

these excavations, all these process-related finds were recently meticulously reinvestigated, measured and recorded by Craig Meredith (the member, since 1969, of IAMS's permanent field team in charge of finds), in order to establish the essential data on the dimensions and shapes of the different furnace types represented by these fragments.

Working patiently through masses of very dusty furnace fragments, Craig noticed and separated a small number of flat, grey-burned, saucer-shaped clay objects, very thick-walled and brittle, for which there was no immediate explanation. These were obviously heavily fired, showing heat stratification in the sections. The bottoms are flat and the top mildly concave, bordered by a vertical rim several centimetres high. All these fragments came from Layer 1 of Timna Site 30 which related to Egyptian 22nd Dynasty activities during the 10th century B.C. These latecomers to Rameside Timna (14–12th centuries B.C.) introduced a new and much advanced copper smelting technology, involving tempering the clay furnace lining and tuyères with tiny bits of crushed slag (Bachmann and Rothenberg, in *Antikes Kupfer im Timna-Tal*, ed. Conrad and Rothenberg, 1980, p. 220). Craig's enigmatic objects showed the same slag temper but otherwise they could

not be fitted into the furnace model of this period (see Rothenberg, *Copper Smelting Furnaces in the Arabah, Israel: the Archaeological Evidence*, in British Museum Occ. Papers No. 48, 1985, pp. 129–30, Figs. 12–13). There was simply no way in which these saucer-like objects could be parts of the wall or bottom of a furnace. Further close inspection established that these 'saucers', which were not slagged must have been used in a horizontal position and that the heat was mainly concentrated on their inside, observations confirmed subsequently by the British Museum Research Laboratory.

At the end of his task, Craig presented his detailed report, including a surprise chapter: Casting Moulds. Subsequent measurements and comparisons resulted in the final definition: Casting moulds for ingots, the first ever identified.

The identification of casting moulds for bun-shaped ingots provides essential additional archaeological evidence for the historic reality of our newly proposed copper smelting models.

The detailed results of this research programme are due to be published in *The Ancient Extractive Metallurgy of Copper*, Researches in the Arabah, Vol. 2, IAMS, London, 1988.

Beno Rothenburg

The Production and Trade in Copper in Medieval Times

Underwater and land-based sites have produced evidence of extensive Bronze Age trade in metals, and this continued into the Roman period with lead, tin and copper all finding their way across the Mediterranean in the general direction of Rome. Until we come to Venice in about A.D. 1000, it is difficult to find much evidence of trade in the 1st millennium A.D. but, by the Early Middle Ages, Venice had an extensive trade, obtaining her raw copper from Italy and Central Europe. The arsenal at Venice processed this and exported it to various sites in the Mediterranean and beyond. Later, this trade was taken over by the Portuguese who extended it into Africa.

In the elucidation of trade and production of copper, archaeology is our only tool up to medieval times, as detailed descriptions of technique are lacking and trading records confined to tablets which rarely give a clue as to place of origin.

In the medieval period we begin to get written records of how things were done, paintings of furnaces and equipment, and we can say that the prehistoric period of metallurgy comes to an end. We not only have technicians such as the twelfth-century monk, Theophilus, and others like Biringuccio and Cellini, but also writers and theorists like Agricola and Leonardo da Vinci. Their technical treatises are more than supplemented by trading archives which begin to give us details on prices and quantities, although it is not easy to get accurate data on the output of metal as these often pass through several hands.

Venice

Venice was one of the earliest trading centres after the Roman period, and it is useful to take it as an example. It imported copper at first from the area south-east of Bolzano, and Tuscany and later from Central Europe generally and Turkey (Kastamonu). Some of this copper was refined and stamped in Venice and its environs, like Treviso. The rest was sent onwards as part of Venetian trade, mainly with the East.

This work was done in the *getti* the area near the arsenal on the east end of Venice (*gettando* = casting) and the term 'Ghetto' is said to have originated from the fact that in 1516 the sites of the old and new foundries, Ghetto Vecchio and Ghetto Nuovo, were assigned to the Jews.

Venice got its refined copper mainly from the Harz and Tuscany. Copper was refined in the arsenal in Venice and was stamped with the shield of St Mark (probably like those so often seen in Venice today). It was made in two grades: hard and soft. The former was used for bells and mortars; the latter for malleable applications such as wire and sheet and it was sold as buns, masses, etc. The ductile yellow copper came from Poland through Bruges and, up to the fourteenth century through Krakow (probably from Slovakia?). The copper office in Venice – the Getto – refused to refine the hard copper, presumably because it needed too much fuel.

Lots of copper came from the north Italian mines

around Bergamo. Copper was exported to Malabar by the Venetians and this came from Nuremberg and apparently was exchanged for copper from Cochin (China?).

After about 1500 most of the Fugger's copper went northwards, but between 1495 and 1504 Fugger exported more than 3000 tons of copper from his Hungarian mines (Slovakian) through Venice. In the fourteenth century a large part of the copper arriving at Venice came from the mines of Pontus (around Kastamonu in Turkey, Ramen de Romania in Italian).

Portuguese Transport 1460–1600

During 1494–5, 71,000 manillas went to Africa from Europe, and in 1514, 384 tonnes were sent. In all, for

the period 1495–1524, 1250 tonnes of manillas, etc., were exported from Flanders (Antwerp). It would seem that most of this came from Central and Northern Europe. The manillas had variable compositions and, according to Herbert in 1948, analyses of those in circulation in Nigeria gave: Cu 62.68%, Pb 30.05, Bi 0.05, As 0.65, Sb 2.81, Sn 2.05, Zn 0.98, Ni 0.48. This composition has been used since 1720. The weight range was about 8.5 to 10ozs. (300g.).

The objects produced include wire for pins, sheet copper, bells and cauldrons, and guns. While the total output of copper in Europe in 1550 was no more than 2000 tonnes, this was increased by the use of scrap and alloying elements such as zinc ore to some 2500 tonnes of copper-base alloys and was to become a very important factor in Renaissance civilisation.

R. F. Tylecote

Director's Report

This opportunity is taken to give an up-to-date overview of the ideas which led in 1973 to the formation of IAMS, and to discuss what has been achieved so far, together with our future research and publication plans.

IAMS was formed to initiate internationally the investigation of the fundamental technological parameters of metal history as well as the often decisive role of metal in history.

1. From 1964 to 1970, the Arabah Expedition, led by Beno Rothenberg, excavated ancient copper smelting sites in the Timna Valley (Southern Israel). This was the first systematic field research ever undertaken at metal production sites. The excavations culminated in the discovery of a unique Egyptian-Midianite mining temple – which led to the Timna Exhibition in 1971 at the British Museum and other major museums of Europe.

In the wake of the highly successful Timna Exhibition in the British Museum, Sir Val Duncan (RTZ chairman) and Sir Mortimer Wheeler (Secretary of the British Academy) initiated the setting up of IAMS, joined shortly afterwards by Sir Ronald Prain, OBE, Professor R. F. Tylecote, Sir Sigmund Sternberg, KCSG, JP, Dick Altham, Nigel Lion, Professor John Evans and others. In the late 1970s IAMS became affiliated to the Institute of Archaeology, University of London, where it initiated and supported the development of archaeo-metallurgical teaching and research. I would like here to thank Sir Sigmund Sternberg for his continued support of our teaching project. The comprehensive, final report on the excavations of the Timna Temple (*The Egyptian Mining Temple at Timna, Researches in the Arabah, Vol. 1*, by Beno Rothenberg and others) is now in the press and is scheduled to be published early in 1988.

The Arabah (and later also Sinai) Project under the of IAMS, could be conceived as a large scale and long term systematic archaeological and metal-technological research programme, which continued, mainly due to the financial support of the Volkswagen Foundation, up to 1984, with the active participation of English, German, USA and Israeli scientists, students and academic

institutions. Ten years of intensive field and laboratory studies, included the first ever excavations of Bronze Age underground copper mines (undertaken with the German Mining Museum, Bochum), extensive excavations of copper smelting camps dating from the beginning of extractive metal working in the 5th–4th millennium B.C. to Roman times as well as theoretical (mathematical modeling) and experimental metallurgical research programmes. The results of this unique project, which covered 5000 years of copper mining and smelting, provided the first firm scientific base for a major chapter of the history of metal, due to be published in 1988 as Vol. 2 of *Researches in the Arabah: The Ancient Extractive Metallurgy of Copper – The Archaeological Data; theory and experiment*, ed. H. G. Bachmann and Beno Rothenberg.

2. Already in 1973 Sir Val Duncan had initiated the setting up of the Huelva Archaeo-Metallurgical Project, with the emphasis on Rio Tinto. RTZ has since been the principal support of IAMS in Spain and in general.

As most of the huge mineral deposits of the Huelva Province and Rio Tinto consist of primary sulphidic ores, exploited in ancient times for silver, gold and copper, the Huelva project was indeed a 'natural sequence' to the Arabah-Sinai research programme (which dealt exclusively with secondary, oxidized ore types). As a first, exploratory step, our Huelva Project undertook a detailed archaeo-metallurgical survey over the whole of the Huelva province, published by Beno Rothenberg and Antonio Blanco Freijeiro, *Studies in Mining and Metallurgy in SW Spain (Metal in History, Vol. 1*, IAMS, London; Spanish edition, Barcelona, 1981). This survey produced the picture of a huge area – the Southern Iberian Pyrite Belt – of ancient metal production which, compared to the Arabah and Sinai, presented totally different technological challenges for the ancient miner and substantially different extractive problems of metal production.

Since 1978 IAMS's Spanish activities have been based on the Rio Tinto mine. This mine, because of its