) gives 722 B.C. as the earliest historical record for the production of iron from ore in China. Copper (used until a recent date) was used for spear-heads and swords until 685 **B.C.,** contemporary with iron hoes and hatchets. Pliny and Strabo wrote much from hearsay and are not accurate. Pliny (xxxix, 5) mentions Seric iron as imported from China; it was probably invented in India as the Chinese quality was poor. The Seres were a people in Western Asia and South Arabia; *vide* Rickard *(cit.* F. Hirth, *Ancient History of China,* p. 235). It is not improbable that the art of producing iron from ore in Arabia dates from that period. It was exported in a manufactured condition from Mocha to East Africa during the first century of our era *(vide The Periplus of the Red Sea)**

Fig. 1.

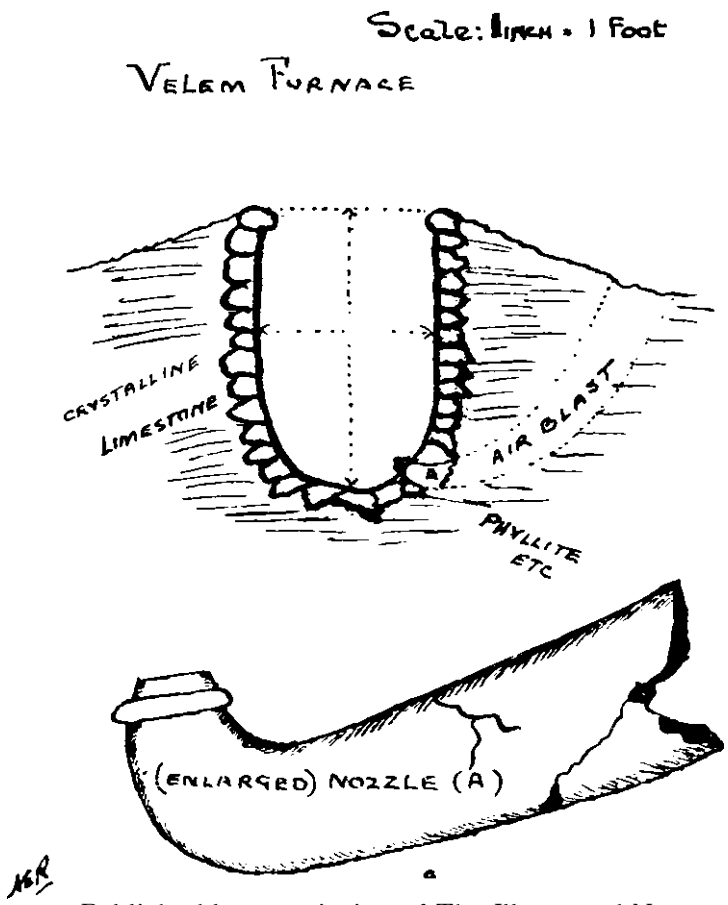


SECTION of a Lump of ORE in process of reduction.

This represents the IRON a.o.a forming like small Stalactites ccc in the slag. The CORE B is VITREOUS.

TEMPERATURE (Max) circ: 1000° C. (Deep ORANGE). FINAL temperature (bloom formed) reaches 1200-1300° C (Orange White).

(PERCY: METALLURGY of IRON and STEEL' pp. 298-306).



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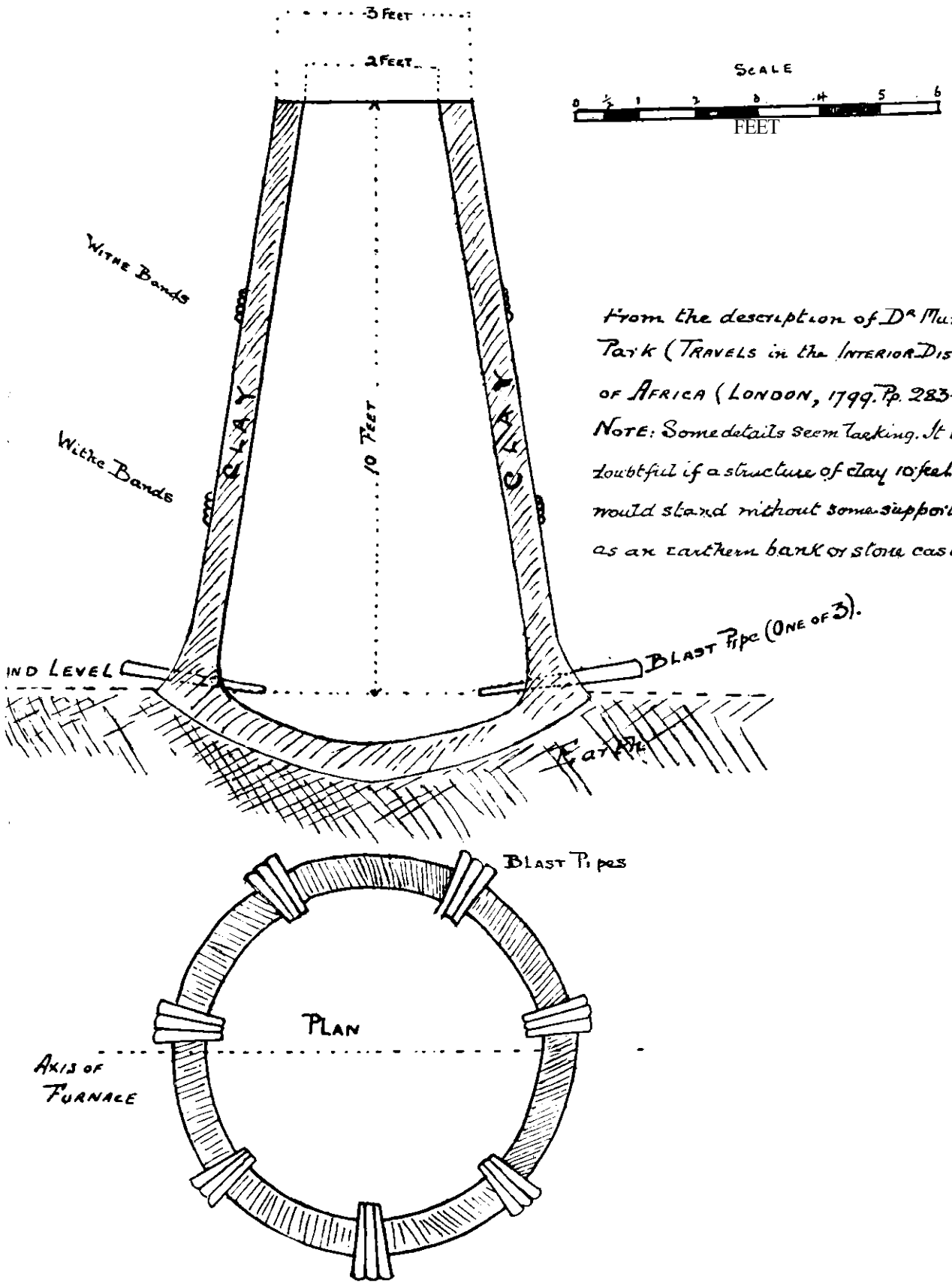
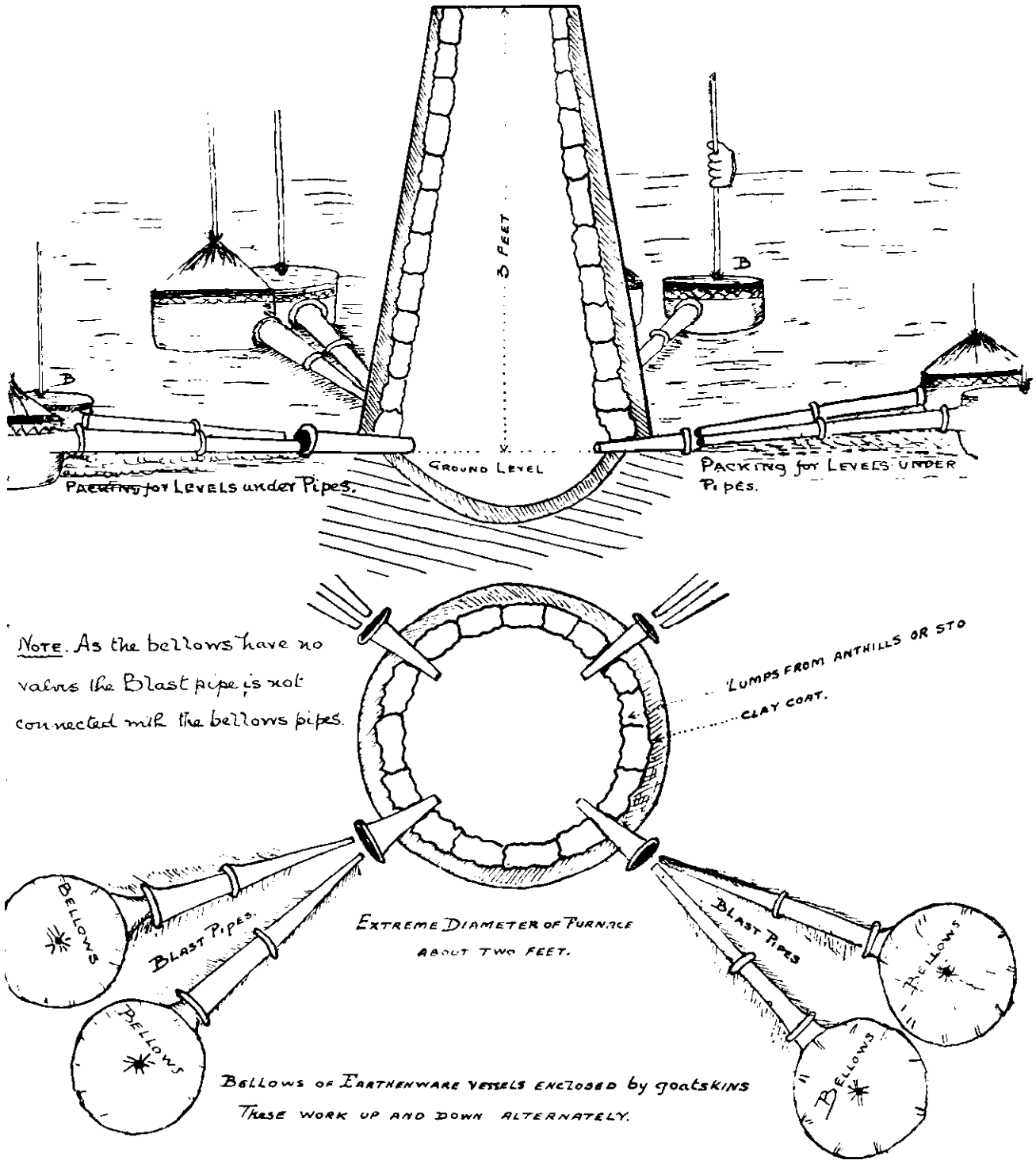


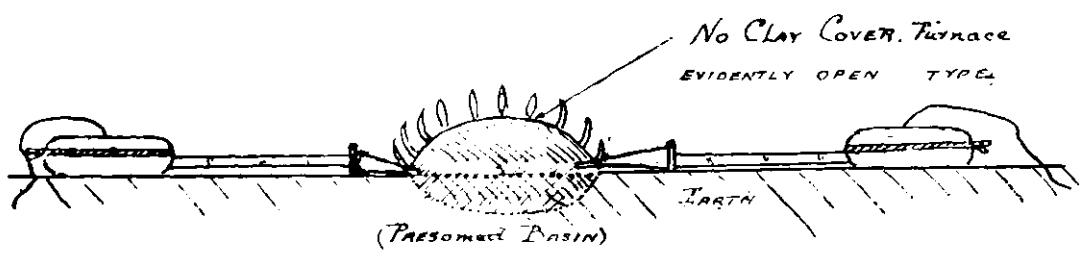
Uganda Iron Furnace

PLATE 3

Scale: 1 inch = 1 foot.

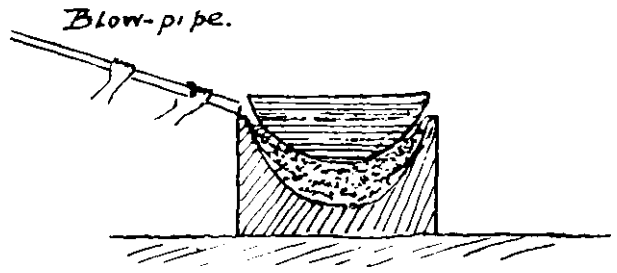


Bee Hive Type Furnaces etc.



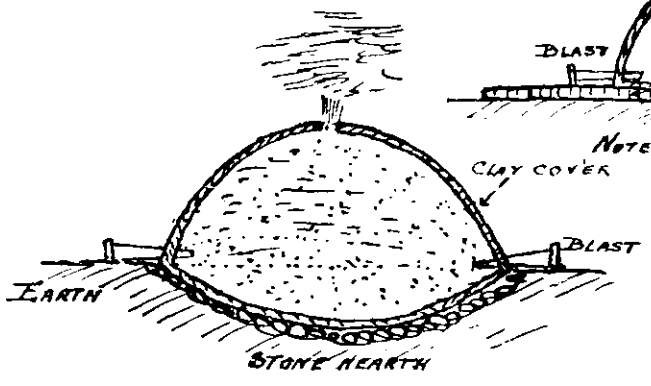
Egyptian Blast. Furnace (Copper and ? Iron).
(Thebes).

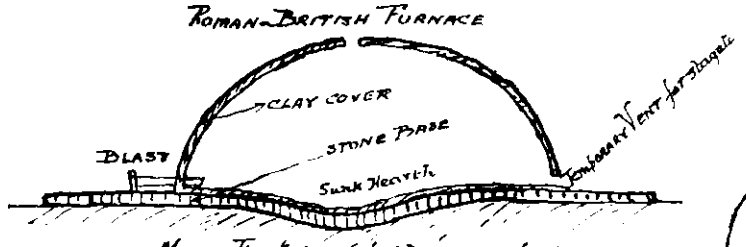
Note. It is considered by some that a valve was fitted in these bellows although most of those used in Africa are valveless.



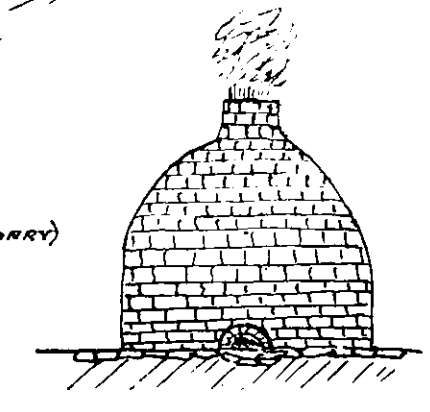
Egyptian Blow-pipe Furnace for melting gold.
(Beni-Hasan.)

N.B. A furnace of identical type is used by the Bida (Nigeria) for melting glass for re-manufacture. Native women are extremely conservative and old types of beads are made.

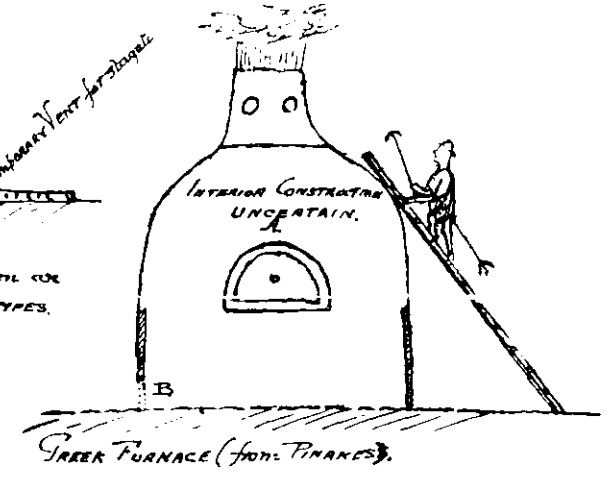




Note. The type of bellows used is controversial. It may have been ox-hide similar to medieval types.



Medieval Furnace (Masonry)
for Smelting Iron.



Greek Furnace (from Pinakes).

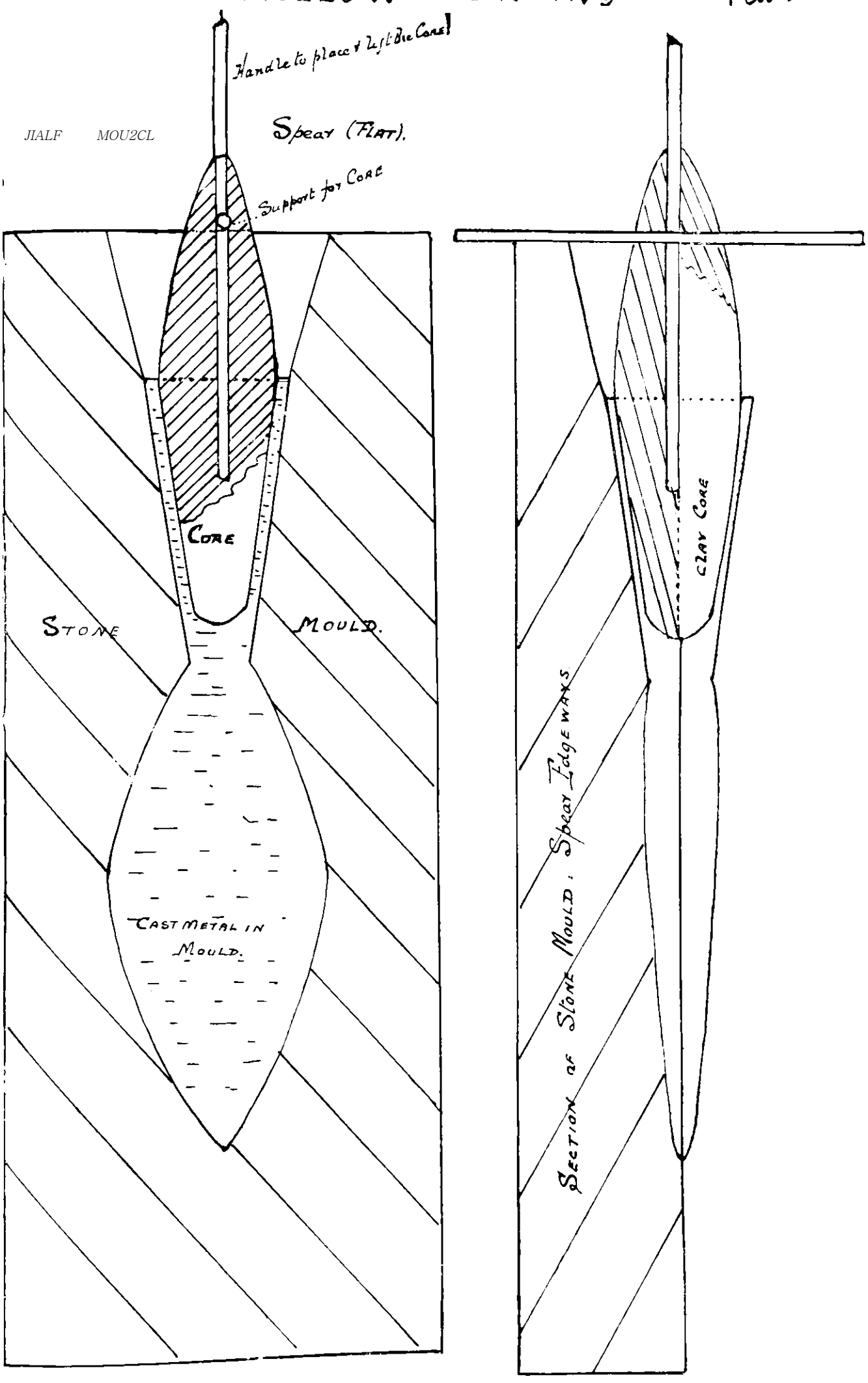
A. Would appear to be a door to a hearth. Slag and ashes may be removed at D. Some of these furnaces had a raised platform surrounding the furnace on which the men stood at work.

The possible ancestor of the Catalan hearth used in Elba and Spain.

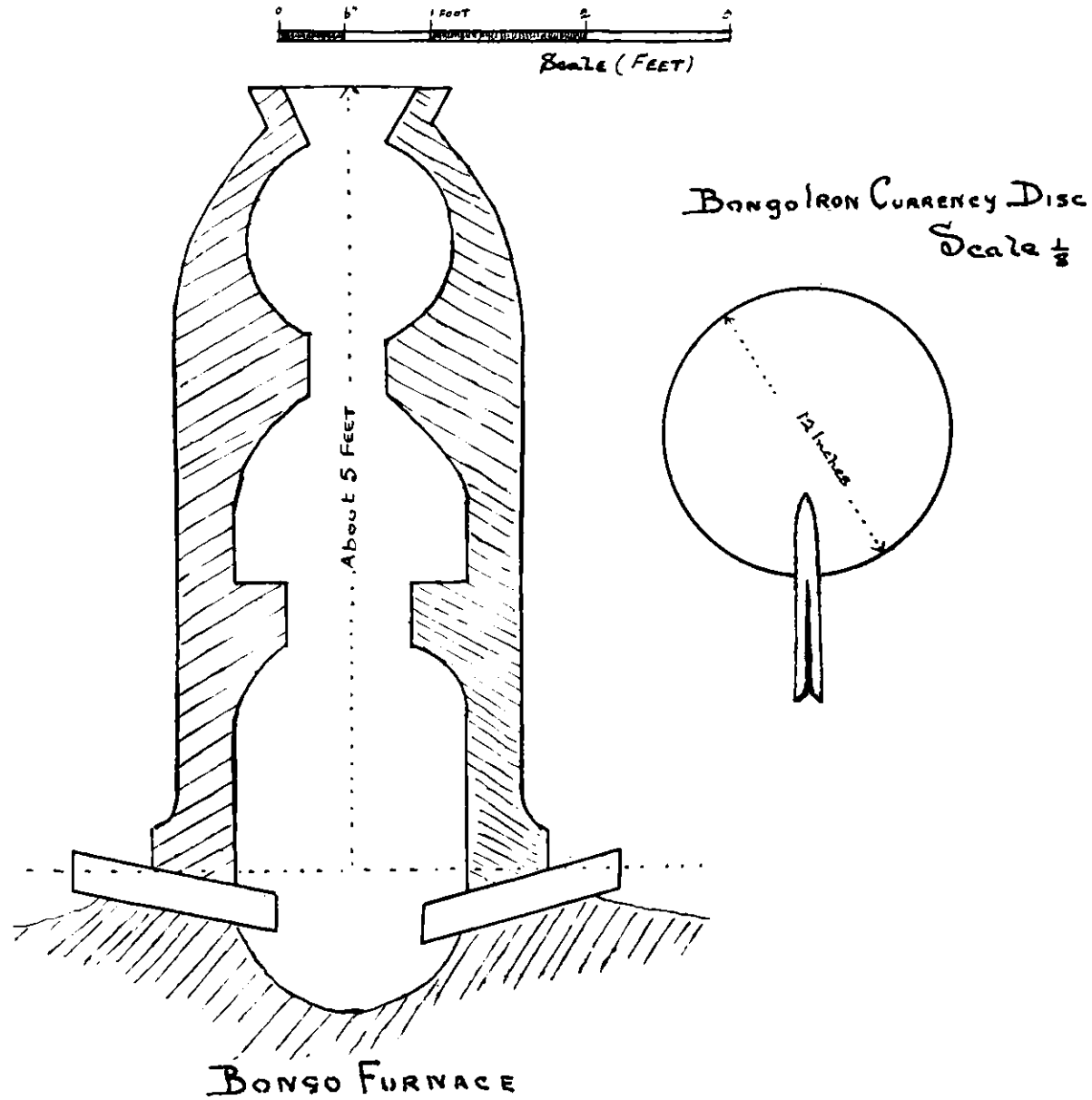
Egyptian (? portable) Furnace used by Metal-Workers
(Thebes).

HOLLOW CASTING Plate 5

JIALF MOU2CL



FRICAN IRON FURNACES



BONGO FURNACE

BONGO IRON CURRENCY DISC
Scale 1/8

certain areas. Metals such as silver or iron were very rare, but (natural) copper seems to have been plentiful in certain parts of the continents of America and Africa. Natural metal is generally found in association with ores. The Incas apparently had commenced to produce copper from ore at a recent date prior to the arrival of the Spaniards. Dr. Reisner during his excavations in the Nile Valley, considered that in some parts of Nubia the population relapsed to a neolithic state from an acquired and superficial Egyptian culture. Against this it can be argued that once the knowledge of producing metals was known it would never be lost. Metal users are not necessarily metal producers, and my view is that if no suitable ore or fuel was obtainable the second or third and definitely the fourth generation, if deprived of imports of metal and unable to produce their own requirements, would be found to have reverted to a neolithic culture. It is difficult to account for certain local lacunae of culture otherwise.

There is really no definite date that can be fixed for the first use of metals by man, nor can any date be fixed for the first production of metals from ore. All that can be done is to accept tentative chronologies based upon such evidence as is now available.[20] Meteoric iron was found in Wadai[21] and other places, *vide* Kumbary, *Comptes Rend.,* vol. lxx, p. 649. Chiefs' weapons were made from it.

[20] See the article in *Antiquity,* vol. x, pp. 355-7, by C. Hawkes, etc.

21 A meteoric iron dagger was found at Ur and dated to *circ.* 3100 **B.C.** Most of the early meteorites were considered sacred. Wainwright *(op. cit.)* gives a list which includes the black stone at the Qaaba (Mecca) and an idol found in a Mexican temple. The meteoric iron beads found at Gerzah are pre-dynastic as regards manufacture *(circ.* 3500 **B.C**. or earlier). The fragments of iron found at Ur are also meteoric and like the Gerzah beads (wrought cold) chalcolithic. The date is *circ.* 3500-3000 **B.C.** A bronze dagger hilt found at Tell Asmar showed a fragment of non-meteoric iron supposed to be the blade but quite possibly a fragment of the hot slag, similar to that found attached to the bronze objects of the Abydos (Vlth dynasty) lump of iron. This is not meteoric iron but quite possibly slag from smelting a ferric-cooper ore such as is found in Sinai. Wainwright *(op. cit.,* p. 14), citing Hrozny *(Archiv. Oriental,* 1929, i. 281), states that King Anittash (who ruled *circ.* 1925 **B.C.)** possessed a throne and sceptre of iron obtained from a man of Purushkanda. This is the earliest record of the manufacture of iron known and the metal seems to have had a peculiar place in the religious life of the Hittites and Syrian people. Iron first appeared in Egypt during the reign of Totmes III (1501-1447 **B.C.)** in a manufactured state (Breasted, *Ancient Records,* ii, 537, etc.). The earliest types of copper spears were merely small flat beaten plates of metal. They

By the courtesy of Mr. Hawkes and Mr. Shorter, of the British Museum, I was permitted to examine the Abydos specimen of iron dated to the sixth dynasty (figured with associated objects in *B. M. Guide,* 1920). The piece adheres to a bent spear-head (one of the copper articles found in association). The original form of the piece of iron has been destroyed by cutting. The analysis showed that no nickel was present. It is possibly the result of smelting a ferrous-copper ore, but why the fragment should have been preserved with manufactured articles is inexplicable, and there is no evidence that it was produced as the result of a knowledge of the metallurgy of iron.

U.S.A. From private information no chronology (or period) has been fixed for the Americas similar to that of Sir John Evans for Britain, for the metals.[22]

GOLD. An ancient mine rich in gold has been re-discovered at Kazakhstan by Russian mining engineers. It is considered to date *circ.* **1000 b.c.** The hammers and plaques for crushing the ore were made of stone. Bronze tools and implements were found but no iron *(vide Sunday Times,* 18 April, 1937). Egyptian mining is the earliest known.

The use of stone hammers for crushing ore was recently discovered by French engineers who re-opened Roman mines at Bona. Their use in mines was continued until a late period. These mines, like those in Britain, had been worked by slaves, and one theory of the servile character of iron-workers is that they are the descendants of slaves who probably escaped from time to time from various places where mines were worked and the ore reduced to metal.[23]

were inserted in a slit in the shaft and secured by raw hide binding which passed through holes in the blade. Sir Flinders Petrie has illustrated types in his *Tools and Weapons* which are almost identical with those found among Red Indians of the U.S.A. until comparatively recently. The open-socketed spear was a later development and is found in use (made of wrought iron) now.

22 Prehistoric iron beads found in Egypt were made by bending meteoric iron. The mound builders of the Mississippi valley adopted the same practice. Prehistoric mounds contained celts of meteoric iron alongside those made from native copper (Rickard, pp. 141-7, citing Zimmer *et alia).*

23 The reason that so many gold mines are " worked out " is that the fuel question is not so important as it is with producing the base metals from ore. The mechanical process of crushing and washing the quartz takes the place to a great extent of the chemical process of smelting or reducing the ore.

The period during which native copper was first used in Europe and Asia was either the proto-neolithic or *early* neolithic. The invention of making baked clay vessels seems to have preceded that of smelting.[24] It is possible that the ancient process of heating water by placing red-hot stones in vessels containing water disclosed the presence of metal in these " fire-stones," specimens of which are found on pre-historic sites.[25] During the proto-neolithic and neolithic periods animals were domesticated and agriculture invented. The latter industry required continual vigilance to protect the growing crops from herbivorous animals. The domesticated beasts had to be watched whilst grazing by daylight and coralled (or tethered in herds at night by fires) to prevent attacks by carnivora. For these reasons the recent excavations at Maiden Castle and their results are among the most important in our history up to the present time. The effects of the domestication of animals and agriculture were to cause a definite division in the mode of life of the population. The hunters became nomadic pastoralists and agriculture produced the " mixed " farmer. For many centuries the interests of these two classes have caused conflicts and divisions.[26] These became first clans and later, tribes or nations. The industrialisation caused by the production and barter of metal, produced by smelting, introduced another factor which exists to-day. All this I saw in Africa, and it is the gist of our present problem in Palestine. There are three divergent interests: A, the nomadic pastoralists; B, the intensive cultivator; and C, the industrialist who produces nothing edible. It is to the " mixed farmer " or sedentary agriculturist that the world owes its present great metal industries. The use of marl for fertilising the soil in Britain is mentioned by Roman classical writers.

24 Certain tribes in Africa weave grass so perfectly that they use grass vessels for milk containers. There is no necessity to coat the insides of these vessels with clay to render them tight. From the fragments of ancient sherds it seems clear that the first burnt clay vessels were made by coating baskets with clay and roasting them until the outer basket cover was burnt.

25 Hematite (iron-stone) was frequently used for this purpose.

26 See the articles on *Erosion* in the *Geographical Magazine* for Sept., 1937, and March, 1938, by Mrs. Elspeth Huxley, also my *Dessication or Destruction* (in *Sudan Notes and Records,* 1935, vol. xviii, part 1, pp. 119-130).

PROCESSES FOR OBTAINING METALS FROM ORES. It is not intended to cite Strabo, Pliny or other classical authorities. Much of what was written was merely hearsay. In recent years considerable research has taken place in metallurgy, and in some cases the ancient processes have been found in practice until comparatively recently. Experiments have been made at the Royal School of Mines, and metal has been produced by some of the ancient processes.[27]

Fire was the principal agent employed to produce metals from ore. With the exception of iron, all the ores were smelted and molten metal was produced. As a general rule, the temperatures necessary were considerably higher than those required to melt the metals in a pure state. The actual processes varied very little for some thousands of years, so that a general description is in most cases applicable. The washing of iron or copper ores was not a ceremonial rite but merely a simple way of getting rid of matter which would only increase the quantity of fuel necessary, prolong the operation, and cause more slag to remain in the furnace.

MINING. Only rich ores found on the surface or in the beds of dry streams were treated.[28] When these visible supplies failed the art of mining developed. The outcrops and veins in the cliffs were attacked by means of open pits or tracing trenches. This is most

27 Unfortunately no records would appear to have been preserved of the total amount of fuel (charcoal) used by Professor Gowland when he smelted copper ore in an open furnace. One estimate which was kindly given to me was that the same weight of wood would be necessary as that of the ore smelted. A blast was used (private letter from School of Mines, Camborne).

28 In ancient times the copper miners cut nodules from the sandstone with flints. Ancient mines (pits) in the sandstone were found at Alderley Edge. Stone hammers were used with withy handles. The Llandudno pits were similar (Rickard, *op. cit.,* pp. 120, 200 and 458). The mines at Hofra-en-Nahas (Dar Fur) which were re-opened by a Copt, Shenuda, from Egypt in 1854 consist of pits 100 by 10 feet wide and 20 feet deep. They occupy an area of about half a mile square, and were described by D. C. E. Comyn in 1911. Mines were found at Arabah (*Illust. Lond. News,* 7, VII, 1934, p. 26) and may have been used by King Solomon. Delafosse (*Haut Senegal,* 1912) states that the metal from the Tegaddah copper mine was exported to Kubar, Zaghay and Bornu (Kanem). Gautier *(Sahara-Algerien,* plate xxxi) has illustrated the Tamegroun mine. The Katanga mines were probably worked by Arabs and Lake Bangweolo Ba-bisa (traders). Barth met a caravan from Hofra-en-nahas en route to Kano, the people of which town imported old copper and zinc from Tripoli at that time (*Travels,* vol. ii, p. 141, etc.). See also Herodotus iii, 23, 102, 115, etc., also C. T. Alford, *A report on the ancient and prospective gold-mining in Egypt,* 1900.

noticeable in the history of modern mining in India, Australia, South Africa, and the Yukon, where quartz is now treated instead of alluvial gold. The mines at Carthagena were great pits from which galleries ran. The rocks were split by fire, and although pre-historic flint miners sank shafts and worked in the chalk, modern mining engineers consider that the sinking of shafts and working of underground galleries in Britain dates to the Roman occupation. It seems certain that this branch of mining has been identified from the most ancient times with forced labour. It is possible that the early raids by the Egyptians into the Sudan were to recruit labour for the Sinai mines. Prisoners of war, criminals and political offenders have been sent to state mines until our own times. Caesar was impressed by the skill of the northern Gauls in military mining, but whether they were serfs or slaves is not stated. At the Great Orme's Head (Llandudno) copper has been mined from very early times. I was informed, when there in 1931, that at one time the sites of the pits, adits and Roman workings could be clearly traced. Until recently the rocks in the iron mines in Sweden were split by fire. Faggots were piled up against the gallery face and ignited. The drawing reproduced by Prof. Gowland shows a safety door.[29]

It is considered by some authorities that the Romans generally used quicklime, where it was available, in order to split the rocks. A boring was made in the face of the rock and a charge of quicklime was rammed in. Water was then poured on the lime with the result that the heat and expansion caused the rocks to crack. I saw a boring in the face of the cliffs at Llandudno which could have been used for this purpose. It is more probable, however, that it is a modern shot-hole intended for a charge of gunpowder. There is no sign of firing in the ancient Egyptian gold mines which were worked under the most appalling conditions by prisoners of war from a very early period. From the

29 *The Metals in Antiquity (J. R. Anth. I.*, vol. xlii, 1912). This is perhaps taken from the standard work of Agricola (*De Re Metallica,* Basle, 1556), which is one of the most valuable records of late medieval processes extant. Rickard has reproduced one showing the process of smelting iron by natural draught and another is the frontispiece to *Copper through the Ages.* This shows the process of washing the ore, etc.

account reproduced by Diodorus Siculus from Agatharchides young children were forced to work in these mines. Experienced Cornish miners have assured me that unless they had seen these galleries they could not have believed that human beings could have worked in them.[30] The children transported the pieces of broken rock in baskets containing about forty pounds weight by crawling between the feet of the miners. All the loose material was taken out of the mines. On arrival at the surface it was broken up and the non-metallic pieces discarded. In Carmarthen 500,000 tons of crushings represent Roman gold-mining there.[31] In places where hematite was found in clayey or earthy deposits deer-horn picks were used until a late period. The pieces of rock brought to the surface after sorting were broken up by hand-hammers or stone mauls on flat rocks or boulders. For the base metals, pieces of the size of a hazel nut were considered suitable for placing in the furnace. Gold was always smelted (like copper) in crucibles. Gold ore was reduced to a powder, similar to the pannings of alluvial gold. There were no means of ventilation in the ancient mines. If water was entering it was removed in vessels, and if not controlled by these means the mine, or such part of it as was necessary, was abandoned. Falls of roof were common, and as many as fifteen victims were found in one gallery in Spain.[32]

30 One of these mines has a shaft 275 feet deep and is being worked now. Messrs. Taylor & Sons, the mining engineers, published a history of Sudan mining some years ago. Sir Wallis Budge (*The Egyptian Sudan,* vol. ii, cap. 17) gives a long account of the industry and has reproduced the oldest mining map known, the original of which is in Turin. He gives a summarised translation from Diodorus. There is no copy of this work in the St. Albans Public Library, but any reader may borrow the work from the writer by application through the Hony. Secretary of the Herts. Archaeol. Socy.

31 There is no evidence that the Romans occupied Ireland. The largest quantity of ancient gold ornaments in Europe has been found there.

32 The Greek pinakes show miners working with an iron tool shaped on one side of the haft as a pickaxe and on the other half as a heavy sledge hammer. A roughly shaped pickaxe (found at Khorsabad) is figured by Neuberger (fig. 25, no. 5). One end is to be sharpened and the other flattened by further forging. It should be noted that these articles are wrought iron and not " crude blooms " as described in the text. The furnaces figured on the Greek pinakes are above-surface types and one is so high that it has a ladder to the top. They may be for silver or ceramic furnaces, but these high furnaces were used later for iron. The high factory chimneys are one of the methods adopted for increasing the draught. The present type of furnace is merely a development of a German type of high

FURNACES. The earliest furnaces were of the sunk basin type. Contrary to a generally expressed opinion, natural draught was used for producing iron. A hill-side furnace was found at Epernay (Marne) of which the base was *2 1/4*\ metres wide and the extreme height 2 3/4 metres. Similar types of furnaces (used with forced draught) constructed by cutting down a vertical section into the bank and facing the cavity with clay, have been found in use in India. A pair of furnaces were found at Huttenberg (Carinthia). They consisted of two shallow basins lined with stone and clay. (A) was 1 1/4 metres deep and 2 metres in diameter. (B) was three-quarters of a metre deep and *2 1/4* metres diameter. It is presumed that the shallower one (B) was used for roasting the ore to a red heat before being smelted in (A). In none of these ancient European furnaces is any air channel provided, A third type was found in Carinthia which was *2 1/4* metres high and one metre in diameter. In this the wind channel was a quarter of a metre wide at the entrance and narrowed to about half this size where it entered the furnace. Forced draught was not used.

Figure 1 represents a more modern type which was found at Velem (Hungary) by Baron von Miske and Dr. von Bandat. It was published in the *Illustrated London News* (March 2nd, 1929), and is reproduced to scale by permission of the proprietors of that journal. It is remarkable that many articles of bronze have been found on the site. The furnace apparently represents the transition stage from iron to bronze and is dated to *circ.* 1300-1100 B.C.

Figure 3 shows the system by which continuous forced draught is maintained in African furnaces to-day. It is similar to the apparatus found by Speke in use near Lake Nyanza. An Egyptian wall-painting of the period of Totmes III figures a similar apparatus also worked by two men.[33] Iron was known in Egypt then.

furnace which was used for smelting iron. The Fipa furnace and that described by Mungo Park are types of the high furnace found in Africa, of which the medieval iron furnace for smelting iron for casting (shaped like a beehive or cone) was the first used in this country.

33 It has been suggested that these paintings represented the " bloomery process " for producing iron. I have not seen the original fresco and cannot

It will be noticed that the African bellows are inflated by the use of sticks fastened to the skins over earthen pots. There are no valves and there is a certain loss of wind between the process of deflation and inflation as the pipes do not fit tightly into the nozzle fitted to the furnace. The Egyptian bellows were inflated and deflated by means of strings held in the men's hands. They stood and depressed the bellows with their feet. A similar arrangement to this was found in India worked by one man who worked alternate bellows by his feet. The bellows were inflated by strings attached to bamboos which he pulled down or released.[34]

As a general rule, charcoal was used at a very early period, but the first furnaces were fired with wood. This took a much longer time to produce the metal, although some African tribes still use wood. With charcoal and continual blast the process for producing iron takes about 4 1/2 hours, and with wood (in a surface furnace) from 20 to 24 hours or more.

express any opinion. Wilkinson (*The Ancient Egyptians,* 1878 ed.) has illustrated a gold smelter using a crucible and blow-pipe (figs. 413 and 415) at the time of Usertsen. The bellows are shown in fig. 432 (see also *Book of Exodus,* cap. xxxii, etc.). It must not be overlooked that a socketed iron spear-head was found at Buhen in Nubia which has been dated by stratification to the XIIth dynasty period. This terminated (as the Middle Kingdom) *circ.* 1788 **B.C.** Totmes III ruled as the sixth ruler of the XVIIIth dynasty, and an iron sickle found at Karnak is dated to his reign. It seems improbable that the production of iron in East Africa can be attributed to either Egyptian or Asiatic influences at that time, as Livingstone and other travellers considered. The well known spring shears or clippers which are made in one piece were invented in Egypt during the Roman occupation after iron was extensively employed in the manufacture of agricultural implements. At first the shears were made in three pieces, a spring and two blades which were rivetted together. This implement was possibly introduced by the Romans into Britain. The Romans also introduced the iron sickle into Egypt, which replaced various types of reaping implements used there.

34 Illustrated by Dr. Percy, *The Metallurgy of Iron.* It is evidently a labour saving device of the Egyptian type. Only two pots are used and one man does the smelting and blowing. The charcoal is fed by an inclined plane into the top of the furnace, so the third man (stoker) shown on the Egyptian painting (and used in Africa) is unnecessary. The skin bellows (similar to a carpet bag) were used in Egypt (*vide* Wilkinson, *op. cit.,* vol. ii, p. 313). Types of bellows noted by me are:—

Single clay pot; Jutland.

Ditto; Kordofan (?), generally used by blacksmiths. I am doubtful if one would be sufficient, as a continuous draught is necessary unless wind also is used.

Multiple clay pots: (four or more) Swabia, China, India, Uganda, Ancient Egypt (Rickard, fig. 31), Akikyu, etc.

Skin bags; Indian (Percy, p. 255), Akamba, Masai (Africa), etc.

Forced draught is necessary for wood fires in order to obtain a temperature exceeding 500° Cent.

All these furnaces were clay lined, and when the clay was fresh the furnace was heated gradually until it became very hot. It was lighted by a fire in the bottom and charcoal added until the necessary heat had been attained. Then handfuls of charcoal were added to make alternate layers of charcoal and ore so that the furnace was full. A cone of about three inches high of charcoal above the furnace mouth completed the charge. The blast was applied gradually until full pressure was reached, and as the charge began to sink it was replenished so that the quantity of metal to be produced was (by past experience) represented by the ore fired. Firing was then continued until all the contents had sunk to the bottom. The unconsumed charcoal, if any, and the slag were removed through the open mouth of the furnace. The metal which had sunk to the bottom was allowed to cool before removal by bent sticks, tongs, etc. This type of furnace could be used repeatedly and is frequently called the Catalan hearth.

The beehive type (Fig. 4) is also found is Africa, but it is small and does not produce the quantity that the same type of furnace figured by Mr. Straker[35] and used by the Romans for producing iron did. It is obvious from the dimensions of the Velem furnace that this would produce only a small quantity of metal. Probably sufficient bronze to cast one or two hollow celts or palstaves or some very small article in iron, such as the iron rings (money) found on the site. The African furnace[36] was merely a depression in the earth lined with clay of about a foot or more in diameter. A heap of charcoal and iron ore in alternate layers was then piled up, and when the pile was completed in the form of a cone it was enclosed by a thick

35 *Wealden Iron,* London, 1931, p. 19, states that the hearth of the furnace was 7 feet to 9 feet diameter (citing Bergrat Hundt for hearths used in Westphalia).

36 A fragment of a tuyere (blast pipe) was found underlying polished stone celts at Abodum (Gold Coast). Similar association of iron with stone implements was found by Capt. Rattray (*Ashanti,* chap. 26). See *Archceology on the Gold Coast in Antiquity,* vol. x, 1936, pp. 469, etc., also R. P. Wild (*Gold Coast Review,* 1927, iii, 2) *The Stone Artifacts of Gold Coast and Ashanti,* cited above. In view of Dr. Gsell's views (cited *ante)* these evidences may indicate a relapse of culture or the direct transition from a neolithic culture to iron at some unknown and perhaps comparatively modern period.

coat of clay. A hole was left at the top and fire was kindled by means of a burning brand or actual embers inserted in a hole made in the clay coat. The blast was applied through another hole and gradually increased. Both these holes were on the surface level. When the furnace was well alight it was kept replenished by alternate charges of charcoal (or wood in some cases) as in the preceding examples. The fire-hole was closed and all the charging was done from the top. As the heated material sank the fire-hole was re-opened and slag removed if possible by means of iron rods. The process was complete when all the charge had been consumed. The resultant mass (bloom) of impure iron was removed by breaking down a part or all of the clay cover. It was then treated as described later for iron. If the furnace were overheated the entire operation was a failure and the natives blamed some evil influence. Among some tribes the presence of women and certain other circumstances were considered as constituting causes of failure. It is obvious that overheating would produce cast iron in a very impure state (see later).

There is another type of furnace which was found by Mungo Park in use in West Africa. Fig. 2 is drawn from his description. A similar type of furnace in East Africa is described by Mr. R. C. H. Greig.[37] He describes the furnace as a kiln. It is the same type as Sir Richard Burton and others called the Indian. This type of high furnace was the predecessor of the great blast furnaces of to-day. The building of a Fipa furnace takes two days or more. Fifty or more men with their wives and children (for whom beer and beef must be provided) are necessary- A sacrifice is made before the walls are erected and another when the work is finished. Possibly, another before digging out the iron-stone. Part of the sacrifices was eaten and at one time the craftsman wore special clothing. The furnaces are

37 *Iron smelting in Fipa (Tanganyika Notes and Records,* No. 4, Oct. 1937). Glass beads and bangles are made from imported beads, pieces of old bottles, etc., by the Bida of Nigeria, who use an open furnace and crucible apparently. Capt. Mellor found a German mark on a sword captured and suggests these weapons came from the Sudan or Tuareg; that is that they are imports and not made locally (*Geographical Magazine,* Feb., 1938, p. 240).

about twelve feet high with a circular base of about six feet. The walls incline so that the building tapers to a diameter at the top of about four feet. They are constructed from the material found in ant-heaps, thoroughly kneaded by the feet with water. A hole is dug in the ground, and after the sacrifice has been made in it about twelve men stand in a circle and, starting with a thickness of about nine inches, ram and plaster the earth together. Scaffolding is used near the top where the walls are about four inches thick. The furnace is allowed about a month to dry by the heat of the sun. The pipes are made by covering long sticks[38] with ashes and coating them with the kneaded material from the ant-heap. They are also sun-baked. When the furnace is dry ten slits are cut in the walls at the ground level for the draught pipes. More pipes are placed end to end in a circle around the bottom of the furnace. Several pipes are placed in each slit and at least two layers about the bottom. The layers of pipes inside connect with those in the slits. The furnace is then charged with charcoal to a depth of about one foot, then a layer of wood, then a layer of ore and alternate layers of charcoal and ore until it is full. Two small pieces of lighted charcoal are then placed upon the top *and the furnace is then left.* No artificial blast is applied. In about thirty hours or more the operation is completed. A small peephole in the wall is left open and the slag trickles out at the bottom. When it is cold the impure iron is sorted out from the ashes. It is then treated further in a small blast furnace of about a foot high and about a foot wide. There are four holes spaced evenly at the base of this furnace (made from an ant-heap). One is for the slag and the other three are for blast pipes worked by three pairs of bellows of the " goatskin-bag " type fitted with clay nozzles. After the blast process the iron is reheated in an open hearth (a hole in the ground) and forged by men who use heavy stones and a large stone as an anvil. It is of interest to note that formerly the craftsman was given the temporary rank of a chief *(silungu)* and the first hoe made each year was presented to the

38 The pipes from the bellows to the furnace illustrated by Wilkinson were hollow reeds apparently.

tribal ruler who provided the special clothes for the *silungu.* The foregoing is merely an abridged account of the process given in detail by Mr. R. C. H. Greig. It is the only one which I have seen in which two firing processes are used without smelting the ore. Roasting the ore in Europe was generally conducted in open fires, and the ore was considered fit for the furnace after it had been heated to a red heat and allowed to cool. Neuberger has illustrated (Fig. 23, *op. cit.)* a type of furnace which he has described as a " Kordofan bloomery." The iron industry has been carried on there from an unknown period. This furnace consists of a hole in the ground shaped like an inverted hollow cone.[39] The blast is furnished by a bellows of the " bowl-and-skin " type common among native blacksmiths, but the pipes are led about halfway down the furnace. From the quantity of material piled on top of the furnace above the ground level this would seem to be similar to the early tin furnaces found in Cornwall (of prehistoric date) described by Professor Gowland. At a later period the Cornish furnace for smelting tin was constructed in a bank and assumed the U shape with the back longer than the front. Two holes were made, one at the bottom for the exit of the molten tin, and another at a point higher up for the blast pipe. In Japan the tinstone was smelted in a basin furnace, the lip of which was at ground level. The blast pipe from a box bellows rested on the lip of the furnace at a slight downward incline. The metal was ladled from the furnace and cast in moulds. The drawing before me (reproduced by Professor Gowland) has a specially human feature. The exhausted coolie who has worked the blast is sitting down smoking and watching four other men work.

These are the principal characteristics of numerous types of furnaces used by the ancient metallurgists. As a general rule certain types were characteristic of certain territories. In Africa they vary considerably

39 Said to be later development of the sunk U type. Magnetic sand was treated in Kordofan, *vide* J. Petherick, a Cornish mining engineer at one time British consul in the Sudan. Iron nails were used as currency.

in different tribes and localities.[40] Whether this is due to diffusion of culture, migration or exotic influences seems to be a moot point in each particular case.

* * * *

COPPER AND BRONZE. After the ore had been smelted the slag was removed from the top of the furnace and the metal allowed to cool. It was then withdrawn through the open top of the furnace. The Bexley Heath hoard (found in 1930) on exhibition at the British Museum, contained some cakes of the metal which had taken when cold the shape of the bottom of the furnace in which the ore had been melted. It is possible that any solid impurities in these cakes were expelled by hammering, but the exhibits show no signs of such treatment. Pure copper cannot be cast satisfactorily, but a very small percentage of tin or zinc makes the operation practicable. The reason is that pure copper cools, leaving bubbles, etc., in the cast. Whether these could be expelled by hammering is questionable. Many of the ancient flat celts (axes) found in Egypt are almost pure copper, and it is a curious fact that the socketed axe was not adopted for general use until a late period. Tin has not been found in Cyprus, the principal source of Egyptian copper supply at one time. The earliest moulds were of the open type. I have seen specimens in museums labelled half-mould. The cast was beaten when cold so that both sides coincided in shape. It is by hammering only that copper and bronze were hardened to an almost steel-like state. In some cases the edges of weapons were ground after hardening but generally the cutting edges of axes and spear-heads were hardened by hammering.[41] Later closed moulds in two halves were used. No sand moulds have been

40 During the Sudan Mahdia all the wrought iron posts were used. Blacks from Dar Tama made weapons for the dervishes from manufactured (and imported) iron of all kinds. The lead seals used by the Customs at Suakim and all available supplies of lead were melted for bullets. The Sudanese-Arabs have not taken naturally to the musket or rifle as the North American Indian and other races have done.

41 I understand that the metallurgy of copper forms now a special subject of research, as far as ancient methods are concerned, at the special laboratories at Twickenham. The casting of metals and the manufacture of articles from ingots of forged iron or cast bronze or brass was frequently done at sites many miles distant from the sources of the metal supply.

found. A wall painting at Karnak, dated to *circ.* 1600 **B.C.,** shows the process of casting in sand a pair of temple doors in bronze. These doors have no hinges and are of the " pintle " type of which specimens in wood are in use at Luxor, etc., to-day. Sand was used apparently and the molten metal was carried in crucibles and poured into the mould through numerous vents. The beauty of the carving and the accuracy of the stone moulds have never been surpassed in modern times. Swords were cast in stone moulds heated to red heat, otherwise the metal was so thin that it would not have been evenly distributed. The metal for casting was invariably smelted in a separate vessel (crucible). Most of these crucibles are small, as they were arranged in the furnaces as far as practicable to prevent the vessels cracking. Most of the ancient types held only sufficient metal for a celt or a large hollow palstave. Ireland was a great source of copper supply until comparatively recently. As late as the middle of the last century a cargo of copper ore was sent from Ireland to Swansea to be smelted. In the sixteenth century when an attempt was made to re-open the Cornish mines the ore was sent to Neath to be smelted and the copper ore found at Worle (Somerset) and calamine were converted into brass at Tintern Abbey. The oldest working mine in the world is at Falun (Sweden). It is still at work and owned by the same company which was founded during the thirteenth century. The copper ore mined at Keswick was smelted at Brigham. It is claimed that the use of copper in Ireland dates back to **2500 B.C.** as compared with the bronze era in England and Ireland of **1800 B.C.** (round barrows of the neolithic period). There seem to be considerable variations in the metal chronologies of most of the northern countries of Europe. It is quite possible that Ireland and

Wire-Drawing:—This was done by drawing soft metals such as copper, silver, wrought iron, etc., through plates of hard metal which were perforated by holes of varying sizes. It is practised now in the West Indies by the Indian coolies who have settled there after employment in British Guiana. I have seen native jewellers in Africa doing this, but the manufactured strips and wire have displaced most of the handwork in native jewellery now. The Akamba tribe use a bow (G. Lindblom, p. 530). At the end of the 17th century a wheel was used in Europe and a longer staple produced.

Scandinavia used copper at a later date than the southern Britons, although iron was found in both countries.[42] In Ireland metal production has been handicapped for some centuries by the lack of fuel. One of the finest specimens of castings in bronze is now in the Tower of London; it is a Turkish cannon dated 1464 and weighs 18 tons. Guns of this type were used against a British fleet at the Dardanelles in 1807. The calibre is 25 inches and a stone shot weighing 6 cwt. killed and wounded sixty men. When I was at Suakim stone balls of a much less calibre were found outside the walls. They had been used by the ships (probably Portuguese) of the 16th century, but had been fired from iron cannons. Suakim was sacked by the Portuguese.

The " cire perdue " method of hollow casting was illustrated by me in a paper on coins. Fig. 5 is a simple sketch of the process for casting a hollow socketed spear-head. Although solid castings in bronze were made by some of the pagan tribes in West Africa the " cire perdue " process was unknown to them.[43] The method is as follows. A clay core resembling the article to be cast is fixed on a stick, or rod of metal. This is thickly coated with several layers of beeswax and the exact details of the casting are if necessary cut in the wax. This waxed core was then covered with a thick covering of clay, generally ewer-shaped with a mouth to admit the molten metal. As the metal was poured in, the wax was consumed by the heat, or displaced. Later moulds were made in sections and the quantity of metal used is very small. From an early date, brass and copper vessels have

[42] It is possible that some of the Scandinavian rock drawings are of the Iron Age. The chronology of many reputedly prehistoric rock pictures in Africa has been somewhat discredited by French scientists lately. A complete wooden plough (dated *circ.* 400-0 **B.C**.) was found at Traesagar (Denmark). See p. 227 and *Origin and Early diffusion of the Traction Plough* by C. W. Bishop (*Antiquity,* X, 1936) and my remarks in *Man* (April, 1938).

43 Tanged implements and weapons represent both forging and casting probably, in all metals, except iron in ancient times or among people who used raw copper (i.e., native copper). It is probable that the plated Roman coins in the Taunton Museum were cast from copper mined in Somerset or old worn coins re-smelted. Copper is found in Yorkshire and the same remarks apply to the coins in the Yorkshire Museum (York), of which illustrations (photographed) were published by me.

been hammered from sheets or thick slabs of these metals. The Eastern gongs and large hemispherical drums now found in Africa were all made by hammering the metal.[44] For these large objects it is probable that some form of mould was used for hammering the large brass drums from Dar-Fur which I examined in Khartoum. A section of a copper pipe made by beating a plate around a wooden mould was found in a rock trench (embedded in gypsum) in the temple of King Sahura at Abusir. It is now in the Berlin Museum with many other Egyptian antiquities which were presented to the King of Prussia by Muhamad Ali Pasha, about the middle of the last century.

TIN. This metal was produced by smelting tinstone. Its use in Cornwall may date to an early stage of the neolithic period. There is no evidence to connect the Phoenicians with Cornwall, but the authenticity of the Egyptian faience beads to which Mr. Crawford drew my attention some years ago is beyond question. They have been analysed and found identical with those of the XIX dynasty *(vide* Petrie, *op. cit.,* p. 63).[45] Further it has been definitely proved that the box-wood from which the Egyptian chariot wheels were made was obtained from Southern Europe. When I was a boy I was shown a temple under the cathedral at Ancona. The panels in this temple were said to have been Egyptian and the temple

44 The illustration (plate XIX) reproduced from a work by Duhamel du Monceau in 1764 in *Copper through the Ages* represents a comparatively-modern process. The heavy hammers are worked bv a water-wheel. The first of these in England is attributed to Seaton. The basin is fashioned on an inclined plane, but kettles and similar articles were hammered bv the same processes as those illustrated in the *Encyclopedia Britannica* for silversmiths. I suggested that the distortion in many of the coins of the 5th century was due to the use of brass dies produced by hammering two discs (on top of each other) in old dies. Skin-Casting:—The first glass bowls were made bv this method, i.e., the molten material was poured into a mould (probably very hot) and then the mould was moved in a circular manner until all the inside was covered. It is said that metals were cast by this method but the vessel was filled with molten metal and then when the sides had cooled the interior molten metal was poured out.

45 Some of these beads are in County museums and Mrs. Wheeler found one or two Faience beads of a later period at Verulamium. They were worn by women as charms against childlessness, etc. (see *ante* re lead poisoning). At one time the tin coins found in So. Wales and at Reculver were supposed to be earlier than the British and Gaulish types, but I understand that they are possibly later than the Christian era or even the Roman evacuation of Britain.

dedicated to Isis. Whether the Egyptian ocean-going ships ever traded to any other ports west of Cyrene during the second millennium B.C. I have not seen discussed. The earliest finds of tin in Britain date to the late Bronze Age. The pig of tin dredged up at the entrance to Falmouth Harbour has two projecting arms at each end. It apparently was cast in sand. It measures **2** ft. **7** ins. long and is **10** ins. wide by **4 3/4** ins. thick in the centre, from where it tapers on one side only to the ends of the arms. This shape was said to have been made to facilitate transport by boats and pack animals *(vide* Col. James).[46] Tin was found in Ireland in the streams and gravels of Wicklow, but there is no evidence that the Romans had any settlements there. The Etruscans mined tinstone in Italy, and there are ancient mines in Spain. The most ancient mines are considered to be those in Khorasan (Persia), and some authorities consider that the ancient Egyptians drew their supplies from there. The metal is plentiful in China.

As a general rule Roman taxes were paid by tributary peoples in kind and not in money until the Roman coinage had been established in the country. It is clear from the evidence of Dio Cassius that metal producing people paid in metal. The currency bars in the British Museum are probably iron examples. From the situation of the furnace at Trereife Professor Gowland was of the opinion that the manufacture of tin from ore was conducted by a semi-independent tribe in Cornwall. Such a policy would be consistent with the character of Vespasian or the policy of Agricola.

From an early time tin has been used for plating other metals. When I first went to Egypt native cooks used copper vessels, and numerous cases of digestive

46 It approximates to the " bull's hide " Cretan copper ingots in shape. Mr. Theodore Bent found a soapstone mould at Great Zimbabwe of a similar shape. This was used probably for casting copper or gold. The Portuguese Jesuits introduced currency ingots of copper, shaped after a St. Andrew's cross, in the Congo, which are illustrated in *Le Congo Illustre.* Poncet found similar tokens made of iron when he travelled in Nubia in 1698 on his way to Abyssinia to cure the king of that country of scurvy. See also Wilkinson *(op. cit.,* vol. ii, p. 245) for Kordofan iron money (hashasha = hoes).

trouble[47] occurred among the British community. I replaced my cooking pots in the Sudan by aluminium as the enamelled pots were just as unsatisfactory.

SILVER. As a general rule silver is associated with lead in ores. Until recently the silver could not be extracted from the ore unless lead was present, *i.e.* by adding it in the smelting process. In a molten state the metals do not separate like water and oil. Lead oxidises on exposure to the air and will disappear in time. If a piece of galena (ore of lead and silver) were used as a hearthstone and left or abandoned after the metal had become molten from it, the lead would disappear and a tiny bead of silver remain. A refinery for producing silver from galena was found during the excavations at Silchester. The furnace was a hole in the ground surrounded by a low stone wall. Similar furnaces were found at Laurion (Greece) and in Derbyshire. The metal produced was a mixture of lead and silver. This was separated by cupellation. The laboratory process for assaying is described in the *Encyclopaedia Britannica.* In commercial practice the ancient practice was to enclose the hearth by a stone or thick clay cupel (dome). The hearth consisted of a shallow cavity in a layer of bone ash which was enclosed by the cupel in such a manner that it left two chambers, one above the other. The somewhat extraordinary iron furnace of the Bongo tribe illustrated by Dr. Schweinfurth (Fig. 6) is suggestive of cupellation to the layman. A charcoal fire was made in the cupel and the lead from which the metal was to be extracted was placed upon it and melted. The fire was then raked off and a blast of air introduced to oxidise the lead, which was then absorbed by the bone ash. A cake of silver was then left in the furnace. This silver cake might contain gold. If copper were present the operation was repeated with the addition of a small quantity of pure lead in another cupel. The process in Japan is shown by Professor Gowland on Plate XXVIII of the Huxley lecture given by him in

47 Caused by verdigris. Possibly caused by the procedure of cooking salt with the food and not adding it at table, also uncleanly pots, etc. Tin volatilizes at a low temperature and is easily attacked by common salt. The practice of tinning copper cooking-pots is not always effective.

1912. It is very remarkable that the Japanese have practised this process since the "Dolmen Culture" period of their history. It must be remembered, however, that this was much later than our Avebury, Stonehenge, and possibly the Carnac period.[48]

The use of silver was unknown in Northern Europe in the pre-Roman period, and it seems that cupellation was introduced into Britain by the Romans or from Gaul. The Scandinavians and Germanic races refused to accept the base silver coins of the Romans. One of the first steps the Saxons took was to melt down the copper-cored and silver-plated coins. This must have been done by heating each coin separately so that the silver coat melted before the copper core. Very few of the coins now found in England are plated with pure silver.

ZINC. This metal was unknown in a free state in England until it was discovered in the cargo of a captured Spanish galleon. It was imported into southern Europe from the East.

LEAD. This appears frequently as a natural alloy with copper. It caused the bronze produced to be soft and easy for casting. It is, however, now considered to be an artificial alloy if more than 8 per cent, lead is found in the bronze. The metal seems to have been regarded as practically useless in the Bronze Age as it was too soft for implements or weapons. It has been suggested that iron was not used as the metal when cast was so brittle that it was dangerous as a weapon and useless as an implement. The Japanese warriors continued to use brass swords, battle axes, etc., long after they also used iron for other purposes. Socketed celts with a high percentage of lead which rendered them useless have been found in burials, and it is believed that they were cast for sepulchral purposes only.

The earliest known specimens of lead were found at Hissarlik as shapeless lumps. They date from *c.* 3000-2500 B.C. A figurine and wheel from the same

48 The dolmen cult still exists in Assam, I believe, and the huge stones are carried bv many men who have what is practically a raft of poles under the monolith. There was an article in *Antiquity* some time ago upon the subject.

site are dated to 2500-2000 B.C. The metal was obtained from a neighbouring site. Lead discs were found at Mycene. At Tiryns lead was used for repairing the large earthenware jars in much the same way as tinkers used to do in this country. The great Laurion mines in Greece may have been worked by the Myceneans. Lead was little used in ancient Egypt. A wooden hawk covered with lead sheet was found at Naqada and is considered to indicate a stage in the manufacture of metal statuary, etc. Lead mining was developed in Britain by the Romans, who used lead very extensively in architecture and for domestic purposes. Pigs have been found dated to the reign of the Emperor Claudius, so that the industry must have been started soon after his occupation of the island. The process of smelting lead from ore is the simplest and oldest extant. An open shallow hearth can be used. This is filled with a bath of molten lead, and on this a coke (or charcoal) fire is floated which is maintained by blast pipes placed above the level of the molten lead bath. Ore is placed on top of the coke and continually stirred so that the galena melts and the lead sinks, leaving the slag which is skimmed or tapped and generally re-smelted. Pliny confused tin and lead. Roman pipes were soldered as they were made of plates rolled round wooden rollers or moulds.

IRON. The Bloom Process. I am not satisfied 'that this process was not originally used for the production of copper in Egypt from certain ores before smelting was invented by means of the artificial blast. For many years Victorian antiquaries and travellers declined to accept the metallurgical fact that iron could be produced from ore at a temperature less than the melting point of iron.[49] One of the earliest records of the "Bloom Process" is that of Diodorus Siculus, which survives in parts of his own and other copyists. He wrote *circ.* 8 B.C.[50] after travelling extensively in Egypt, etc. He wrote of Elba as follows:—"In the island of Aethalia (Elba) abounds ironstone which the

49 As an example see Wilkinson *(op. cit.,* vol. ii, pp. 248 *et seq.).*

60 There is a French translation in the British Museum. I know of no English translation of the original work, which is in a dialect of Greek and mostlv the result of personal observation.

natives dig and cut out of the ground to melt, in order for the making of iron; much of which metal is in this stone. The workmen employed first cut the stone in pieces, and then melt them in furnaces built and prepared for the purpose. In these furnaces the stones, by the violent heat of the fire, are melted into small pieces, in form like great sponges " *(i.e.* blooms), "which the merchants buy by the exchange of other wares.[51] They export them to Dicaerchea and other market towns."

As far as we know now the Hittites were probably the first people to produce iron from ore on a large scale. It is curious that Herodotus should speak of the Curetes (Cabiri, Idaei, Dactyli, etc.) of ancient Euboea as previously copper workers at Chalcis before they became iron-workers, as it would seem to show that iron followed copper from Asia Minor westwards. The iron bedstead of King Og of Bashan was made of wrought iron produced by the " Bloom " process (see Deuteronomy, cap. iii, verse 11).

The temperature necessary for the bloom process of iron should not be lower than 700 degrees Fahr. or exceed 932 degrees Fahr. (500 Cent.). Some of the vitreous slags become molten during the process, but the iron is merely soft (at a white heat) and disintegrated from some of the elements with which it was in combination as ore. Ores containing less than 40 per cent, of metal were not treated by the ancients.[52] In Chandghur (India) " pakka " *(i.e.* purified iron) of a quality superior to British, produced by the bloom

51 From *The History of the Iron Trade* (p. 12) by Harry Scrivener, London; for the loan of which I am indebted to the late Professor Bone. The currency bars of Britain, the iron hoes and spear money of Africa and the iron rings found in Austria, etc., are all forms of local and standardised currency to facilitate barter. See Camden, 1607 ed., p. 65, for large finds in Britain. Mr. Thomas has illustrated a curious form of currency found at the Hofra-en-Nahas copper mines. There are also specimens of iron currency used in Dar Fur, the Bongo, Congo, etc. *(vide* catalogue of the ethnological collection of the Egyptian Royal Geographical Society, Cairo).

52 In the 16th century the iron masters in Glamorgan and the Forest of Dean re-smelted the slags (discarded by the Romans) to save the expense of mining ore (M. A. Lower, *Hist. & Arch. Memo, of Iron Works of S. E. England).* Large heaps of slag have been found in Yorkshire which are attributed to the Brigantes whose territory extended from the Humber to the Wall of Hadrian. There was a branch of this tribe in the counties of Wicklow and Waterford. As late as 1642 dug outs (Cots) were used to transport the ore from Mountreath in Queen's County by water to Waterford for shipment to So. Wales.

process, required tons of ore and 81 tons of charcoal (or 41 1/4 tons of wood) to produce one ton of iron.[53] As a rule the crude bloom produced last 50 per cent, in weight during the process of expelling the impurities by hammering. Prior to A.D. 1086 water-wheels in England were used for milling grain. After the invention of water-power hammers, bellows, and other machinery by Smeaton and Watt, the windmill was introduced for milling corn. As a result the sites of the two industries became reversed. The corn was milled on the hill tops and the iron was produced in the valley by a stream.[54] A similar change of location took place when an Italian water-blast was used.

The Emperor Hadrian founded a college (guild or Fabri) of armourers (Fabri aerarii and Fabri ferrarii) at Bath. This was regulated later by the Justinian and Theodosian codes. The sale of iron weapons to non-Roman citizens was a penal offence, but the use of iron agricultural implements was permitted to slaves or serfs. It is possible that such articles were sold openly, but the export of iron in any form to Barbarian tribes was interdicted under a death penalty. During the second century the army smith was called a primicerius and no person was allowed to forge weapons unless a member of the Fabri or guild. These persons were branded on the arm (stigma) and performed a life service at the craft.[55]

According to the Domesday Book the town of Gloucester furnished a tribute of 36 dicars (each ten bars) of iron bars and 110 bars of iron rods (for nails and bolts). In the tenth year of Edward II the Scots raided Furness (a seat of the iron industry) and carried off all the iron. This incident might render some basis

53 Under the most favourable conditions about 70 per cent, of the metal content of the ore treated by the bloom process was produced as iron. Scotch and Cleveland ores were not worked. Some of the present copper mines yield a profit now with a nett result of 1 per cent, metal of the ore treated.

54 See Straker, *Wealden Iron,* Ree's *Encyclopedia,* and Dr. John Percy *{op. cit.)* for illustrations of medieval furnaces, hammers, blowers, Catalan plant, etc.

55 Jupiter Dolichemus was the protector of the iron-workers. An altar erected by Calpurnius has been found. I suggest that those branded were not free-men. About **A.D**. 86 Sallustus Lucullus, the Governor of Britain, invented a lance and allowed it to be called the Lucullan. He was executed by order of the Emperor Domitian (Suetonius, Loeb's edn., Domitian X).

to the view that the raids of the Picts and Scots during the Roman period were due to the interruption of their trade in iron, etc., with the Brigantes. After the reign of William the Conqueror most of the iron was not made in Britain but imported from the continent. Imports of iron were prohibited in 1483. In the eighteenth century the quantities of foreign iron imported (in consequence of the diminished production through restrictions on fuel consumption dating from 1558) were so large that its production in the American colonies by slave labour was encouraged. Protective duties were enforced against foreign manufactured iron from 1772 until 1826. Numerous works were started by Germans, among them those at Tintern Abbey.[56] The history of the British iron and steel trades is not one of steady development and expansion by manufacturers.

CAST IRON. Statements that African or Asiatic natives smelted iron, published in books of travel, etc., must be received with caution. The casting of iron in Britain, etc., is a comparatively modern art as compared with that of copper. It is possible that the Chinese were the first to utilise the molten metal for hollow castings. There are in the British Museum cast iron vessels of the Han dynasty (206 B.C.-A.D. 220). The earliest specimen of cast iron known in Britain is in Burwash churchyard. It is a memorial tablet on a grave of the fourteenth century. Georg Agrikola[57] has described the process of making cast iron. The first mention of mined coal for fuel is in a land grant of Peterborough Abbey: dated 853. As late as 1665 Dud Dudley stated that no iron was made in Scotland.[58]

56 For further details see Scrivener *(op. cit.)* and the *Encyclopedia Britannica,* xiv ed. It is possible that the sceptre, attributed to Jupiter, which is illustrated in the *Antiquaries Journal* (Jan. 1938) is the insignia of some Iron Master and not that of a British king. Venutius was king of the Brigantes in **A.D**. 71 and was attacked by the Legate, Quintus Pettalis Cerealis, who founded York. See also *Mapungubwe* by C. van Riet Lowe in *Antiquity* X, 1936, pp. 282, etc. Finds were similar to those at Zimbabwe. The occupants of the site (in Northern Transvaal) were Shona (from Rhodesia) and Sotho (from Bechuanaland). They were the vanguard of the Bantu invasion and the Sotho appear to have introduced a little iron. Quantities of copper found. Earliest date assigned medieval or post-medieval.

57 *Mineralogische-Schriften* ubersetzt von Ernest Lehmann, Freiberg, 1810.

58 *Metallum Martis* **or Iron made with Pit-coale, etc., London,** 1665.

In 1611 a patent was taken out for smelting iron by using coal, but it was not until one hundred years later that Abraham Darby produced cast iron in pigs. The first cannon were made of wood and then iron bars were later forged together and secured by rings shrunk on.[59] The casting of iron cooking pots is a modern invention, as also that of casting artillery.[60]

An apprentice who had assisted his master in experiments *re* pots discovered the cause of his employers constant failures. He preserved his secret until the ironmaster discontinued business and died. The ex-apprentice then patented the process and made a fortune. The tripod iron pot was at one time a standard article of trade between Britain and Africa until German competition severely affected the manufacture here.

WELDING. Although many African smiths can weld iron it is not a general practice. Pure iron at white heat oxidises immediately upon exposure to the air. A flux is necessary to prevent a film forming. British smiths use sand which is beaten out in the process of joining the pieces of iron by hammering. The joints on some iron weapons I bought near Abyssinia were shrunk and bound with raw hide.

NATURAL STEEL. This term is applied to the nodules formed in the slag from which certain iron ores are reduced by charcoal. In India the slag is broken up and these nodules melted in crucibles so that the metal can be re-heated and treated as wrought-steel in a similar manner to wrought-iron.

Wootz was at one time considered a form of natural steel. Its manufacture has been described by Sir Richard Burton,[61] who has compared it with iron

59 First iron cannon used in Europe was at Baza in 1323. Mons Meg and similar guns are wrought iron. The celebrated Columns of India which were considered at one time to be cast are wrought. They are probably the finest specimens of wrought iron in the world. The workmanship is so excellent that the joints where the rings were welded are not noticeable and the columns are rust-proof. The Delhi pillar is 22 ft. high, upper diam. 1*2 1/2* ins. and lower diam. **16 1/2** ins. It is dated **A.D**. 300 and the Dhar column (A.D. 321) was twice that size before it was broken by the Moslems. These columns appear in old books as of 1200 **B.C**. date.

60 Pure wrought iron was used. They were cast solid. The core was bored by water-power. Hence the term " bore " applied to firearms and artillery.

61 *Book of the Sword.* Much of the Wootz made in India was produced from African iron which was exported from East Africa.

manufacture in Africa. The Fipa iron (see *ante)* would produce natural steel if the metal were worked in a charcoal fire and continually re-heated at a red heat, beaten and plunged into cold water before re-heating in charcoal. It is this steely-iron which is such a characteristic of African smiths who manufacture throwing knives, spear-heads, etc. It might be described as malleable steel, perhaps, or wrought-steel. The Portuguese prohibited the export of iron as they found it returning as weapons for natives.

WROUGHT IRON. This is produced by the bloom process. For some time the process of hardening by plunging the metal into cold water when red hot appears to have been unknown. Polybius alluded to the poor quality of the Celtic iron in **223 B.C.** as their long swords bent at Addua. Several chariot burials contained iron rims (wrought-iron) of nearly three feet in diameter. No scythed or sickle axes have been found in Britain similar to those of Pontus dated 47 **B.C.** The Wookey Hole dagger (illustrated by H. E. Balch in " Wookey Hole ") is considered to be one of the earliest known specimens of British iron manufacture. Iron agricultural implements of an early date were found at Glastonbury, but as a general rule iron weapons are few in the *early* iron ages.[62]

The bloom process is still used on the continent, and I saw a plant in Norway which I believe was worked by water power and re-smelted cast iron scrap. The early iron cauldrons were made of wrought iron and rivetted similarly to early bronze types.[63]

GOLD. This metal was first obtained by washing auriferous sand in shallow dishes. An expert native washer can obtain gold by this means under conditions with which the most modern and scientific

62 A very large bloom was found at Corstopitum, near Corbridge, which weighed 3 cwt. 8 lbs. A simple test for iron or steel is that of nitric acid. A drop produces a black spot on steel but pure iron remains bright. The Roman *follis* (bellows) originally consisted of two skins. The blacksmith's bellows was developed from the Roman domestic type. The earthen-pot system has been described by some writers as Moslem, but it is clear that the ancient Egyptians used them at an early date. The skin bellows may have originated in Asia, but the evidence is so conflicting that it is difficult to determine any definite traces of cultural diffusion or local invention under existing conditions, and opinions differ.

63 There is a fine collection of wrought iron utensils in the Royal Scottish Museum, Edinburgh.

methods cannot compete economically at present. I saw natives washing gold on the Abyssinian frontier near the site of Muhamad Ali Pasha's " El Dorado." These people had constructed artificial streams in the bed of a perennial river and at short distances had excavated basins to catch the deposits washed down. They then washed these deposits. In India a similar process has been adopted for an unknown period for washing sand for gold and also iron. The methods described by Herodotus are merely attempts to debar powerful nations from seizing the land and enslaving the inhabitants to work for their conquerors. In other words, a trade secret.

Quartz mining has followed exhausted alluvial deposits all over the world. The earliest quartz mines known are those of the ancient Egyptians in Egypt and the Sudan. Expert mining engineers consider that some of the disused shafts in South Africa were made by a pre-Bantu race, and that the "Sofala" alluvial deposits were worked by Bantus or natives (who had no knowledge of quartz mining) since the Moslem era and subsequent to the exhaustion of the Indian alluvial deposits, where so many Roman and coins imitated after Roman types have been found.

The Egyptian mines have been worked by ancient Egyptians, Persians, Greeks, Romans, Bega, Arabs, Europeans and Australians, all of whom have left distinctive traces behind them. The Egyptians used forced labour under conditions similar to the Russian mines in the Urals and Siberia. Practically no machinery was used, and the tools were of the most primitive character.

The ore was crushed by stones (held in the hand) on a large rock until it was about the size of a hazel nut. The earthy matter was washed out as far as possible, and any metal separated from the dust in the process. The small pieces were then crushed to a powder by rolling them with heavy rounded stones in a shallow stone trough.[64] At a later period (probably

64 Fig. 4, *The Metals in Antiquity,* by William Gowland (J. R. A. I., vol. xlii, July-Dec., 1912). In South Africa the crushing is done by Zulus in a mortar with a pestle. It is remarkable that the pestle (wood and iron) and mortar (stone) are the same patterns as the grain crushers used in the Sudan.

Roman) beautifully fashioned mill-stones similar to the type used in Japan in **1872** were used.[65] Their successors used very crude querns, some of which were made from the broken mill-stones found on the site.[66] Stone chisels were used, and at a later date bronze, but stone hammers and mauls continued in use until a late period.

The crushed dust was washed as free from earth as possible in the trough. The remaining mud was then placed on a washing table constructed of stone in the form of an inclined plane.[67] Various methods have been suggested for the sifting of the metal from the earthy matter. The most obvious is the simplest, suggested by Dr. Bloss *(op. cit.* pp. **314-5)** viz., a coating of clay was made on the table, and as the mud was washed on it the particles of metals adhered to the clay and the refuse was run away with the water.[68] The metallic residue was then purified by smelting it in a crucible with salt and washing the product in hot brine.[69] Other methods for refining the gold have been suggested, such as that cited by Budge, the use of fleeces, cloths on the tables, etc.[70]

65 Gowland, *op. cit.,* sup. Pl. xxvii, fig. 2 and Pl. xxviii, fig. 2.

66 J. F. E. Bloss, *Relics of Ancient Gold Miners,* Pl. xxviii, fig. 2 (*Sudan Notes and Records,* vol. XX, part II, 1937). The ancient Egyptians did'not timber the shafts. This has been done by later workers who enlarged the shafts and galleries. The Ptolemaic crushers used implements for crushing similar to those in use in South Africa.

67 J. A. Rickard, *Man and Metals,* fig. 37, from a photograph supplied by the present writer.

68 See fig. 8 (p. 3) and painting from Beni Hasan, 16th century **B.C.,** and figs. 28-30 (Saqqarah, etc.) in *The Technical Arts of the Ancients* by A. Neuberger, London, 1930.

69 Gowland, *op. cit.*

70 J. A. Rickard *{op. cit.,* pp. 244-254) considered that the Bantus mined in deep rock from 1550-1872 and that prior to that period alluvial deposits in South Africa were worked. The Um Rus mine (Egypt) is 292 ft. deep and 1,500 ft. long. Dated to 600 **B.C.** by Rickard *{op. cit.,* p. 226). Strabo states that the Phoenicians were great slave raiders (? from Herodotus, I, 1, etc.) and upon one occasion sold 10,000 Taphians in a day. Strabo gives the original home of the Phoenicians as Bahrein (near the ancient copper mines of Oman) and a detailed account of the transactions of these Semites will be found in Ezekiel, cap. xxvii. Their power was destroyed by Alexander the Great. The principal cities were Sidon, Tyre, Gaza, Berytus and Bibylus (where tin was found). The Idaean Dactyles were supposed to have discovered iron after the forests on Mount Ida had been burnt. The Curetes were the priests of Jupiter in Crete, and are the Abantes of Homer. The Chalcideans founded Cuma in Italy and Naxos in Sicily during the first millennium **B.C.** (Mythical history). The Chalybes mentioned by Xenophon as iron-workers are possibly the same as the ancient Chaldei of the N.W. mountains of Mesopotamia, and maybe were akin to the Hittites, or fugitives when the Hittite empire was destroyed.

MERCURY. The metal was first mentioned by Theophrastus in the third century B.C. It was not used in England for the purpose of refining silver until 1540, and there is no evidence that it was used in Egypt by the Persians before the Christian era.

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Although the ancients (and some African tribes do now) used a variety of substances as fluxes in reducing ores or smelting metals, the processes for extracting metals from pyrites (sulphides) were later developments. The pyrites processes might be considered to date a definite period in metallurgy. For these reasons analysis of ancient slags and expert metallurgical opinion is necessary before any definite chronology can be placed upon each individual smelting site. The archaeological evidence is not sufficient and open to question.

Since this paper was written Mr. H. R. Hulbert, of El Obeid (Sudan) has informed me that a syndicate has been formed to develop the iron ore deposits in the vicinity of Assuan. Professor Lindblom has sent me a copy of his monograph, "Wire-drawing, especially in Africa" (Stockholm, 1939), and I believe a copy has been sent to the publishers of this paper.

Mr. Coghlan, F.R.A.I., has given me considerable information and is publishing a paper dealing with the metallurgy of copper throughout the ages.