Monte Romero September 1986 — the discovery of a unique Phoenician silver smelting workshop in south-west Spain

Monte Romero is a modern mine, now abandoned, located in the Sierra de Aracena, c. 100km. north of the town of Huelva. From the late nineteenth century until several years ago different ore bodies were mined here for copper, lead, zinc and silver, but many grooved mining picks found by mining engineers as far back as 1879 provided evidence for the exploration of these lodes in prehistoric times (I.Pinedo Vara, Piratas de Huelva, 1963, 403-9).

Several lodes of rather different mineralisation were recorded at Monte Romero belonging to two major types; one, mainly chalcocite, carbonates and chalcopyrites containing 6–20% copper, some native copper and only low Zn and Pb, the other mainly biende and galena. A typical sample of the latter contained (according to Pinedo): 16.2% Pb; 31.4% Zn; 2.1% Cu; 26.7% S; 9.0% SiO₂; 0.4% As; 0.6% Sb; 0.01% Sn, 0.09% Cl, 0.1% Fe; 500 gms/t Ag; 1.5 gms/t Au.

In view of the complexity of the latter ore lode, which is rather difficult to smelt, it must be assumed that the prehistoric grooved stone mining tools were originally used for the mining of copper ore, probably from outcrops on the upper slopes of the hills of Monte Romero, traces of which can still be seen.

IAMS's Huelva Survey 1974–75

In 1975 the IAMS research group to south-west Spain (The Huelva Archaeo-Metallurgical Project directed by Beno Rothenberg), located on top of a low hillock within the boundaries of Monte Romero, a small barren area, c. 30 x 20m., with different types of slag, clay tuyères, stone tools and potsherds (Site 56 on the Survey Map in B. Rothenberg and A. Blanco Freijeiro, Studies in Ancient Mining and Metallurgy in South-west Spain, London, 1981, 84–90). The pottery found at this site could be dated to the eighth–seventh centuries B.C. and appeared to be related to the Phoenicians. Our special attention was drawn to Monte Romero, not only by this apparently early date for the extraction and smelting of complex ores, hitherto considered unworkable by the ancient metallurgists, but also by the peculiar nature of the metallurgical debris indicating very sophisticated metallurgical processes.

The most outstanding find was a pile of complete slag balls – some globe-shaped, others like a rugby ball or bun-shaped, but all with a flattish surface, which gave the impression that they reflected the shape of the small furnace (c. 20–25cm. diameter) from which they originated. All of these slag balls were extremely viscous and porous, showing many inclusions of free, unmolten quartz pieces (c. 1–2cm.) and could not have been tapped out of a furnace at the end of the smelting operation. Most of the slag was extremely dense (heavy) but some was of very low density (very light) and the chemical analyses (Samples HP146 and HP148, in Rothenberg-Blanco, ibid, 87) showed both to be silver slag. However, next to the ball slag we also found a handful of lumps of
solid platey tap slag with 'ripples' on the upper surface which, when analyzed (Samples HIP147 and HIP145A, in Rothenberg-Blanco, *ibid.*, 86-7) proved to be copper smelting slag, some containing a considerable quantity of matte. Considering the sulphidic ores of Monte Romero, the presence of matte and fayalite slag was to be expected, but the free-silica containing ball slag, and the process which produced it, remained unexplained. Similarly unexplained was the fact that both types of slag - tapped copper slag and highly viscous non-tapped silver slag - appeared mixed together at one and the same spot on a 'Phoenician' site. Monte Romero, as seen by the IAMS survey team, was clearly an enigma: prehistoric stone tools for mining at a complex ore deposit, together with several different, and not well-understood, slag types of copper and silver smelting and mainly handmade pottery of 'Phoenician' type. Only systematic excavation and very detailed archaeo-metallurgical research might solve these problems, which seemed to indicate a hitherto unknown chapter of the history of metallurgy.

**Excavations at Monte Romero, September 1986**

Excavations at Monte Romero were carried out in September 1986 as part of IAMS's Southern Iberia Archaeo-Metallurgical Project (IAMS Newsletter No. 5, 1983), sponsored by the Volkswagen Foundation, Hannover, Rio Tinto Minera A. S. Madrid, and Rio Tinto Zinc plc, London. Fieldwork and the archaeological processing of finds and findings were directed by Beno Rothenberg and Phil Andrews, and the scientific investigation of the metallurgical finds by I. Keesmann of Mainz University. The pottery will be studied by A. Perez-Macias, Rio Tinto Mining Museum.

Two adjacent squares of 5 × 5m, each (A2 and A3), containing the previous find spot were selected for excavation. Due to the shallowness of the soil cover above bedrock (20-40cm), no complete metallurgical installations were preserved. However, enough debris and fragments were left, many in situ, to enable us to form a coherent archaeo-

metallurgical picture of two distinct but closely interlinked extractive processes which produced silver as well as copper from the same complex ore deposit.

**Square A2**: On roughly circular, hearth-like installations (as at Locus 12), where there was no slagging discernible, the sulphidic ore was apparently first 'roasted' in preparation for the smelting operation. It was then smelted in adjacent small furnaces, many fragments of which, consisting of slaged slate plates, were found in a heap (at Locus 13). A dark, charcoaly working floor spread over most of Square A2 and on it a heap of fine clay (Locus 5) was obviously raw material for furnace linings and tuyères.

The slaged furnace fragments were unusually heavy and did not show the porous slag build-up commonly met with in

**Locus 12**, an ore roasting installation.
copper smelting furnaces (as in the Late Bronze Age furnaces at Timna, *IAMS Newsletter* No. 5, 1983) and it seemed that these fragments were heavily impregnated with lead. A well-preserved tuyère was found with the furnace parts and its slagging indicated its protrusion into the smelting hearth at an angle of c. 35° to the horizontal. A pile of slag next to the furnace spot consisted exclusively of lumps of solid tap slag. The density of many of these slag pieces indicated that matte was produced here as a phase of the production of copper and silver (see sample HP145A for matte and HP147 for copper, in Rothenberg-Blanco, *ibid*). Locus 30, which consisted mainly of a thin but rather hard layer of crushed slag (and most probably matte), could well have served as a 'roasting floor' of the matte, as part of its subsequent processing to metallic 'black copper'.

**Square A3:** At the north side of A2 and all over Square A3 a totally different picture was met with which was dominated by the free-silica rich ball-shaped slag and a peculiar kind of fired or charred yellowish soil, which was found next to and underneath some installations built of slate plates on edge (Loci 10, 11, 14). One of these installations (Locus 11) was relatively well-preserved and at its narrow end showed an opening with clay packing, perhaps the location of bellows. There was no slagging on any of the stone structures in Square A3, not even on Loci 11 and 10, which appeared to be some kind of furnace structures. The tuyères found in this area were also quite different. Although clearly fired and obviously used in a metallurgical process, they were not at all slagged and very brittle. The explanation for this fact may well be their shape, these tuyères were curved, i.e. used to blow air across the top of a crucible or cupel and not into a smelting hearth.

The most exciting part of the multi-phased extraction process found here spread from the south-east end of Square A2 to the north-west end of Square A3 and was found at Locus 1 in Square A3. Somehow related to Wall Locus 2 and stone 'platform', Locus 22, was a 'storage area' for used cupels, a number of which were found stacked on top of each other in a shallow depression in the bedrock. No such cupels had ever been found previously at a mining site and here were about a dozen complete ones. There was also a large quantity of heavy litharge spils and lumps, dispersed over this part of A3. Somewhere nearby must have been the cupellation centre where, at the end of the smelting process, lead was oxidized in a cupel to free the silver.

The tentative metallurgical process model

A metallurgical process model, albeit still tentative in detail, can already be proposed, based on the nature and locational sequence of the findings at Monte Romero and their preliminary metallurgical inspection:

1. After some roasting of the complex ores of Monte Romero these were smelted in Square A2, or nearby, to a matte-like copper, lead and silver rich metallic compound. This was the first intermediate product of a complex chain of operations which ultimately produced silver and copper.
2. Subsequent liqutation of this metallic compound together with additional lead, dissolved and collected most of the silver into the lead, which could then be separated from the copper matte by gentle heating.
3. The silver could then be separated from its lead collector by cupellation in the special vessel ('cupel') whereby the litharge (lead oxide) would be run out, leaving the metallic silver behind in the conical bottom of the cupel.
4. The litharge could be recycled by reduction to metallic lead to be used again in a further leading process of matte.
5. The desilvered matte was further (partially) roasted and then smelted (probably with silica flux) to metallic raw copper ('black copper'), a process which would produce the kind of copper slag found at the site.
Handmade decorated vessel, 'Phoenician' period, seventh–sixth century B.C.

The metallurgical principles underlying this extractive model are quite well known from much later historical and recent periods and were still expounded in early twentieth-century text books of metallurgy, but this is the first time that almost all of its components were actually found, and in a locational sequence, in an early smelting site.

We are, however, still left with one major problem: the much discussed 'Phoenician free-silica slag', i.e. the ball-shaped slag with large unmolten rock inclusions as found in Square A3, does not appear to fit into this process model. A further surprise awaited us here.

The investigation of the cupels and ball slag, although still in a preliminary stage, showed that very little remained of the original ceramic material of the cupels, which was replaced during the cupellation process by lead oxide containing many crystals of metallic silver as well as silver-rich metallic copper. We now have to recognise the free-silica ball-shaped slag as being a product of the melting down of the used cupels, and possibly also of heavily leaded furnace wall fragments (as found in a heap at Locus 13). The rock inclusions would have acted as a 'sieve' to facilitate the separation by gravity of the metal components, i.e. allowing the metal to drip through the porous conglomerate of unmolten rock fragments at a low temperature.

Although the pottery from the excavation has not yet been processed, it all seems to belong to the same 'Phoenician' horizon previously indicated by the survey findings.

Monte Romero is a unique site with its complete sequence from the complex ore deposit to the final cupellation and beyond. The study of the various products of Monte Romero will also provide essential new information for the understanding of many other ancient mining and metal working sites, where only partial and fragmentary evidence of metal production is available.

The historical implications of the appearance of such sophisticated extractive metallurgy at the time of the Phoenician cultural domination of southern Spain will be far-reaching, but more work must be done at the site and on the finds by archaeologists, scientists and historians, before major conclusions can be drawn from the surprising discoveries at Monte Romero.

Beno Rothenberg, Phil Andrews and Ingo Keesmann

Metal from the Depths of the Sea

In the wake of the discovery in the sea near Haifa, Israel, of ancient tin and copper ingots IAMS announced (Newsletter No. 1, 1980) a new archaeo-metallurgical research programme to study ancient metal trade routes as represented by metal hoards found in the sea. Preliminary investigation of the ingots strongly suggested the need for further, more intensive exploration in the sea in search of reliably located and better dated metal finds, before the commencement of a full-scale archaeo-metallurgical research programme. E. Galili of the Centre for Maritime Studies, Haifa University (CMSH), reports here on the finds made by recent underwater explorations (surveys and excavations). IAMS, in collaboration with Dr N. H. Gale of the Department of Earth Sciences, Oxford University, has now begun the systematic archaeo-metallurgical investigation of these important and, mostly, unique finds. The extractive-metallurgical aspects and the manufacturing processes of the different types of tin and copper ingots, together with their dating and provenance, will be investigated. This work is expected to contribute important information towards a better understanding of the trade routes of metal in the Ancient World.

The almost straight 2000km. long coastline of Israel did not provide any natural shelters from storms for the ships which sailed along this ancient shipping lane for thousands of years. Once caught in a storm, ships sailing close to the coast, as was normal in antiquity, found themselves trapped and had little chance of survival. Of the numerous ships that sank along Israel's coast in ancient times, about 9% have been found in the 200m.-wide breaker zone close to the shore.

The wooden parts of the wrecked and foundered ships, and the lighter items of their cargo, were washed away by the sea whilst the heavy items sank down to the sand-covered, hard clayey sea bottom. Here, for several thousand years, they have been protected by the sand cover from salvage and reuse by man.

In the last 30–40 years, huge quantities of sand have been quarried away by building contractors and others from many parts of Israel's coast. These activities disturbed the sedimentary equilibrium and thereby created a considerable shortage of sand on the shallow coastal shelf. Consequently, many areas which had been covered by a thick sand layer for thousands of years became uncovered and numerous archaeological sites and objects were exposed. Besides prehistoric settlements which had been swallowed up by the sea, many...
ships' cargoes of pottery, stone and metal objects and, of special interest to us here, numerous metal ingots, were found.

The underwater survey and excavations along the northern coast of Israel, which have been carried out since 1980 by CMSH, located and documented many different types of tin, copper, lead and iron ingots, either in groups or as individual finds. This unique collection of ingots is obviously of considerable archaeo-metallurgical and historical significance, especially for the understanding of the early sea-borne metal trade. However, because these ingots were often found without any related remains of the original carrier or other datable archaeological objects, they presented many problems of dating and provenance within the current archaeo-metallurgical research project.

The following are the principal ingot-types found along the northern coast of Israel:

**1. Rectangular tin ingots with incised signs**
These ingots are brick-shaped, similar to modern gold ingots (though larger and thinner). The marks they bear are apparently related to the Cypro-Minoan script group and appear to have been incised subsequent to casting.

A large quantity of these ingots was discovered in the 70s by a fisherman who gave as their find spot the area of the ancient port of Dor, south of Haifa (IAMS Newsletter, No. 1, 1980). He sold them to scrap metal merchants and today only four of these ingots survive: two are in the Museum of Ancient Art, Haifa; another is in the Maritime Museum, Haifa, and the fourth on temporary exhibit at the Haaretz Museum, Tel Aviv.

Subsequent inquiries established that the fisherman had given a false provenance to mislead other potential treasure hunters. It is now also by no means certain that, as originally reported, these ingots were found together with copper ingots. The find spot of this important group of tin ingots is still obscure.

Some of the ingots were published, including some chemical analyses, by R. Maddin *et al.* in *Expedition* 19, 1977. Although the apparent Cypro-Minoan signs could indicate a late second millennium date, similar signs are known from Iberia at much later dates. Rothenberg suggested (*IAMS Newsletter*, No. 2, 1981, 4), based on some preliminary analyses at the British Museum Research Laboratory, that these tin ingots may have originated from the Iberian peninsula.

**2. Round copper ingots**
These ingots are of a fairly regular bun shape, but each is of a different size and weight (10-20kg.). They were found by the same fisherman (mentioned above) in the early 70s, probably in the area of Megadim. About two tons of copper ingots were found together in two large piles, which must have sunk together with the ship, and it seems likely that more copper ingots are still to be found at the site. Several of these ingots were acquired many years after their sale to a scrap metal merchant. Two are now in the Haifa Maritime Museum; one at Haifa University and several on temporary loan to the Haaretz Museum, Tel Aviv.

**3. Irregular bun-shaped tin ingots**
A hoard of five irregular bun-shaped (flat top and curved body) tin ingots was found near Kefar Samir by the CMSH in 1982, together with one 'ox-hide' copper ingot (No. 4 below), and four stone anchors. Their weight varies between 2-4kg.

Different signs of Cypro-Minoan character were found chiselled into the upper surface of the ingots, which were dated by the excavator to the 14th-12th centuries B.C. (see E. Gallif *et al.* in *Int. J. of Nautical Archaeology* 14, 1985; also includes chemical analyses). Some of these ingots appear to have formed parts of larger examples, a fact which could indicate that the ship was a 'sailing smith's workshop' (see G. Bass, *Cape Gelidonia*, 1967), especially as they were found together with copper ingots (No. 4, below).

**4. Ox-hide copper ingot**
This ox-hide copper ingot of a type common in the Mediterranean in the 15th-12th centuries B.C., was found together
with the tin ingots described above (No. 3). It weighs 16.5kg, and has an elliptical mark, as yet unexplained, on its upper surface. Several copper fragments cut from other ox-hide ingots were also found in this area of Kefar Samir.

5. Plano-spherical tin ingots

A cargo of ten semi-spherical ingots (flat top and semi-spherical body) was found in a single heap at Kefar Samir in 1981. They were heavily corroded and had a gross weight of c. 100kg. Near this hoard was a surprisingly well-preserved tin ingot of similar shape, weighing 27kg. It also was originally semi-spherical but had been cut in antiquity and a hole made through it.

This hoard, which also contained lead ingots (see No. 6), could be dated by an Egyptian 'sickle' sword found in the same context, to the 13th–12th centuries B.C.

6. Small lead ingots


7. Bar-shaped, trapezoid tin ingots

Several bar-shaped ingots with trapezoid section were found in the area of Kefar Samir. It is possible that a number of coins of the 4th–3rd centuries B.C. from the mint of Tyre found next to the ingots may date them by association.

8. Disk-shaped tin ingots

This solitary and, so far, unique ingot type was found in the early 70s near Megadim but, since it was a stray find, it has no archaeological context and is not datable.

9. Iron pigs

Ten oblong iron 'pigs' weighing 8kg, each were found south of Kefar Samir, next to a Roman shipwreck.

Besides the metal ingots described above, the collection of the CMSH contains a large number of sea-borne metal objects which will also be investigated in the ingot research programme.

E. Galili
Radiocarbon (C14) Dating helps to solve riddle of Timna’s Late Bronze Age smelting furnaces

In IAMS Newsletter No. 5, 1983, we published details of a newly discovered rock-cut smelting furnace in the Egyptian copper smelting camp Site 2 of the Ramesside period in the Timna Valley of southern Israel, which was dated to the twelfth century B.C. It was shaped like a tubular bowl or cup, cut into bedrock, and was found with one clay tuyère in its heavily slagged backwall in situ. Attached to this smelting hearth was a second rock-cut pit, which served as a receptacle for the slag tapped from the smelting hearth at the conclusion of the smelting operation. Next to the furnace was a heap of ring-shaped slag cakes, which must have been produced in it since no other smelting installation was located nearby. This furnace stood solitary on a rock-ledge, separated from the Egyptian main camp by a narrow wadi.

Because of the great similarity to the other smelting furnaces of Site 2, which are typical for the end phase of the 14th–12th centuries B.C. Ramesside (Late Bronze Age) smelting installations of Timna, and because of the exclusively New Kingdom pottery found around the newly found furnace and in the slag heap, the rock-cut furnace was dated to approximately the twelfth century B.C.

During the excavation of this furnace a handful of unburned lumps of charcoal was found on its bottom. As this was the only time we had ever made such a find on the bottom of a smelting furnace, and as all other smelting hearth bottoms showed a thin cover of light-grey charred sand—never ashes and never unburned charcoal, we sent this carbon sample for C14 dating (see IAMS Newsletter No. 5, p. 7). We assumed, however, that there was little doubt regarding the twelfth century B.C. date of the furnace.

The result was a considerable surprise which we recorded in our overview of the Arabah Furnaces, published in Furnaces and Smelting Technology in Antiquity, ed. P. Craddock and M. J. Hughes, British Museum Occ. Papers No. 48, 1985: 'charcoal found in the furnace bottom gave a date of 1210 ± 100 (BM 2242)', i.e. 7th–8th centuries A.D., and added the caution: 'Thus the Late Bronze Age date for Layer 1 type furnace of Site 2 may have to be revised after further investigations (added June 1984)'.

The problem which had arisen through this Early Islamic C14 date, instead of the expected Late Bronze-Early Iron Age date, involved not only the newly excavated furnace, but all the Timna Site 2 furnaces which had been generally accepted as the typical Late Bronze Age smelting furnace (see R. F. Tylecote, The Prehistory of Metallurgy in the British Isles, 1986, p. 19). This new C14 date also threw doubt on all other sites and installations where the unique ring-shaped slag cakes had been found in the same archaeological context.

To radically explore this unexpected problem, especially in view of the fact that the definitive excavation reports were already finalized and forthcoming in Researches in the Arabah, Vol. 4, IAMS London, all the sites where ring-shaped slag was found, and the installations which produced them, were systematically sampled for charcoal and a series of samples sent to the British Museum Research Laboratory and to the National Physical Research Laboratory (Dr. Vogel), CSIR Pretoria.

Here are the first results: CSIR Anal. No. Pts 4121 – 3090 ± 60bp., calibrated date for the slag, produced in the rock-cut furnace, is fourteenth century B.C.; BM2382 Site 2, Layer 2 (the slag next to furnace V) 3220 ± 50bp., calibrated date thirteenth century B.C., i.e. New Kingdom dates for the Timna Site 2 furnaces.

However, Pts 4117 – 1390 ± 50bp., i.e. calibrated date 640 A.D. (Early Islamic) for slag at Roman Beer Ora, in addition to the similar date for the charcoal in the rock-cut Late Bronze Age furnace, created a new situation.

The radiocarbon dates vindicated our original New Kingdom (Late Bronze Age) date of the 'typical LB furnaces'. They also showed that during the Early Islamic occupation of the southern Arabah in the seventh century A.D., there was, apparently, an extensive secondary use of the ancient smelting camps and installations, both for copper smelting and/or casting (with the adaptation in Islamic Beer Ora of the useful Late Bronze invention of the ring-shaped tap slag and secondary, mechanical extraction of entrapped copper prills and ingots from the old slag heaps). There was also the use for non-metallurgical, more domestic purposes, such as the cooking hearth located in a New Kingdom smelter. The Early Islamic C14 date for charcoal in the Late Bronze Age furnace of Site 2 in Timna does not alter the date of the Late Bronze furnaces of Timna; it establishes the existence of an additional period of extensive activities in the Arabah during the Early Islamic conquest of the region.

B.R.

News from the director’s desk

Thanks to the Volkswagen Foundation
Intensive fieldwork since 1977 in the region of the Rio Tinto Mine in south-west Spain (see IAMS Newsletter Nos 1–3 and especially No. 8, 1986) produced unique archæo-metallurgical material from the beginning of metal-working in southern Iberia during the early Copper Age, when copper and silver produced at the scale of cottage industries, to the first full-scale production during the Late Bronze Age. From then on its ever-growing dimensions led to the huge industrial copper and silver production of Ibero-Roman and Imperial Roman times. Preliminary analytical studies of the slag heaps of Rio Tinto — covering about 8km² — were limited by the lack of sufficient funds, but produced a first picture of these techno-historical developments. However, the proper understanding of the different processes used by the ancient metalurgists during the three-four thousand years of mining at Rio Tinto (and at many other sites investigated by IAMS’s Iberian Research Group, see IAMS Newsletter No. 5, 1983), made additional field exploration, excavations and, foremost, intensive and sophisticated scientific studies, imperative.

Recently IAMS formed a new composite research group to undertake such a comprehensive South Iberian Archæo-Metallurgical Research Project, under the overall direction of the Director. Co-directors are: Professor A. Arrillaga Palau (Palma University); Professor F. Molina Gonzales (Granada University), and Professor I. Keesmann (Mainz University).
study of bronzes, except dating, are brought together, and this is one of the aims of the book. Born is concerned that the archaeologist, conservator and natural scientist should work in concert rather than independently. So often reports on the technical examination of a bronze, commissioned by the art historian in charge of the publication, are published as appendices completely undigested and divorced from the main text, sometimes even contradicting it. The often ephemeral information on the construction and decoration of a bronze surviving only on or in the surface patination is brought home very forcibly in this book, not least by the truly excellent photographs. Clearly, the conservators are in the best position to observe and record this information, but only if they are fully integrated into the investigative team and realise the full potential of what they are examining.

This is an excellent book for anyone involved with the study of ancient metalwork, there is much that is new – techniques, case studies on objects not always familiar to the English-speaking world and, above all, a fresh discussion of new ideas and approaches. All in all, a good book. P. T. Craddock

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