the pit were meant to be added to the smelting charge in order to assist in the formation of the silver-rich lead bullion.

The model (Fig. 2) proposed for the Monte Romero finds may seem rather complex for such an early archaeological period. Nevertheless, it does agree best with the archaeometallurgical evidence from the site. The polymetallic ore would have initially been roasted to drive off a portion of the sulphur. Next it was mixed with quartz and barite flux and charcoal, then charged into the smelting furnace. The products of this smelting step would have been slag, speiss and lead, probably present in three superimposed layers in the furnace. However, separation of these three distinct layers would have been difficult at this step of the process. Thus, rather than being tapped, the slag was cooled and solidified by the addition of large inclusions of crushed rock and removed in the form of these slag balls.

The speiss and lead would have been left in the furnace, where upon cooling, speiss having a higher melting point than lead, would have solidified and could be removed in the form of plates. The primary lead could then be tapped out. The lead produced would have been silver-rich and would subsequently undergo cupellation.

The slag balls, however, still contain a large amount of lead and, therefore, would have been re-treated. They could be crushed and mixed with more barite flux and charged back into the smelting furnace. The barite would react with the lead silicates releasing metallic lead and forming a fluid tap slag. Any trapped metallic prills would also be released and liquate to the bottom of the furnace. Thus this cycle would produce a tap slag and more metallic lead.

The presence of slagged crucible fragments from the site, whose analysis revealed that the slag was in fact layers of lead metal with a mixture of copper and antimony, may be evidence of a drossing step previous to cupellation. In 'drossing' the lead metal is melted, due to the low solubility of the other impurities in molten lead and their lower specific gravity, they float to the surface from where they can be removed. This produces a more refined, silver-rich, lead which would then be cupelled.

Cupellation took place in cupels with an average diameter of 12cm. Although the best material for the manufacture of cupels and cupellation hearths is traditionally known to be bone ash, this was not used in the preparation of the cupels from Monte Romero. XRF analysis of the cupels does not detect any phosphorus. The products would be silver, which has not been found in the site, and litharge, the lead oxide. The cupels found at Monte Romero are completely saturated with litharge.

The fact that much of the lead that does not contain much silver indicates that the litharge was reduced in a final step to produce metallic lead. It seems likely that this was again recycled into the smelting furnace where it would again act as a collector of the silver from the polymetallic ore.

The site of Monte Romero offers a unique opportunity to investigate a silver workshop of this period. Unlike other workshops that have been excavated, such as that at San Bartolomé de Almonte (Ruiz Mata and Fernández Jurado, 1986), Monte Romero is located in close proximity to the mine and shows all the various steps of the process, from the ore to the cupellation. Also, unlike larger sites, such as Rio Tinto, Monte Romero was occupied only during a single period, which avoids the complex strategraphic problems of mixed finds belonging to different processes of different periods.

The sophisticated process established by our archaeometallurgical investigation, shows that the people working in the 7th century B.C. workshop of Monte Romero were competent metallurgists who were able to process even highly complex ores to produce silver.

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Bronze and Iron Age Metallurgy from the Oman Peninsula

Most research concerning collections of ancient metalwork is approached from either a purely analytical or typological viewpoint. In this work, an attempt has been made to combine both approaches. The copper alloy weapons have been investigated using atomic absorption spectroscopy, standard metallographic techniques and scanning electron microscopy with energy dispersive microanalysis. Typological comparisons are made to other metal object finds at sites in the region. The material that forms the corpus of the study, on loan for analysis and conservation from the Al Ain Museum in Abu Dhabi, comprise grave finds from three sites in the

Fig. 1. One of the bronze swords from Qidfa shown before conservation. A small 1mm hole was drilled in an inconspicuous place to remove a sample for compositional analysis. It will be filled as part of the conservation treatment.

U.A.E., namely Umm an-Nar, Qattarah and Qidfa. The three sites represent different archaeological periods and, consequently, different technological horizons.

The earliest group of artefacts are representative of the second half of the third millennium B.C. from the island of Umm an-Nar. The group consists of five simple objects, mostly pins and awls. These objects were very basic forms and not sufficient for typological study. The metal compositions had some characteristics similar to other Umm an-Nar objects, for example with 1–2% of nickel and arsenic. However, the concentrations of tin at 1.5%, 0.6% and 0.2%, respectively, in three of the analyzed objects represents a significant discovery. Although, one object alloyed with tin may seem early for the Umm an-Nar period in the area, the actual alloying with tin and the implied organized trade routes to tin sources would not be unexpected in comparison to what was previously known about the Umm an-Nar acquisition of other materials, such as gold, lapis lazuli and cornelian (Weisgerber, 1985).

The second group of artefacts come from a grave at Qattarah, in the Al Ain oasis. These finds form a representative collection of weapons from a classical Wadi Suq context, c. 2000 B.C. Except for one example with about 5% tin, the other short daggers and triangular blades are unalloyed with tin. The concentrations of arsenic and nickel are below about 1%. Socketed spearheads have similar compositions.

The latest group is from Qidfa, a site on the east coast of the Oman peninsula. The collection is tentatively dated to the latter part of the second millennium, B.C., in an early Iron Age context. From the collection of 26 analyzed arrowheads from Qidfa, the tin concentrations seem random, with no correlation between tin concentration, shape or incised decoration. In contrast, four examples of swords/daggers (32–40cm in overall length; Fig. 1) from Qidfa have between 7–9% tin with the inferred deliberate control of composition. Three heavy rings (each 530–1,220gms.) were analyzed as well showing tin concentrations between 8–13%. A shafthole axe and an adze were also alloyed with tin.

From the objects studied, there appears to be a good understanding of the advantages of cold-working and annealing copper for the material from both Qattarah and Qidfa. The utilization of copper-tin alloys was much more prevalent at Qidfa and seems comparable to alloying practices at later dates (Weisgerber, 1988). A preliminary typological investigation of this material revealed many parallels with other finds from Oman and the U.A.E., both in composition and form. Wider parallels were identified, with the material displaying similarities to material from western Iran, the Talysh region of Iran and from Syria/Palestine. The triangular dagger blades from Qattarah and the heavy rings from Qidfa, however, seem unique to the Oman peninsula. From the results, the introduction of tin to allow widespread use of bronze for weapons and other objects at Qidfa can be documented and manifest characteristics of both imported as well as local metalworking traditions.

The excavator and curator of the material from Qidfa and Qattarah is Dr Walid Yasin of the Al-Ain Museum. Loan of the objects to the Institute of Archaeology, University College London, for archaeo-metallurgical analysis and conservation (Fig. 2) was arranged by Dr J. Merkel through the Tourism and Antiquities Directorate, Al-Ain, Emirate of Abu Dhabi. The archaeo-metallurgical investigation of the material is now complete. It was undertaken as a M.Sc. report by the author under the supervision of Mr C. Phillips and Dr J. Merkel in the IAMS Archaeo-Metallurgy programme at the Institute of Archaeology, UCL. Presently, the metal objects are undergoing conservation treatment by students under the supervision of Dr J. Merkel and Ms K. Tubb as part of their teaching in the course 'Conservation of Metallic Artefacts'. The loan of the objects is gratefully acknowledged. It is a splendid opportunity to work on such interesting, high-quality objects in preparation for their display at the Al-Ain Museum. *Jason Ryan*

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New Archaeo-Metallurgical Evidence for the Beginnings of Metallurgy in the Southern Levant. Excavations at Tell Abu Matar, Beersheba (Israel) 1990/1

In IAMS *Newsletter* No. 17, 1991, the Chalcolithic (4th millennium B.C.) Ghassulian-Beersheba enigma was reviewed as one of the most significant unanswered questions in the early history of the southern Levant intimately connected with metallurgy. This enigma, which was impressively emphasized by the sensational discovery by P. Bar-Adon, a member of Yigael Yadin's famous Judaean Desert Expedition (1960), of hundreds