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## Goat path discovery unlocks secrets of medieval zinc

Medieval zinc furnaces, recently excavated in India, represent one of the most sophisticated pyrotechnical processes in use before the Industrial Revolution – a process which is still basic to all high temperature distillation operations today. Paul Craddock, of the British Museum Research Laboratory and a member of IAMS Scientific Committee, describes the expedition in which he took part last December.

Although zinc minerals were used in Roman times in combination with copper to form the alloy brass, the individual metal was not isolated until much later. In the West it has been produced for little more than 200 years, and only became common in the 19th century.

Of all the base metals zinc is the most difficult to process. Most metals smelted in a simple furnace collect as a molten mass in the bottom, but in such conditions, zinc, with its low boiling point of 907°C, would have been produced as a vapour and lost up the flue.

Clearly a very different process was necessary to smelt zinc ore, retain the vapour and condense it. Such a system was patented in 1738 by an Englishman, William Champion, who designed a furnace fitted with an external condenser. He built a plant at Warmley, near Bristol, where the calcinated ore was reduced in retorts which were set in a furnace with their necks protruding downwards into a cooler chamber where the zinc vapour condensed and was collected in water-filled vessels.

Champion's plant eventually contained 30 such furnaces and by 1760 was producing metallic zinc at the rate of about 200 tons a year.

### Sources unknown

Whether Champion acquired his technology directly or indirectly from the East is not known for whilst he must be given the credit for introducing the first commercial zinc-making process in the West, zinc had been arriving in Europe for a good many years in ships of the Dutch and British East India companies. Historians have never been quite certain where the metal came from, but most likely sources were India and China. How it was produced remained a mystery.

In more recent years metallurgists and mining engineers visiting the modern mines at Zawar, in the Indian state of Rajasthan, reported seeing huge dumps of spent retorts and other debris of zinc production around the old mines. It was not until last December, however, that they were scientifically investigated in a joint project of the University of Baroda, the British Museum and Hindustan Zinc Limited, the company which now owns and works the site.

Already the intact furnaces uncovered by our excavation, still containing their full charge of retorts, and our analysis of the refractories, have given us a detailed picture of the process – a process that predates

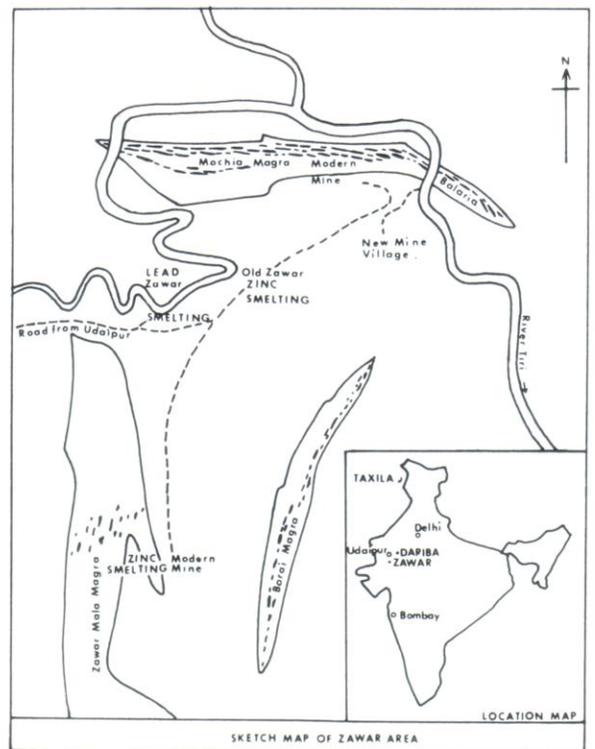
18th and 19th century "discoveries" in Europe by several centuries.

We expected to get most of our information from the study of stratified fragments within the heaps, but on only the third day of the excavation one of the Baroda team spotted the corner of a refractory plate sticking out from a heap by the side of a goat path.

### Mounting excitement

If our conjectured reconstruction of the furnace was correct then this brick was in its right alignment. With mounting excitement we cleared a small area above and around it to reveal first, the edges of furnace walls, and then the tops of retorts still *in situ*.

*continued overleaf*



KEY  
ANCIENT  
Modern  
ANCIENT MINES  
IN DOLOMITE



*This refractory plate, spotted sticking out of the ground by the side of an Indian goat path, led to one of the most significant discoveries of medieval metallurgy. Picture P.T. Craddock*

This was something we had not dared to hope for, and over the next few days as more and more was revealed it became apparent that the whole process was much more sophisticated than we imagined. We had discovered a continuous bank of seven furnaces, four of which we cleared, each originally containing 36 retorts.

Thus a total of 252 retorts could be fired simultaneously. This bank of furnaces is provisionally dated by radiocarbon to the 16th century, and another and even larger set, which we also excavated, is dated to the 18th century.

In principle, the process was quite simple. The ore at Zawar is sphalerite, zinc sulphide. This was roasted in air to convert it to oxide ready for reduction – a process which was not “invented” in Europe until the 18th century. The roasted ore, together with charcoal and

other ingredients, was then placed inside an open clay retort. The medieval Indian alchemists listed various exotic ingredients which cannot now be verified. Salt was also specified and this was found in the Zawar retorts which we examined. Once again, the addition of salt was common European practice centuries later to increase the overall efficiency of the process.

### Clay condensers

Clay condensers were then luted in place and sealed retorts were put in the furnace to rest on a perforated clay plate with their necks protruding through large holes into a cooler chamber below the main furnace.

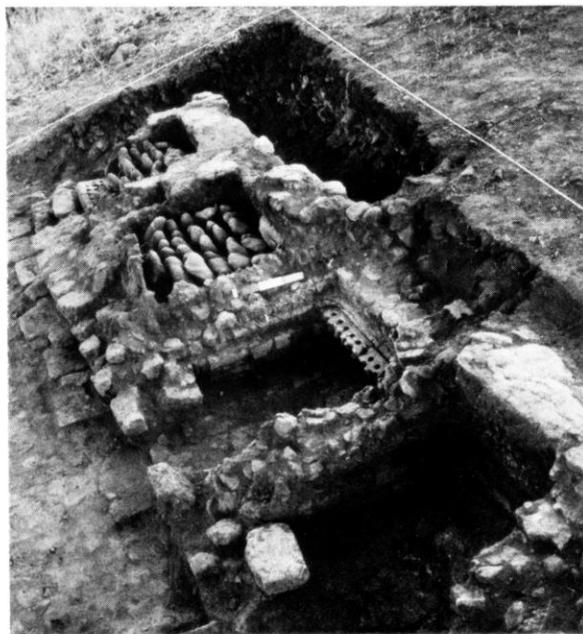
The fire was built above and around the retorts and was maintained at a sufficiently high temperature to cause considerable softening of the clay retorts. Scientific examination of sections of the vitrified retort walls by scanning electron microscope in the British

*continued in col. 2 opposite*

*Furnace walls and tops of retorts found in situ in a remarkable state of preservation. Picture P.T. Craddock*



*Four of the seven furnaces cleared by the expedition. Each originally contained 36 retorts. Picture P.T. Craddock*



## Facts about zinc

The Romans' method to produce brass was to heat a mixture of zinc and copper oxides, or zinc oxide and metallic copper, with carbon in a closed crucible. The zinc vapour produced during the reduction dissolved immediately in the metallic copper. A similar method was used in Europe until the beginning of the 18th century.

Earliest use of the word "zinc" was by Paracelsus (c 1490-1541) who described it as a bastard form of copper.

Georgius Agricola (1494-1555) refers to zinc in *De Re Metallica* by the name "contrefey" but in other works he uses "zincum" for ore found in Silesia.

The term "spelter", employed for commercial grades of zinc until about the middle of this century, came into use in 1660. It was derived from the Dutch word "spianter", which meant both zinc and pewter, a fact that emphasizes continuing confusion over the true nature of the metal.

An ancient idol, containing 87% zinc, discovered in prehistoric ruins in Transylvania (modern day Rumania), is the oldest known zinc object. Zinc-filled silver bracelets dating to 500 BC have been recovered on the island of Rhodes.

Zinc ores are commonly found in association with those of other metals, notably lead, though frequently with copper or gold and silver. Mining operations are typical of those used generally underground. Owing to the nature of the ore veins, most zinc mines are underground rather than open pit.

The lead-zinc mine at Trepca in Yugoslavia, one of the biggest in Europe, was discovered in 1926 by investigating the remains of mines developed first by the Romans and later by Saxons. In one ancient adit explorers came across the figure of a Roman centurion carved into the rock. The late Sir Alfred Chester Beatty, who initiated the exploration, ordered the carving to remain undisturbed and always referred to it as "my Roman consulting engineer."

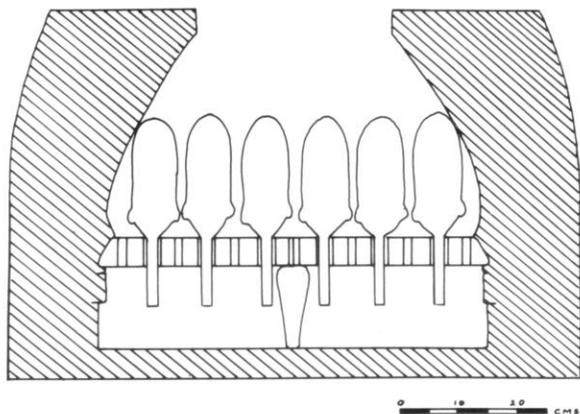
World zinc production is currently running at between 4 million and 5 million tons a year. Major producing countries include Canada, USA, Russia, Belgium, France, Germany and Australia.

Biggest single application for zinc is for the protection of steel against atmospheric corrosion. It also forms the basis for one of the best alloys used in die-casting and, of course, in brass.

Zinc can be readily rolled into sheet and in this form is used in building construction, giving long service at reasonable cost.

A major boost to the zinc industry in the United States recently has been a move to copper-plated rolled zinc for the one cent coin. Composition was switched in 1982 from 95% copper and 5% zinc to 97.6% zinc and 2.4% copper, including the plating. As a result, US consumption of rolled zinc almost doubled, and last year the Mint used more than 50,000 tons.

In common with other base metals, zinc has been in over-supply during the world industrial recession, but demand has increased substantially over the past few months.



This drawing by B. Craddock illustrates how the retorts were set in the furnace with their necks protruding into the cooling chamber below

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Museum suggests temperatures of around 1100°C – which was the temperature recommended for the retort process used in Europe in the first half of the 20th century.

Inside the retorts the zinc oxide would be reduced to zinc vapour which would permeate to the cooler region of the condenser neck where it liquified and ran into collecting vessels.

Great skill must have been necessary to keep the temperature conditions right throughout the retort and condenser. If too hot, then the retort would melt and the zinc would issue as a vapour from the condenser. If too cold it would solidify in the condenser and block it.

The reducing conditions had also to be rigorously controlled. If the vapour was not intensely reducing right down into the condenser then it would reoxidise instead of condensing as metallic zinc. And, of course, every one of the 36 retorts in each furnace had to be carefully watched.

The whole process was probably the most complex and sophisticated pyrotechnical operation in use before the Industrial Revolution, and is almost certainly ancestral to Champion's method and to all high temperature distillations which are carried out today.

## Tourist Gold Mine

Visitors to the Welsh village of Pumpsaint in Dyfed will soon be able to inspect the remains of a Roman gold mine at Dolaucothi in the nearby hills.

The mine was worked sporadically since Roman times but finally closed down in 1936. Recently some of its workings have been exposed by members of the mineral exploration department of University College, Cardiff, and the site – the only place in Britain where evidence has been found of Roman gold mining – is to be opened as a tourist attraction.

## Huelva Report

Copies of *Studies in Ancient Mining and Metallurgy in S-W Spain*, a report of the exploration by IAMS and the Universities of Seville and Madrid in the Huelva Province in 1974-78, are now available to Newsletter subscribers at the reduced price of £10.

A few copies are still available of the IAMS monograph *Chalcolithic Copper Smelting*, by Beno Rothenberg, R. F. Tylecote and P. J. Boydell, at £2, half the original price.

Orders should be sent to IAMS secretarial offices, Institute of Archaeology, 31-34 Gordon Square, London WC1H 0PY.