

## Heavy Metal Thunder: Early history of metal use in human culture

Major revolutions in human culture closely follow developments in the use of geological materials (including metals). This is reflected in the terms commonly used for technological "ages" (e.g. Stone Age, Copper Age, Bronze Age, Iron age).

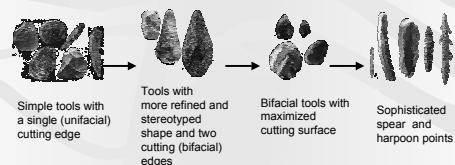
Although many metals have found wonderful uses in technology, many of them were originally used for ornamental purposes (as artistic media).

This is true for both precious metals and base metals.

## The Stone Age

Prior to the use of metals, humans relied on materials such as obsidian, chert/flint and quartzite for the fashioning of tools.

Increased sophistication of tool making is apparent in tool types found at archeological sites of different ages.



## The Copper (Chalcolithic) Age (Began at about 4,500 BC)

At roughly the same time, native copper was also discovered and used by humans (earliest use dates back to about 6,000 BC, but widespread use dates to about 4,500 BC).

There was considerable overlap during the Neolithic in the use of lithics and relatively novel copper tools. Consequently a transitional interval between the Stone Age and later ages of predominant metal use has been identified, known as the Chalcolithic or Copper Age.

Native copper, which occasionally occurs in large masses was "cold-worked" to make delicate objects such as hooks and needles, which were otherwise difficult to make from stone and bone.



Cold-worked copper needle

Greek: "Chalkos" = Copper  
"Lithos" = Stone

## Rough-hewn early Copper tools

As cutting implements or weapons, early Copper tools left much to be desired and were definitely not an improvement over lithics (the latter were much sharper and easier to use).

Consequently, many of these were used merely for demonstration or status purposes.

Only members of the nobility of the time could afford these luxury items made from metal.

Actual use of cold-worked copper was limited by the brittleness and softness of the metal, which could not hold a sharp edge for very long.



Cold-worked copper daggers

## Other Metals Used by Copper Age Humans

Other metals that could have been used more or less as-is included silver (which occasionally occurs in native form as veins)



Native silver

Iron/nickel alloy, occurring naturally in iron-nickel meteorites (core material).



Earliest documented use of the latter dates back to about 4,000 BC

Both sources, of course, were rare.

Iron-nickel meteorite

## Heat treating and Annealing Copper

A major improvement in copper technology came when it was discovered that copper could be annealed when heated. Annealing involves reordering of the microstructure of the material through heating at relatively high temperatures, followed by slow cooling. In this process, metal atoms actually move within the solid material. Redistribution of material reduces the areas of weakness within the metal and makes it more pliable under cold-working conditions (more malleable).

This permitted stronger tools to be made, although such tools were still "status items" of the rich (still not really useful for cutting as such).



Copper dagger, central Bulgaria, 4000-3500 BC

### The Copper Age: Discovery of Smelting Methods

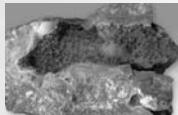
The availability of copper was a major limiting factor in the use of this metal (deposits of native copper are quite rare).

This was also true for other metals.

This situation changed with the discovery that copper could be smelted (separated) from mineral compounds by heating.

The first copper mineral to be smelted was probably malachite.

Why would this have been a good material from which to extract copper?



Malachite  
 $\text{Cu}_2(\text{CO}_3)(\text{OH})_2$

### Smelting

It has been suggested that the art of smelting began as result of accidental "cooking" of metal ores in campfires.

This is unlikely, for two main reasons:

- The heat generated in a campfire is unlikely to have reached temperatures necessary to allow metals such as copper to separate from the ore (the melting point of copper is over 1000 degrees C – well above the temperature of your average campfire).
- The presence of large amounts of oxygen in a campfire would have readily oxidized any metal that was produced by melting (metal oxides are brittle and cannot be worked).

### The Beginnings of Smelting

For these reasons, it is more likely that the first smelted ore was produced in a pottery kiln.

The production of pottery preceded the smelting of metals by thousands of years (earliest pottery extends back to at least 10,000 years before present).

High temperatures could be achieved in a kiln (due to the prevention of heat loss to the open air and the increased temperature generated by forcing air into the kiln furnace to "fan the flames"). Primitive pottery kilns could generate temperatures exceeding 1,400 degrees C. Copper will melt at just over 1000 degrees C.

Special kilns were later developed for smelting (pieces of ore were put in direct contact with charcoal to ensure the highest temperatures possible and to prevent oxidation of ore).



### The Beginnings of Smelting

The oxygen-starved conditions within a kiln would prevent the combination of pure metal with oxygen, so metal could be separated in pure form.

In addition, the presence of fluxes (e.g. limestone, quartz sand), used to lower the melting point of minerals within the pottery could have lowered the melting point of the metals that were inadvertently smelted.

### How did ore minerals end up in a pottery kiln ?

This is obviously open to speculation.

However, one might picture a potter attempting to beautify his/her pottery by adding chunks of attractive coloured or highly lustrous minerals to the clay.

For example, the potter might have experimented with the green mineral malachite (copper ore), or galena (lead ore).

Beads of molten metal that were produced upon baking would have decreased the beauty of the article, but an astute potter would have noted that these beads could be collected and further purified to produce larger bodies of metal.



### The Bronze Age (Began at about 3,200 BC)

It was later noted that the deliberate addition of impurities (especially arsenic) could change the properties of smelted copper.

The arsenic was later replaced by tin (a true metal), possibly as a result of high incidence of death among early arsenic-bronze workers.

As an added bonus, tin lowers the melting point of copper (combined before melting), which made it easier for this metal to be smelted.

Bronze is quite attractive and is relatively easy to work, making it suitable for ornamental objects.



Bronze statue

### Metal sulphides and the earliest alloys

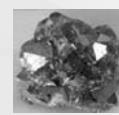
As supplies of easily smelted copper minerals such as malachite (copper carbonate) became scarce, it became necessary for copper to be obtained from sulphide minerals.

Copper sulphides (especially chalcopyrite) generally occur with sulphides of other metals such as arsenic (actually a metalloid; e.g. arsenopyrite).

Smelted copper with impurities of arsenic formed the first produced metal alloy used by humans. This is known as arsenic-copper, or "arsenic-bronze".



Chalcopyrite  
 $(\text{CuFeS}_2)$

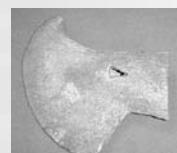


Arsenopyrite  
 $(\text{FeAsS})$

Perhaps more importantly, bronze is harder than pure copper, and is therefore much more useful for tools.

Bronze containing 90 % copper and 10 % tin is twice as hard as pure copper !

Cutting tools can, thus, will be more effective and will not require sharpening as often as pure copper tools would.



Bronze axe

### The Iron Age (began at about 1,200 BC)

The discovery of iron as a useful medium for tool-making probably also came about by accident.

However, it would have taken a keen eye to figure out how to process iron.

In a primitive kiln, smelted iron would not have formed liquid droplets as iron has a higher melting point (~1500 degrees C) than copper.

Instead, at the relatively low temperatures used, the material formed a spongy solid mass of elemental iron and slag (impurities, metal oxides and remnant sulphides) called a "bloom" (also known as "sponge iron").



Iron bloom

### Iron Age

Whereas copper metal naturally separated as a heavy liquid from lighter, silicate-rich slag, the solid iron bloom retained pockets of impurities (slag).

At some point, it was discovered that the slag bodies within iron bloom could be removed by reheating and pounding the bloom on an anvil.

When the hot bloom was pounded, the slag (lower melting temperature) simply squirted out from the mass. The elemental iron would remain in the solid state.

Purification of the metal was accomplished by repeated heating and pounding of the bloom.



### The Iron Age

Humans are believed to have developed the earliest methods of smelting and forging iron by about 1,500 BC (in the region now known as Turkey), but these methods did not become widespread until about 1,200 BC.



Iron mask  
from Africa



Iron spear tips

### Steeling

It was found that the addition of carbon to iron increased the hardness of iron metal – this iron-carbon alloy (containing less than 1.7 % carbon) is what we call steel.

The carbon could have been first introduced to the iron from carbon monoxide generated in the furnace or from carbon (charcoal or coal/coke) in the furnace fuel.



4<sup>th</sup> century AD  
Steel hole punch  
(Netherlands)

### Casting

Meanwhile, in China, artisans developed extremely effective furnaces that were capable of melting iron.

The iron could then be poured into moulds.

The cast iron was then reheated to drive off the excess carbon, making the product more elastic and malleable for final use.



### Tempering

An effective method of altering the properties of iron is tempering.

Tempering involves: the quenching (sudden cooling) of hot metal in water (to increase hardness) and reheating (to reduce brittleness)

The development of tempering must have involved lots of trial and error to produce a strong (but slightly elastic) metal!

The Japanese are famous for their tempered steel swords.



Of course, in the years to follow, steelmaking continued to develop, introducing many varieties of steel (each with different properties).

Steel, in combination with the increased use of coal as fuel, was the backbone of the Industrial Revolution, and remains one of the most important metals in today's society.





*END OF LECTURE*