ART HISTORY PAPER

THE MANIPULATION OF COPPER AND BRONZE IN ANCIENT MESOPOTAMIA AND EGYPT

Submitted by

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Preface

The intent of this research is to investigate the technical achievements of ancient man regarding his ability to manipulate copper and bronze. The research begins with the discovery of native copper ore in prehistoric times in the Near East and continues through the more advanced arts of metal working in Egypt.

I. Discovery of Native Copper Ore

"It is generally agreed among experts that the first awareness of metallic copper, wherever it took place in the ancient world, was an accidental one, and that it occurred around where pieces of copper ore were used as stones to enclose the fire, and were thus reduced by the fuel and the heat."[1.] The lump of metal produced fortuitously in this manner would quickly attract the attention of ancient man simply by its luster.

In the beginning these lumps of copper were used almost exclusively for personal adornment. Copper nuggets were looked on as special "stones" due to their beauty and possessed little practical value in comparison to the other stones man used in the manufacture of tools such as flint. When ancient man attempted to fashion a tool out of copper (circa 6500 B.C.), he was undoubtedly surprised to learn that it did not chip like flint. He also discovered that copper was malleable and became harder under repeated hammering. These facts that ancient man had acquired along with the knowledge of the fire, in which he first discovered the copper nuggets, set the stage for the manipulation and casting of copper.

II. First Uses of Copper

It is assumed that the ancient Mesopotamian region of the Middle East was the birthplace of metal casting. "Through the use of the radioactive-carbon dating process, it has been established that the cast copper frog found in the fertile crescent region of ancient Mesopotamia, was cast around 3200 B.C."[2] (Fig. 1). This dating makes it the oldest known casting in existence today. However,

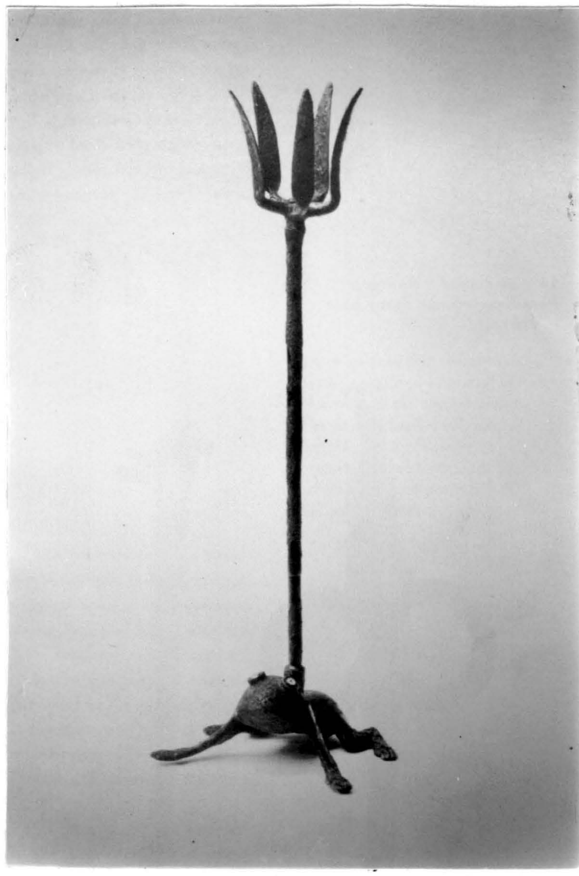

Fig. 1. Cast Copper Frog, Ur, 3200 B.C., Simpson, History of the Metalcasting Industry, p. 13.

long before man was capable of melting and casting metal, he occupied himself with the hammering of the copper nuggets into tools, weapons, and thin sheets to be used for embossing. As practical knowledge slowly improved and new tools were invented, skills in cutting, perforating and engraving were also acquired.

At an early stage man employed the heat from his fire to soften the hammered metals making them easier to manipulate. He slowly learned when to hammer and when to anneal, when not to hammer and when not to anneal. He also discovered that thin sheets of copper could be joined to one another through the process of hammer welding. "To effect the union of two copper sheets through hammer welding, the areas to be fused must be heated. The heat for both annealing and hammer welding, was probably provided by domestic fires which differed in no way from those then used in cooking."[3.]

"Though few in number, relics of hammered native copper, some going back possibly as far as 6000 B.C., have been unearthed at numerous sites over an area which includes present day Iran, Iraq, Syria, Saudia Arabia, Palestine and Egypt."[4.] It is theorized that the scarcity of hammered copper relics dating back past 3000 B.C. is due not only to the deterioration of these relics by time and the elements, but more importantly to the fact that once ancient man was capable of casting metal, he melted his old tools and artifacts of hammered copper and reshaped them by his new metallurgical method. The hammered copper articles that have withstood the test of time are predominately religious icons or embossed reliefs depicting historical events.

An excellent example of true metal engraving can be found in the <u>Bronze Gates of Shalmaneser III</u> (9^{th} century B.C.) from Balawat. Each scene in the gates depicts the kings' victories over various enemies. "The scenes are arranged in bands only five inches high, first engraved and then embossed by hammering from behind"[5] (Fig. 2).

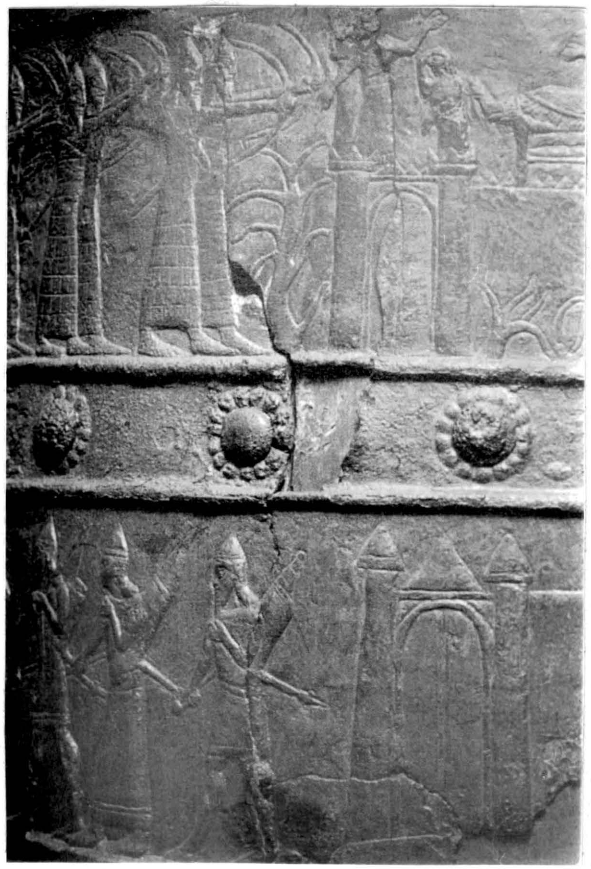

Fig. 2 Detail of Bronze Gates of Shalmaneser III, Balawat, 950 B.C.
Savage, Concise History of Bronzes, p.35.

The strips were once used to sheath the wooden framework of a pair of monumental gates from Balawat near Mosul in present day Iraq. Forged copper nails were used to fasten the strips to the wooden framework.

A magnificent example of early Summerian metal-work is depicted in the Imdugud and Two Stags (Fig. 3)

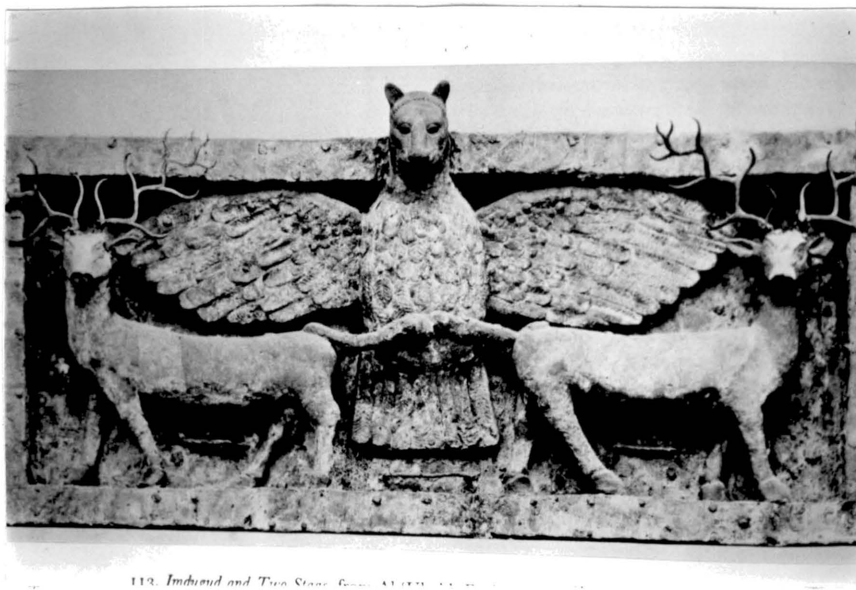

Fig. 3 Imdugud and Two Stags from Al Ubaid,ca.2500 B.C.
Frankfort-Ashmole, Art of the Ancient World,p.100.

dated in the Early Dynastic period (3000-2550 B.C.). The panel was built up from copper sheets raised and hammered into shape, with many of the sections hammer-welded together."The copper panel was then nailed over a wooden core that was coated with a thick layer of bitumen."[6] (Bitumen is asphalt found in a natural state and was abundant in the ancient Near East.) At this stage the metal would have been heated, so that the bitumen would flow closely against it to form a support for the metal during the final surface engraving and chasing. The Imdugud was unearthed at excavations at Al Ubaid, near the ancient city of Ur, in 1919. It is presently housed in the British Museum in London, England.

The life-sized statue of the Egyptian King, Pepi I, (Fig. 4), of the Sixth Dynasty (2400 B.C.), was also fashioned out of sheet copper, the technique employed being similiar to that employed in the construction of the Imdugud mentioned earlier. "The figure was built up of sheets of copper wrought by the hammer. Nails seen on the top edge of the forehead suggest that this was

Fig. 4, Statue of Pepi I, Dynasty VI, (ca. 2410 B.C.), Savage, A Concise History of Bronzes, p.10.

fastened to the wooden core before the missing portion which formed the top of the head was fixed to the core."[7] Like the Imdugud, the copper sheets were heated, along with the bitumen coating, over a fire prior to the final engraving and chasing.

Fire had played an important role, not only in the discovery of native copper ore, but also in the manipulation, shaping, and heating of copper in the forge. It was time for ancient man to employ the knowledge he had acquired concerning fire and copper to develop the casting process.

As the dates of the examples used in this section suggest, even after the development of the casting process around 3400 B.C., the arts of forging and embossing were still practiced extensively in the ancient world.

III. Ancient Furnace Development

To produce a casting in the ancient world, the first step in the procedure was to smelt the native copper ore. Smelting the ore separates the pure metal from minerals and other impurities. Once the pure metal had been isolated, it could then be heated again to a liquid state, then poured or tapped into the mold, resulting in the desired shape. The primary obstacle for ancient man to surmount was attaining sufficiently high temperatures required for both smelting and pouring.

Since the open campfire is not capable of attaining temperatures in excess of 700°c, technological achievements were inevitable in order to achieve 1085°; the temperature at which copper melts. The first of these achievements was to harness the wind. Early furnaces were simply campfires modified to facilitate the use of directed air in order to promote cumbustion. This was accomplished either by (1) "placing their rudimentary furnaces on the sides of hills and cutting trenches leading up to them and lying in the general direction of the prevailing winds,"[8] so that the force of the winds would be directed upon the burning fuel or by (2) scooping a shallow hole in the earth and lining the depression with clay and straw upon which the ore, then the fuel, would be placed. This completely sealed the environment around the ore with the exception of a small opening through which a blowpipe could be inserted. Such a primitive furnace (Fig. 5) was reconstructed by a Professor Gowland for experimental purposes in the laboritories of the Royal School of Mines at

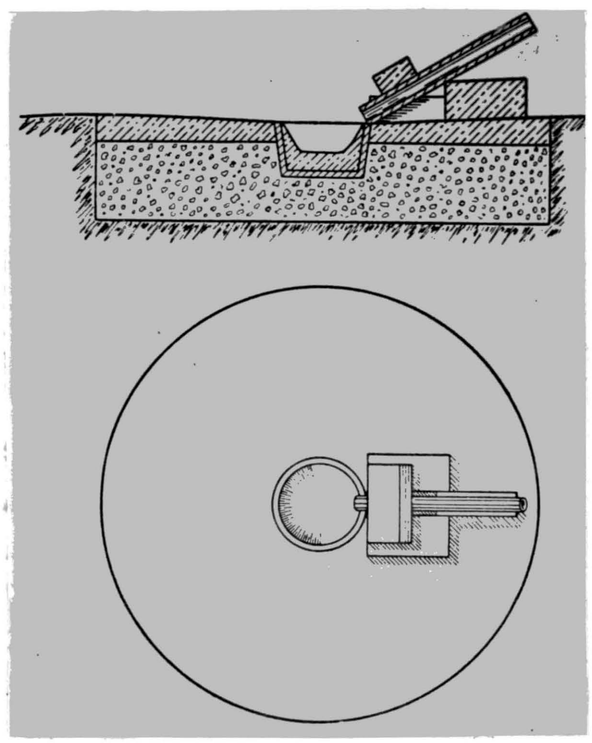

Fig. 5, Gowlands Primitive Furnace, 1912,
Ellis, Copper and Copper Alloys, p.4,

London, England in 1912. "This tiny furnace was used quite successfully for the smelting of copper and tin ores to produce bronze, using charcoal as the fuel."[9.]

Even though these furnaces may have been successful, ancient man strove to improve them and to make his job easier. Since the ceramic arts were quite advanced, it would not be long before the ancients applied the knowledge acquired in kiln building to the construction of a non-ferrous furnace (Fig. 6). This new furnace consisted of an upright shell, usually a hollow log, lined with clay and was charged with alternating layers of copper ore and charcoal. Hollow wood or clay blowpipes, known as 'tuyeres' were introduced into the furnace at the base of the hollow upright shell at the level of the firebox."[10.] At the opposing end of these blowpipes were the first crude bellows. These bellows consisted of a circular box covered with an animal skin, with a small hole cut in the center of the skin. The skin was then tied to a springy upright pole. The operator stepped on each bellows in turn, covering the small holes with his heels, thus forcing the air that was inside the bellows into the furnace. Releasing his foot allowed the air to flow back into the bellows, which were then snapped back to their normal positions by the upright poles. Alternate treading on the bellows delivered a relatively steady stream of air into the furnace. " The bottom of this 'blast furnace' was opened by means of a tap hole plugged

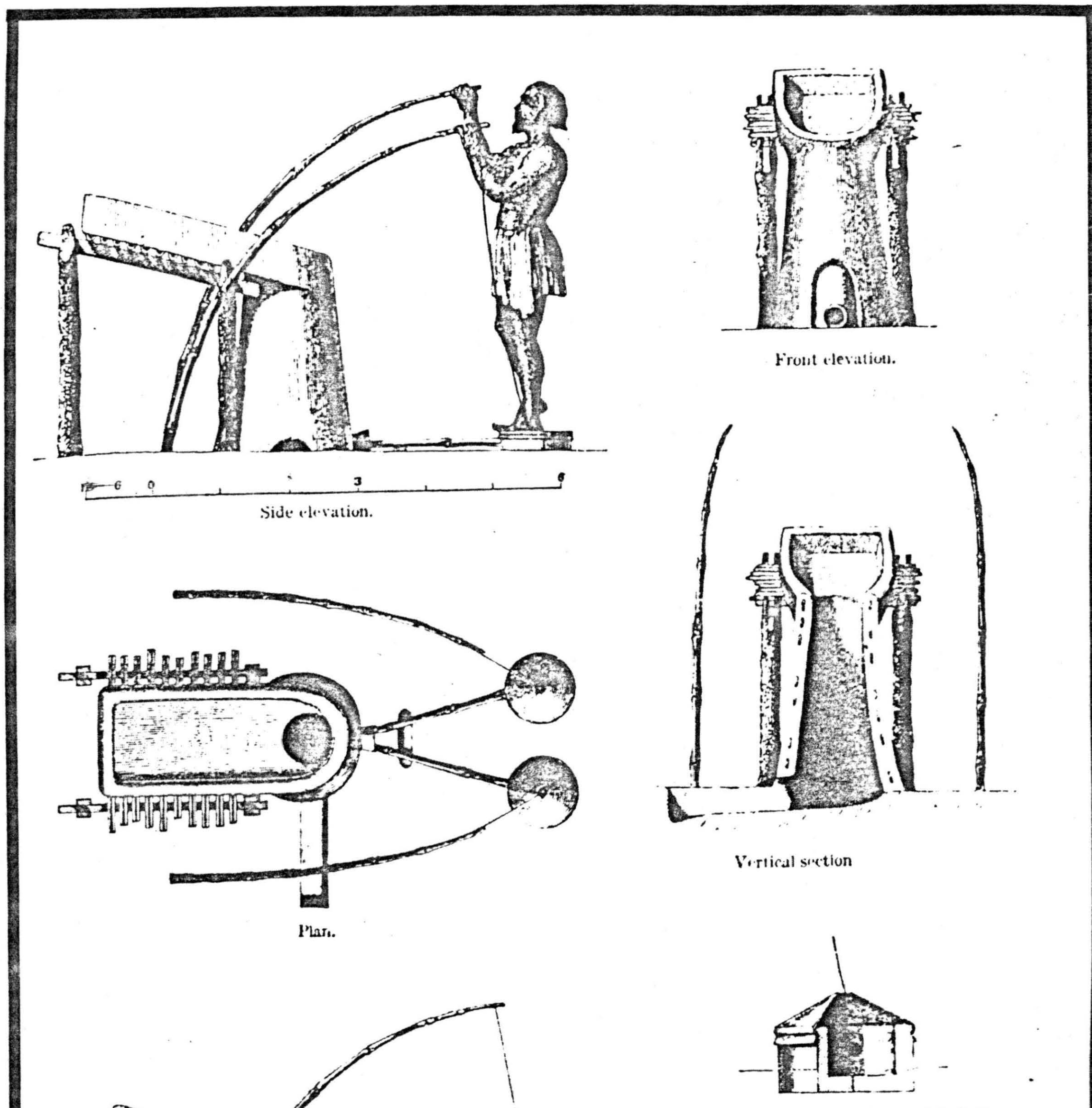

Fig. 6, <u>Illustration of an Early Non-Ferrous Furnace, (ca. 2700 B.C.)</u>

Simpson, <u>History of the Metalcasting Industry</u>, p.11.

by a clay retainer, which was removed when the operator was ready to pour or tap the metal into the mold."[11]

"The remains recently found at the site of Solomons Mines near the Wadi Timna, twenty miles north of Eilath in Israel, showed that dressed oxide ores were smelted in similiar furnaces with a bellows draught."[12] The fine ore was apparently sprinkled into the hot furnace where it was reduced, the metal sinking to the bottom to form a cake or ingot weighing ten to twenty pounds. The slag (impurities that separate from the ore at high temperatures) formed a layer above the ingot, but in many cases it appears to have been tapped off.

It is believed that this type of furnace, with only slight alterations or modifications, was used throughout the ancient regions of Egypt and Mesopotamia up to 1100 B.C., the dawning of the Iron Age.

IV. Molds and Moldmaking

Man's knowledge of molds and moldmaking undoubtedly began simultaneously with his discovery of the melted copper nuggets in the heart of his campfire. Once the coals had cooled sufficiently for handling the shiny lumps of copper, early man realized that these nuggets retained the shape in positive form of the negative shapes where the metal had been deposited. With this understanding, man was set to control the shape of the copper nuggets by fabricating his own molds.

It is believed that the very first molds were merely depressions in moist sand. A casting made by this method would have been of very poor quality with little or no detail. Unfortunately, no articles have withstood the passage of time to corroborate this belief.

The molds of the Early Bronze Age (3500-3000 B.C.), mostly made for the casting of flat axes, knife blades and other primitive tools, were fashioned from stone. The majority of the stone molds produced in this period show little variation in manufacture, and most appear to have been fashioned from natural tabular blocks of sandstone using the technique of hammer dressing with some grinding to somewhat refine the surface of the cavity. "Many molds had cavities for two or more axeheads and some had cavities for casting rectangular bars and other shapes."[13].

"Open" stone molds refer to a single tablet of stone with a negative impression carved into the face of the stone. This would imply that the casting was made by pouring the molten metal into this single cavity and allowing it to freeze with the top surface of the metal to be in contact with the atmosphere. This procedure seems to be unnecessarily wasteful since a good deal of the metal would be lost through oxidation with the atmosphere and the cooling rate would be extremely rapid causing a crystalization in the structure of the metal. "Archeologists presume that these "open" molds would have actually been closed by means of a flat removable cover, fabricated out of the same tabular sandstone as the mold."[14] This cover (Fig. 7) was placed over the cavity before casting so as to leave a space at one end into which the molten metal could be introduced.

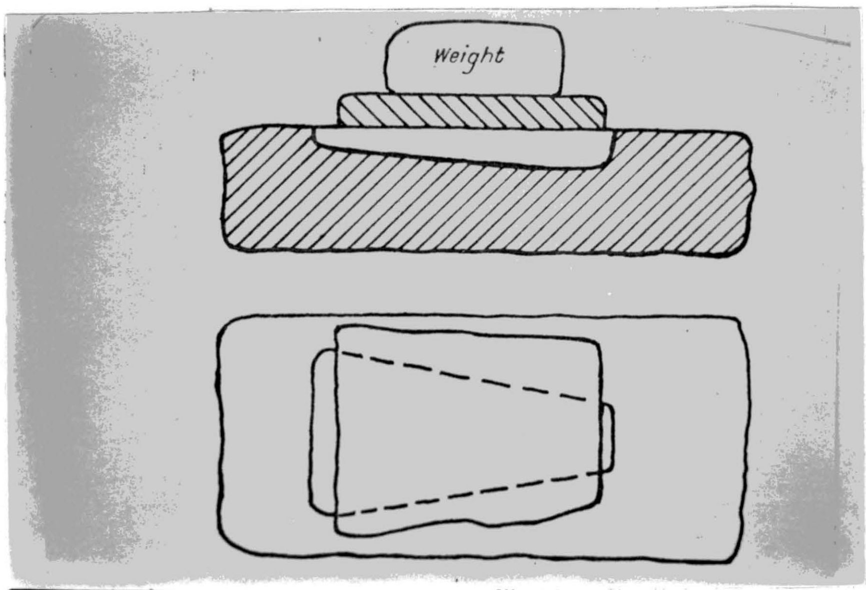

Fig. 7, An "open" Axehead Mold with Weighted Cover, 3500-3000 B.C.,
Tylecote, Metallurgy in Archeology, p.111.

"The article was first cast to approximately its finished shape (i.e. an axehead), the cutting edges being hammered out afterwards when the metal was completely cool, forming a hardened skin of copper on the surface."[15] This confirms the opinion of archeologists that the hardness of the cutting edges of ancient copper and bronze implements was due solely to hammering. Through microscopical examination of these axeheads and other similiar artifacts, their mode of manufacture becomes clear, and this procedure appears to have been continued in vogue for the making of copper and bronze tools and weapons of a simple nature for many centuries.

The Middle Bronze Age (3000-1800 B.C.) in the Middle East evidenced the development of the true two part mold (Fig, 8). An artifact cast by means of the open

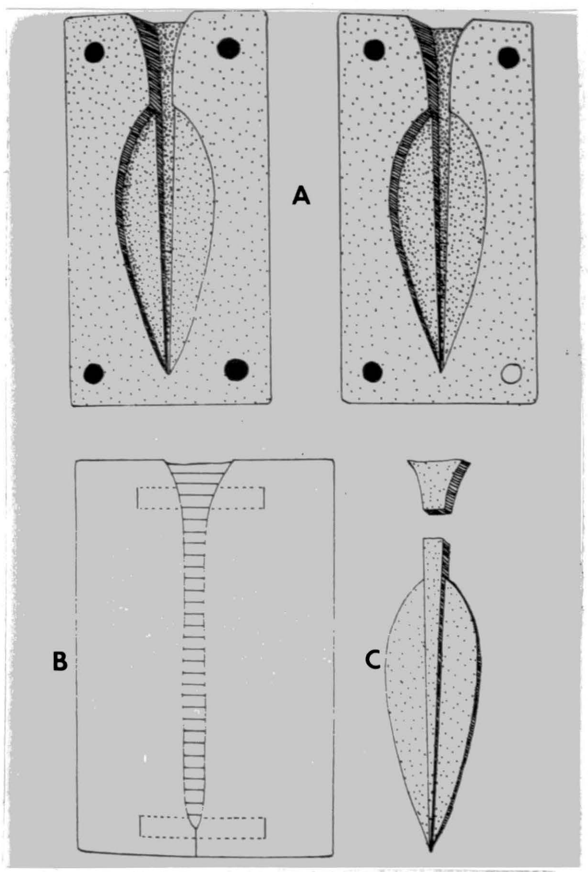

Fig. 8, Two Part Clay Molds, Middle Bronze Age, ca.3000-1800 B.C., Tylecote, Metallurgy in Archeology, p.112.

mold process would leave the exposed top surface undesirable, hence, requiring a great deal of grinding and hand finishing of this surface to achieve consistency between it and the molded surface. The logical solution would have been to construct a mold of two parts with matching cavities. "The majority of the two part stone molds of this period were made of steatite (soapstone)."[16.] Considering the relative inaccessibility of this material in the ancient world, this preference must have been related ti its good casting and carving properties. The carving characteristics of the stone selected would determine the quality of the finished casting. In order to produce a great deal of detail in the casting, the stone would require the characteristics of (1) non-porosity to insure a smooth surface on the cast product and (2) it would have to be soft enough to minimize the amount of time spent carving the negative shape in the mold surface. Analyzation of the stone molds of this period suggest that they were carved with the use of stone chisels and implements. In addition to steatite, fine grade sandstone posesses the proper characteristics for molding either copper or bronze. Apparently, any stone that may have been selected for molding would have to be able to withstand the high temperatures of the molten metal when it is poured into the cavity. Unlike the sandstone molds of the Early Bronze Age, these molds were carefully faced and the cavity far more refined. A number of these two-part molds were also constructed of fired clay held together in the proper position by means of short dowels.

Diagram A (Fig.8) depicts the two halves of a two-part mold with negative cavities and dowel holes. Diagram B depicts the side view of the assembled mold with the dowels in position. At this point the mold is ready for the introduction of the molten metal. Diagram C represents the cast object with the pouring cup detached from the spearhead. The plasticity of clay allowed ancient man to create detailed molds for the casting of specialized tools, weapons, and small ornamental objects.

Early castings of this period were still solid, but with man's knowledge of hammering bronze to a hardened state, the necessity of casting solid for the purpose of strength would soon decline. Scarcity of metal also led man to the development of cored or hollow castings.

The earliest hollow castings employed a core carved from the same stone as the mold to a general shape of the desired cast object and substantially smaller. This core was then suspended in the cavity created by the two piece mold, leaving a relatively uniform space between the core and the mold cavity.

The molten bronze or copper was then poured into this cavity and after the metal had cooled, the core was removed resulting in a hollow casting. It is theorized that instead of suspending the core as discussed earlier (Fig 9) the core was dropped into the mold

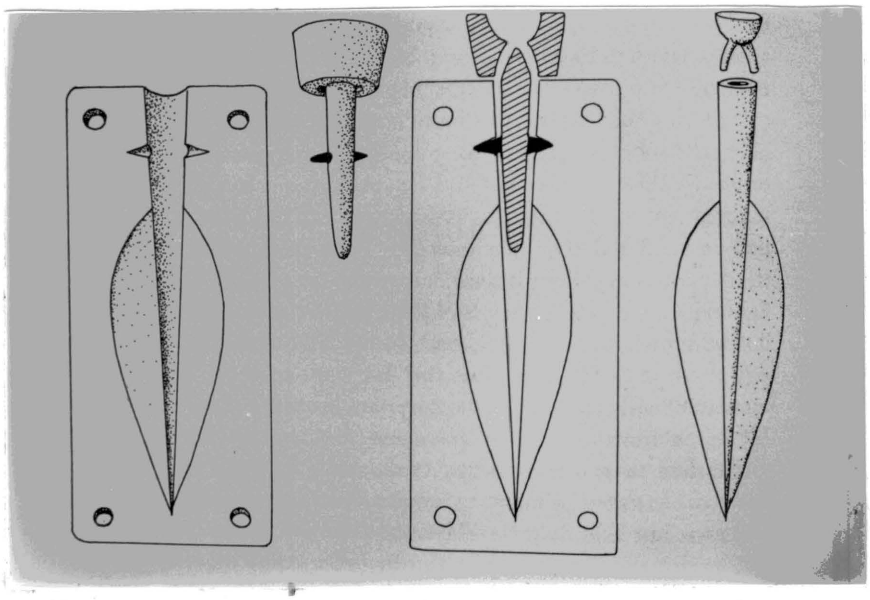

Fig. 9, Stone Mold with Suspended Core, ca. 2600 B.C., Tylecote, Metallurgy in Archeology, p.113.

cavity after it had been filled with molten metal. The metal displaced by this method would have been wasted. In either case the resulting hollow castings would have been identical.

All of the aforementioned molding processes were practiced throughout the regions of the Ancient worlds of Mesopotamia and Egypt up to approximately the Sixth Dynasty, ca. 2400 B.C., for the casting of tools, weapons, and small ornamental objects (i.e. religious icons). At this time the Egyptian artisans originated what is referred to today as the cire perdu process of casting. In modern times this process remains in use in the jewelry and metal working trades with very few alterations or improvements. "In its simplest form the cire perdu process (also known as the lost wax technique) may be employed for making solid castings, the model being fashioned in wax, accurate in shape and detail, coated with the molding substance, and afterwards embedded in sand, loam (a rich soil composed of clay, sand and organic matter), or other similiar materials to support the mold. The whole is then heated and the wax is burned away."[17.] At this point the mold is then ready for receiving the molten metal. Once the metal has cooled completely, the mold is broken away leaving the cast object.

This process was also used for hollow castings with an enclosed core as illustrated by the Egyptian Cat (Fig. 10). The illustration depicts the core modelled from a mixture of sand and plaster with core pins embedded in said core (core pins were fashioned from bronze and their purpose was to secure the core in the cavity). The second figure (Fig 10) depicts the core covered with wax in the shape of the desired object (note the protruding core pins). The third figure (Fig 10) depicts the object to be cast after it has been embedded in the molding substance. Gates have been left at the bottom to allow the wax to run out while the mold is being heated. After the wax has been burned out, the mold is turned up-side down and filled by means of the gates with molten copper or bronze. The molding substance is

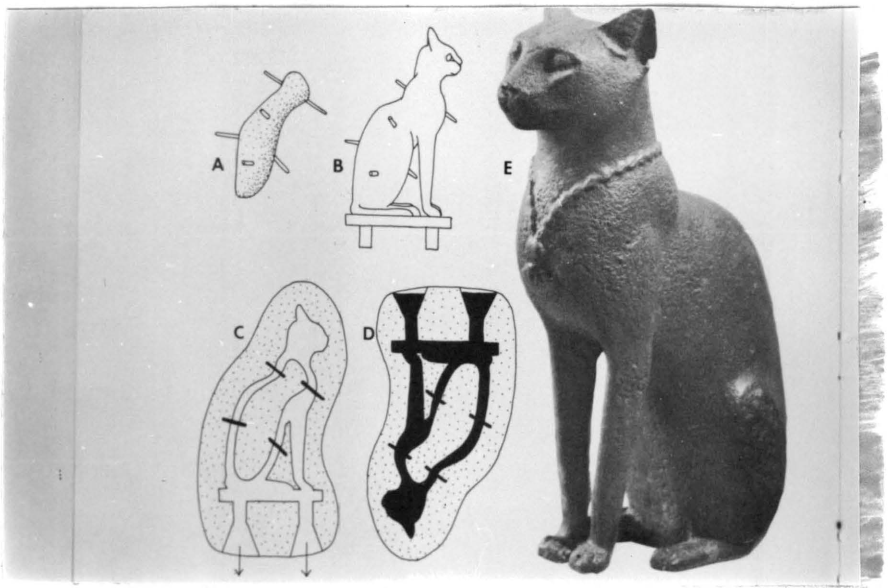

Fig. 10, Diagram Showing the Stages of the "Lost Wax" Process,
Bronze Cat from Egypt, Dynasty XVIII, 1500 B.C.,
Hodges, Technology in the Ancient World, p.150.

broken off after the metal has completely cooled resulting in the finished feline sculpture (Fig. 10).

The Head of an Akkadian Ruler from Nineveh, (ca.2340-2180 B.C.), is believed to have been created by the cire perdu method of casting (Fig. 11). Even though the arts of engraving and chasing were well established, to execute this amount of carefully patterned texture after the piece had been cast would have required years of work and would not have been as precise and uniform.

Fig. 11, Head of an Akkadian Ruler, from Nineveh, Bronze, ca. 2340-2180 B.C., Groenewegen-Frankfort, Art of the Ancient World, p. 102.

V. Soldering and Welding

An insistent problem for all ancient metal workers was the joining of sections of copper and bronze. The sections could be fastened with pins, rivets or forged copper nails, "....which were indeed commonly used at Ur for attaching a handle to a dagger"[18]. (Fig. 12), or for sheet metal work as seen in the Imdugud (Fig. 3). There was also hammer-welding, but this process could only be used

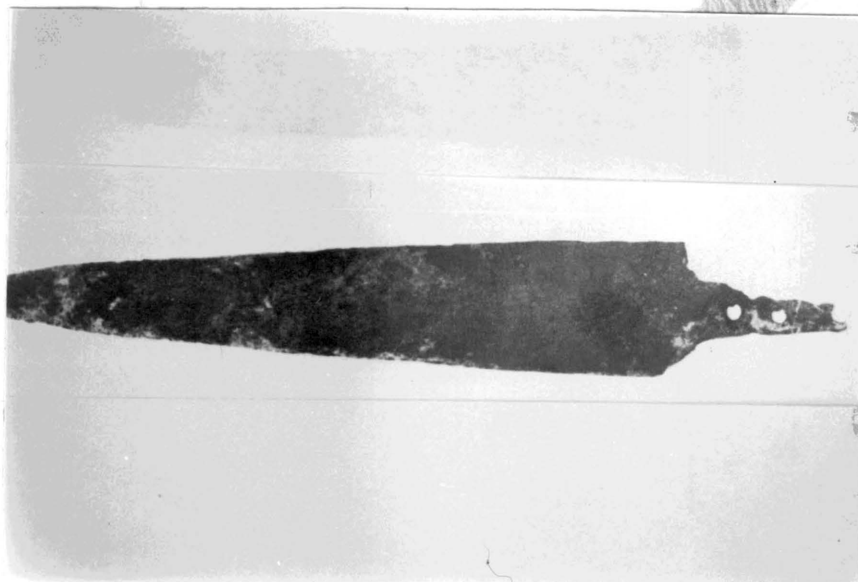

Fig. 12, Dagger with Holes for Rivets, Ur, 2500 B.C., Simpson, History of the Metalcasting Industry, p.43.

successfully in the joining of extremely thin sheets of copper or bronze. It is not exactly known when these methods were supplemented by the more intimate union obtained by soldering and welding. "Glaucus of Chios is regarded by some as the inventor of soldering, or was apparently so considered by the ancients."[19] Actually, however, the arts of soldering and welding were both well known before the time of Glaucus, who lived around the year 700 B.C.

Soldering is the union of two pieces of metal by means of heat or fire and the use of a third metal, which is known as the solder. In ancient times a copper alloy with a high tin content was used as the solder for copper and bronze objects. A few specimens of soldered work have survived the ages (Fig. 13). "In the Louvre is a vase from Susa, before 1000 B.C., from which the heads and shoulders of eight oxen project."[20] The vessel was raised from sheet copper and the bodies of the oxen were driven up through the metal working method of repoussé. Their heads and shoulders were made separately and soldered into position.

Fig. 13, Copper Vase with Soldered Oxen Heads, Susa, Persia, before 1000 B.C., Singer, Holmyard and Hall, A History of Technology, p.650.

Since the alloy of copper and tin melts at a lower temperature than copper alone, the union could be effected with no damage occurring to the sheet copper of the piece.

Welding is also effected with fire, but without the use of a third metal. "Welded pieces of bronze which date back to the year 1490 B.C. were found among the excavations at Thebes, Egypt."[21]. Welding in the ancient world, however, was quite different than the welding that is practiced today. The two pieces of metal to be joined were actually burned together. A bronze sword broken at the hilt might have been repaired in the ancient world by the following process. "The smith fitted the pieces together and formed a mold made of clay around the connection. He left a passage all around the joint, and provided the mold with a funnel-shaped pouring cup to allow the introduction of the molten metal. He then poured several pounds of molten bronze into the mold. The metal flowed between, and heated up, the broken parts of the sword, partially melting them together."[22]. After the metal had completely cooled, the mold was broken away and any superfluous metal could then be cut away and chased. This method effected a surprisingly strong union between relatively thick pieces of cast bronze and copper. Large sculptural pieces that were cast in numerous sections may well have been assembled using this method, though evidence to support this has not been established.

Soldering and welding at no point replaced the more traditional methods of joining metals, but merely added to the diversity of methods available. If a seamless piece was desired, then the methods of soldering or welding were employed, since the surface of this kind of union could be chased to match the cast surface. On the other hand, however, riveting and nailing were often desired for a more decorative type of union, particularly in the assemblage of sheet metal work.

VI. Summary

In light of present day technology, regarding the manipulation and casting of metals, one might be amazed at the achievements of the ancients, with great works accomplished in spite of pitifully inadequate equipment and technology still in its infancy. Out of this infancy, however, were born techniques so reliable that they are still practiced today with little variation. Among these techniques are engraving, repoussé, the lost wax process, and welding. With the exception of more precise and specialized equipment, the modern foundryman is actually closely and surprisingly linked to the past and the metal workers of the ancient world.

FOOTNOTES

[1] H. Garland, _Ancient Egyptian Metallurgy_, London, Griffin and Company, 1927, p.27.

[2] B.L. Simpson, _History of the Metalcasting Industry_, Chicago, Edward Keogh Printing Company, 1948, p.13.

[3] O. Ellis, _Copper and Copper Alloys_, Cleveland, American Society for Metals, 1948, p. 2.

[4] Ellis, _op. cit._, p.6.

[5] Seton Lloyd, _The Art of the Ancient Near East_, London, Jarrold and Sons, 1965, p.203.

[6] R.D. Barnett and D. Wiseman, _Fifty Masterpieces of Ancient Near Eastern Art_, London, Trustees of the British Museum, 1960, p.15.

[7] Singer, Holmyard and Hall, _History of Technology_, Oxford, Clarendon Press, 1956, p. 641.

[8] Ellis, _op. cit._, p.5.

[9] Ellis, _op. cit._, p.4.

[10] Simpson, _op. cit._, p.14.

[11] Simpson, _op. cit._, p.15.

[12] R.F. Tylecote, _Metallurgy in Archeology_, London, Edward Arnold Publishers, 1962, p.28.

[13] Tylecote, _op. cit._, p.111.

[14] Tylecote, _Ibid_.

[15] Garland, _op. cit._, p.35.

[16] Tylecote, _op. cit._, p.113.

[17] Garland, _op. cit._, p.37.

[18] A. Neuburger, _Technical Arts and Sciences of the Ancients_, New York, Barnes and Noble, 1930, p.45.

[19] Neuburger, _Ibid_.

[20] Singer, Holmyard and Hall, _op. cit._, p.650.

[21] Neuburger, _Ibid_.

[22] Singer, Holmyard and Hall, _op. cit._, p.653.

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