A GLIMPSE ON COPPER AND LEAD METALWORKING AT ALTYN-DEPE (TURKMENISTAN) IN THE 3rd MILLENNIUM BC

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Introduction

Surface surveys of protohistorical sites in South and Central Asia, since the early '70ies, have provided a great amount of archaeological information on ancient technology and early urban craft organisation.[1] The purpose of this paper is to present the first results of an archaeometallurgical study carried out on a set of samples of metal and metal-related objects (including fragments of finished objects, small manufacturing residues or semifinished items) collected by the Italian Archaeological Mission to Turkmenistan, in the frame of a joint project by Turkmenian State University & Istituto Italiano per l'Africa e l'Oriente (IsIAO, Rome) at the huge Chalcolithic and Bronze Age site of Altyn-depe in autumn 1998. The collection included about 40 small finds, generously made available by the competent Turkmenian authorities for temporary export and for analysis. Other metal samples were obtained from our Russian colleagues of the Academy of Sciences of S. Petersburg. The analytical techniques so far applied included X-Rays Diffraction (XRD) for characterising the surface patinas, corrosion products and core material of some artefacts, X-Rays Fluorescence (EDXRF) and – for a more limited set of samples – SEM-microprobe for chemical analysis. A metallographic study investigated the micro-structural features of the sampled pieces. The study was carried out at the Istituto Centrale per il Restauro (ICR, Rome) and at the Institute of Physics of the Rome University "La Sapienza". The archaeometallurgical evidence thus gathered is then matched with the published information provided in the past by the Russian and Turkmenian excavators of the site, in the attempt of restoring a sounder and more coherent image of the ancient activities of transformation of metals in this important proto-historic site.

[1] Bondioli et al. 1984; Salvatori & Vidale 1982; Tosi 1989; Tosi & Vidale 1990; Vidale 1984, 1987, 1989, 1990, 1990a.

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The archaeological context

The site of Altyn-depe is an impressive mound, the remains of a settlement that flourished in the central-eastern piedmont sector of the Kopet Dagh belt, in correspondence with the flooding deposits of the rivers Chaacha and Meana, few km at east of the present village of Meana, Turkmenistan (Fig. 1).[2] The site was discovered by A.A. Semenov in 1929 and it was visited by A.A. Marushchenko in 1935 and by M.E. Masson in 1949, while the first test trench at the site was excavated in 1951 by S.A. Ershov.[3] Presently, the dissected mounds of Altyn-depe (the name of the site meaning, as widely reported, "The mound of gold") rise for about 20 m from the alluvial plain; the archaeological layers extend 9 m below the present ground level, bringing the total depth of the cultural deposit at Altyn-depe to almost 30 m. The site was inhabited at least since the Middle Chalcolithic (period Namazga II, about 4000-3500 BC), when it soon reached a size of about 25-30 ha, an extension maintained or exceeded, in the 3rd millennium BC, during the Early and Middle Bronze Age (periods Namazga IV and V).

The compound (Fig. 2) like many other sites of South and Central Asia, has been deeply and widely eroded by rain, wind and, locally, abraded by animal trampling. Other major disturbances were caused by decades of test trenches and extensive excavations, involving massive dumping of removed earth in some sections of the surface as well as the erection of camps of tents for the field teams near the site. Erosion, generally speaking, has followed the rough outline of the main urban features (such as the layout of ancient streets, squares, and possibly peripheral bounding structures in mud-brick and stones), cutting the mound in a discontinuous, irregular topographic grid. Structures in stone and mud-bricks, including massive platforms, sometimes clearly planned in large urban blocks, as well as the outline of kilns and graves, are easily identified on the surface of the mound.

The surface includes wide patches of deflated hard soil littered with potsherds and pebbles, but also extensive grass coverings, while the cuttings of the most relevant gullies often gather and convey downward large amounts of loose cultural materials.

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[2] Kohl 1981, 1984; Masson & Sarianidi 1972; Masson 1988.

[3] Ganyalin 1959, 30; for an up-dated history of Altyn-depe excavations see Kirtcho, Salvatori & Vidale n.d.

Several decades of archaeological research by soviet archaeologists made of Altyn-depe the type-site of the ancient Central Asian Bronze Age.[4] After the first pioneering discoveries, a series of important and glamorous finds (monumental architecture and luxurious grave furnishing showing the unexpectedly high standards of living and ideological representation of the local *élite*), through some influential publications, granted to the site a celebrated place in the archaeological picture of proto-historic Asia. Altyn-depe soon became the key-site for observing, from the peculiar viewpoint of Marxist orthodox research, the development and the final collapse of a rich early state community of the Bronze Age, part of a *continuum* that connected the Central Asian deserts and oasis to the favoured alluvial floodplains of Mesopotamia and the Indus valley in a huge frame of social evolution.

At the same time, many of the previous soviet excavations were never published, or were published only in a summary fashion. Selected materials were brought to Leningrad (now St. Petersburg) and little efforts were spent for developing appropriate, permanent research facilities in Turkmenistan. The recording and processing of artefacts and excavation data was often poor and partial. For a long time, political boundaries and restrictions severely limited exchange and collaboration between Russian, Turkmenian and western scholars, and thus some critical viewpoints assumed by the excavators were left undebated. Following the collapse of Soviet Union, the independence of Turkmenistan, as well as of the other Central Asian nations, has promoted new, unforeseen research perspectives. While the Turkmenian-Italian project in Margiana is going to its conclusion, the know-how and recording technology already applied to the sites of the Murghab delta[5] are currently transferred and adapted to the local conditions of the piedmont strip of the Chaacha-Meana region. A new topographic mapping and a surface analysis of the craft activity areas of the sites of Altyn-depe and Ilgynly depe, and the resumption of archaeometric research, have been the first steps of this new stage of work.[6]

Urban activity areas and surface collections

The map of Fig. 3 had been produced by the soviet colleagues with traditional topographic recording instruments,[7] while the map of Fig. 4 shows the topogra-

[4] Kirtcho, Salvatori, & Vidale n.d.

[5] Gubaev, Koshelenko & Tosi 1998; Salvatori 1995, 1998a.

[6] See Turkmenian State University & Istituto Italiano per l'Africa e l'Oriente, 1999.

[7] After Masson 1988.

phy of Altyn-depe as recorded today by the means of a computerised portable station. The new map was obtained in three days of work by Gianluca Bonora and Sandro Salvatori, with the help of Turkmenian and Russian scholars. This map, besides the morphology of the mounds, reports the archaeological trenches so far excavated on the compound (both after regular excavations and irregular disturbances, such as some military trenches dug during the recent afghan conflict). The reconstruction of the long history of soviet excavations in the site, and the exact relocation of the original trenches laid by 2 generations of archaeologists has been accomplished by Ljuba Kircho, of the Academy of Sciences of S. Petersburg (CSI). The date and meaning of some trenches, nonetheless, still remain unknown. While the old map correctly rendered the basic outline of the site's topography, the second one seems to provide a more precise rendering of the orientation of streets and walls alignments, the shape of what presumably were blocks of the ancient city, and, in general, a better ground to understand the dynamic relationships between erosion and the artefacts clustered and located in specific parts of the mounds.

The ancient city had the shape of a flattened pentagon, with a minor side at west. It might have been provided of at least 4 main gates (respectively at south-west, north-west, north-east and south-east). At least one of these city gates, according to the excavators, was flanked by massive defence towers. This pattern suggests an overall street axis orientation from north-west to south-east and from north-east to south-west. Surface analysis indicates that during the middle Bronze Age a large part of the city was rebuilt in the shape of a grid of rectangular raised blocks, following the described orientation. All along the periphery of the pentagon, such blocks and the alleys flanking them may be still partially recognised.

As commonly happens in many eroded proto-historic sites of south and central Asia, intensive erosion affected mostly the peripheral mounds and the depressions possibly indicating gates, streets and alleys. As a result, it is difficult to ascertain to which extent the "ring" of craft activity areas detected on surface is the result of a selective allocation of craft workshops at the very border of the city or it is just the result of a series of post-depositional transformation processes.

Decades of trampling, dumping and selective collection of small finds have probably altered in several points the original distribution of surface artefacts. Most of the craft activity areas visible on surface were already well known. For example, the main pottery making area at the northern extremity of the site, dated to a mature stage of the Middle Bronze Age, had been previously excavated and published.[8] Another concentration of kiln residues and overfired ceramics has been located in the south-western slopes, and isolated kilns and/or waste heaps have been observed in other points of the city as well. Three major surface concentrations of lithic debitage including drill heads, flakes of agate and other semiprecious stones were located by us around the south-eastern "gate" (again, does this reflect a location near the access or just a higher local rate of erosion?). A smaller concentration of calcite flakes and rough-outs in the western border of the central plateau was dumped after the manufacture of banded calcite vessels, while some of the residues were turned into beads. The find of small hoards of semifinished blocks and rough-outs in calcite and selenite (gypsum) in the early Bronze Age houses and courtyards recently excavated by Ljuba Kircho[9] shows the presence of some form of craft production organised and monitored *ad hoc* by well-to-do residents.

The past excavations had brought to light an isolated room (in excavation 10), in the north-eastern part of the mound, where apparently somebody had been crushing an amount of copper ore.[10] Small objects occurring in micro-clusters and indicating copper melting have been mapped in almost every activity area recorded at Altyn-depe. Fragments of copper objects, prills, small ingot pieces and kiln linings with copper drops are scattered in various parts of the surface of the site, supporting the hypothesis of a pattern of diffuse processing (by recycling and re-melting) of copper objects in the houses of Altyn-depe, with a single major cluster in the southernmost tip of the mound. The copper-bronze objects we collected and analysed, to a great extent, come from this cluster (AS 2), while other samples were randomly collected in other parts of the site and analysed mainly because of their palaeo-technological relevance.

Thanks to the continuous assistance of Ljuba Kircho, the surface contexts were easily datable after the associated ceramics. AS 2, in particular, presented a coherent association of forms referable to a mature stage of the Middle Bronze Age or Namazga V period, i.e. may be dated, following the chronology more generally accepted by western scholars, around the end of the 3rd millennium BC. Although in theory it is not possible to exclude that some of the metallic artefacts we collected are older or more recent then the 3rd millennium BC, as the site was abandoned at the end of the Bronze Age and the outcrop of the

[8] Masimov 1976.

[9] Kircho 1994, 1995.

[10] Masson 1988, 35.

Chalcolithic deposits is easily recognisable, the collection we analysed may be rather safely ascribed to the Middle Bronze Age.

The "Copper Mound"

AS 2 was recorded on a isolated hummock in the southern border of the site, thus called "Copper Mound" by the former soviet scholars because the surface was covered with a wide scatter of copper-bronze residues. Nonetheless, the previous excavation of this site by a Russian team in 1971-1972, under the direction of V.I. Knyshev, had previously demonstrated that the surface concentration of copper-working indicators was not matched by a corresponding stratigraphic context *in situ*, but was probably the output of a long, gradual process of erosion and surface dispersion of deposits by a copper-working activity area temporarily installed on the mound). In fact, the excavation of part of the mound's top brought to light some domestic architecture with little relationship, if any, with the overlying surface deposits. The examination by one of the writers (MV) of the collection of copper artefacts coming from this excavation, at the stores of S. Petersburg, showed a very limited group of unsubstantial copper artefacts (mostly awls and other light tools), and few small slag fragments, well in accordance with Masson's report.[11] The surface collection of 1998 included more than 800 indicators, including several undetermined copper scraps, fragments of finished objects, among which some pieces of scalpels, vessels and a fragment of a compartmented seal, slag, prills, kiln linings, but apparently no pieces of crucibles or moulds (the possible crucible fragment in Fig. 6:42 comes from another spot). On the whole, on the basis of the surface record we might hypothesise the performance of a light-duty copper metallurgy, more centred on selecting and re-melting small broken artefacts than on the smelting of large amounts of copper and other ores.

Our survey and mapping of the surface east of the 1971-1972 excavation trench (AS1, AS2, 20×40 m) revealed the presence of one or more copper melting kilns trampled and eroded *in situ*, (see below) but it still remains unclear to which extent the presumable squatting occupation of the area by metallurgists directly involved living and working in the last houses built on the spot.

[11] Ibid., 37.

Ancient metallurgy at Altyn-depe: general remarks

Large copper-bearing ore deposits have been reported from the eastern boundaries of Bactria, presently in northern Afghanistan. Here proto-historic craftspeople used to roast powdered carbonate ores (malachite) within large open crucibles. Other metalliferous deposits might have been exploited at the eastern limits of the South-Turkmenian region and within the present political territory of Uzbekistan. In every case, such source areas would be located very far from the Chaacha-Meana basin, as reported in Chernykh.[12] The same author recognises for the Bronze Age of Central Asia two different technological traditions, one centring on Margiana and Southern Turkmenistan, and the other on the Bactrian planes. In absence of large, immediately available source areas for metallic ores, Chernykh considers the former as a tradition largely focused on secondary transformation technologies. At any rate, it is clear enough that soviet authors, while discussing the Kopet Dagh piedmont sites, completely neglected the rich copper deposits of north-eastern Iran, such as, for example, those in the Torud-Abbasabad region, about 100 km south-east of Damghan (including carbonates and sulphides, with malachite, chrisocolla, azurite, chalcocite, chalcopirite, covellite, bornite and pirite). Other metal-bearing deposits are presently found in northern Khorassan.[13] In the past this area, rich also in turquoise and gold, might well have provided Southern Turkmenia with copper and lead.

The general characters of the ancient metallurgy of protohistoric Southern Turkmenistan have been previously defined thanks to the studies of N.N. Terekhova;[14] we use here also the synthesis provided by V.M. Masson in his book on Altyn-depe.[15] In general, the Central Asian metallurgical tradition of the Late Chalcolithic and Early Bronze Age (periods Namazga III and IV, from the end of the 4th to the first half of the 3rd millennium BC), appeared to be limited both in terms of quantity and quality of production. In contrast, during the Middle Bronze Age, and particularly at the end of the 3rd millennium BC, with the development in the core regions of large fortified settlements and extensive cemeteries (in Margiana, Bactria and Tajikistan),[16] one witnesses an extraordinary development of metallurgical technologies.

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[12] Chernykh 1992, 179.

[13] Pirite, chalcopirite, magnetite, sphalerite and galena: the source is Ministry of Economy 1969, 71ff, 87ff.

[14] Terekhova 1981.

[15] Masson 1988, 82.

[16] Ligabue & Salvatori 1979; Pottier 1984; Hiebert 1994; Salvatori 1995.

Due to the scarcity of regular excavations and the wide-scale destruction carried out by illegal excavators in the southern Bactrian region, it is still very difficult to understand such evolution. As far as Altyn-depe is concerned, V.M. Masson[17] remarked that the reported absence of suitable copper-bearing deposits in Southern Turkmenistan might have forced the local inhabitants to a constant re-cycling by re-melting every possible copper or bronze scrap. Masson also observed that the most important metal objects were found in rich élitist graves, while the excavation of common dwellings used to bring to light only fragments of copper/bronze points and awls. This description – whatever the reason might have been – fit rather well with the evidence available in the excavated trench of the "Copper Mound", in the nearby AS2 as well as in other clusters of craft indicators detected on surface.

Some typical copper/bronze artefacts from Altyn-depe (3rd millennium BC) are presented in Fig. 5. When we look at the Middle Bronze Age grave furnishings, the picture is completely different. The repertory of copper/bronze products includes adzes, small chisels having a rectangular section, awls, needles and pins having variable shapes, knifes with a single or double cutting edge and hafting tang (Fig. 5.1 and 12; as a rule, flat; only few blades show a central ridge), arrow heads and sickle blades (Fig. 5.3). Among personal ornaments and make-up articles range concave mirrors, with or without handle; beads and pendants; ear-rings with twisted wires; bangles having egg-shaped sections; finger rings; a wide repertory of pins having the extremity in form of spiral, double spiral, lozenge, stepped lozenge, animal or animal head (Fig. 5.4-5) (our collection includes a pin terminating in the body of a stag or bovine – the horns are missing: see Fig. 6.27 and Fig. 10). On surface are also common fragments of copper/bronze vessels (Figs. 5.2, 6, 24 and 25). One of the most common and distinctive southern turkmenian artefact, both in settlements and graves, is the bronze compartmented stamp seal (Fig. 5.6-11). Shapes vary from simple geometric patterns (very often crosses and circles), to complex animal shapes, sometimes composite.

The ritual loss of valuable copper products by the means of burial in graves appears as a distinctive economic and ideological attitude, most probably matching with the evidence of intensive re-cycling in the living settlement: copper and bronze were very costly, their use reserved to the uppermost spheres of the society, and part of these goods was not inherited but destroyed at the death of the

[17] Masson 1988, 83.

owner. Nevertheless, any hypothesis on raw material, semifinished and/or finished goods procurement, production and trade have to be embossed in a clear chrono-cultural frame to avoid dangerous and misleading generalisations. The above described attitude to "destroy" significant quantities of metal (bronze, silver, gold) and stone objects by means of burying them in the graves is a phenomenon which reach its peak during the Middle Bronze Age (Namazga V) as well attested both in the piedmont of southern Turkmenistan and in the deltaic areas of Margiana and Bactria.[18]

The period is one of large transformations in the political organisation of Central Asian Bronze Age culture with the appearing of a widespread cultural *koinè* we can now appreciate with its regional variants, as firstly hypothesised by Masson[19] in the entire area mentioned above.[20] The most important trait of the transformation in action, as we can see from the well studied Murghab delta developments, is the rising of strong chiefdoms with a well defined central place with political and administrative control over large territories by means of satellite settlements of second order. Such an organisation which is accompanied by the presence in grave and settlement contexts of large concentrations of "prestige", traded or locally manufactured, goods (both precious metals and semiprecious stones)[21] seems to allow a strong control over raw material resources and their circulation. A large set of items from the Altyn-depe and Bactria-Margiana Middle Bronze Age cultural variants are widespread all over the Iranian plateau, from Khuzistan to the Indus Valley.[22] The emerging picture of Central Asian affluent societies which hold the control of important sectors of the international trade which involves, almost surely, even farthest countries like the Ordos to the east[23] completely justify the above reported behaviour of "destroying" material richness burying it in graves. We have not to forget, in fact, that Middle Bronze Age is, in this geographical context, a formative period and thus such a behaviour is intended to settle a new social order to be reinforced through ideological paraphernalia. The above outlined process of growing political and organisational complexity abruptly collapsed at the end of the period. In the piedmont area

[18] Salvatori 1998b.

[19] Masson 1988, 91-92.

[20] Salvatori n.d.

[21] Salvatori 1994, 1995, n.d.; Sarianidi 1998.

[22] Amiet 1986; During Caspers 1994a, 1994b; Jarrige & Hassan 1989; Salvatori n.d.; Salvatori & Tosi 1987.

[23] Biscione 1985.

the Namazga VI (Late Bronze Age) settlements are dramatically reduced in size while in Margiana the large Middle Bronze Age settlement of Gonur 1 North (ca. 30 ha) is replaced by a 4-5 ha new settlement (Gonur 1 South). The Murghab delta is now dotted with a number of second order sites and a very segmented regional organisation has now substituted the more centralised Middle Bronze Age pattern. Such a collapse, which is mainly political in character,[24] yielded a strong fragmentation of the political control over the cultural region, from the piedmont of southern Turkmenistan to Bactria and thus dramatically interfering with the rights of access to raw material resource areas. Such a point is well documented in Margiana where re-cycling of any kind of material (metal and stone objects) is attested by the systematic pillage of the rich Middle Bronze Age graveyard of Gonur 1 North and by the discovering in the Central Building of Togolok 21 of a hoard of stone columns many of which were evidently cut and broken and use to produce smaller stone objects.[25]

To go back to our point, re-cycling activities in the field of utilitarian production of metal objects can be largely justified even inside an affluent society being linked with a segmented social dimension of the production and consumption. Only when re-cycling becomes a general attitude in the production process, involving any kind of material, it can be assumed as a symptom of organisational and economic faults.

The 42 copper/bronze and copper-related objects in Fig. 6 give an idea of the finds recovered during the surface survey of autumn 1998 and show the form and size of the objects which underwent a partially destructive testing. The objects included kiln linings (1), slag-like drops (2-5), prills and other seemingly spilled drops (6-15), pieces of possible small castings and ingots (16-22, 18 being a rare example of the upper extremity of solid casting canals originally belonging to a closed lost-wax mould), a hammered folded sheet (23), pieces of copper/bronze vessels (22-23), a fragment of a cross-shaped stamp seal (26), a fragmentary zoomorphic pin (27), a set of small pieces of pin or needle-like pointed objects (28-33), a broken spiral wire (34), fragments of bar-like items having a square section (35-37), a piece of a possible pointed tool having a semicircular section (38) and three fragmentary flat-pointed scalpels (39-41). No. 42 is the broken spout of a rough, heavily chaff-tempered ceramic container that might have been used for pouring metal, or for other types of craft processes: it had no metal encrustation (some of these artefacts also appears in Figs. 8-11).

[24] Lamberg-Karlovsky 1994; Salvatori n.d.

[25] Salvatori 1995, 49-50.

Metal processing techniques and alloying

According to the soviet scholars,[26] at Altyn-depe metallurgists mastered and applied 3 different techniques:

- cold hammering of semifinished pieces obtained by casting (a technique used for awls, needles, pins, bangles);
- secondary finishing of flat semifinished pieces obtained by casting (used for knives, daggers, adzes): in reality, a variant of the former technique;
- casting of complete objects without hammering or secondary finishing (used for seals, pins with complex three-dimensional heads, tube-shaped objects).

The third technique (simple casting without hammering) might have been used with open moulds, closed lost-wax moulds, or with composite moulds provided with cylinder-like inserts for obtaining the cavity of the handle.[27]

The alloys identified after the first analyses were rather variable, and are described by Masson as follows:

a. Copper and silver
b. Silver and copper
c. Copper and lead (with the latter varying from 7% to 12%)
d. Copper, lead and arsenic (with copper up to 7% and arsenic up to 8%)
e. Copper, tin and arsenic

(besides copper and bronze, the elements will be hereafter identified with their chemical symbol).

The alloys described by Masson and Terekhova seem to be somehow unusual (as revealed by the comparison with our own data, see below), and obviously the order of the list cannot be imagined as an order or relative frequency. The reported lack of standardisation in the alloys' components and percentages might be a typical feature of a long transition between metal technologies still anchored in the Chalcolithic traditions and the later need of a substantial rationalisation. The earliest Cu-Sn alloys are dated to the first part of the 3rd millennium BC (Namazga IV), and appear to become more common in the Late Bronze Age levels (early Namazga VI at sites like Sapalli depe and Namazga depe). In some Late Bronze Age Bactrian sites not less than 40-45% of the copper-based objects had Cu-Sn alloys, but another site of the same area and period such alloys amounted to only 9% of the total. In more or less contemporary sites of Namazga VI date in Margiana such binary bronze alloy is just absent.[28]

[26] Terekhova 1981.

[27] See Chernykh 1992, pl. 7-9, Figure 27, fig. 29, 25.

[28] Chernikh 1992, 179.

This noticeable variability has been explained with the hypothesis of the use as raw materials of poly-metallic minerals having different compositions rather than with intentional alloying techniques. In general, the most common alloy at Altyn-depe was reported to be arsenical copper, leaded copper being second in popularity. According to V.M. Masson, the coppersmiths of Altyn-depe cast products with a high Pb content, and avoided to finish such castings by the means of heavy and prolonged hammering.

The following archaeometallurgical study will test and integrate with new evidence the described, unavoidably partial picture. Among the items we collected, 3 turned out to be exceedingly high in Pb and will deserve particular attention (see below).

New chemical analyses

Few of the artefacts we collected and cut for studying turned out to be completely corroded, and as a precaution were not included in the present research. However, most retained a solid metal core, preserved enough to allow the recording of metallographic structures. Thirty-four fragmentary artefacts (excluding the kiln linings, analysed on metal spots without preparation and damage, see below) were thus cut, and prepared for Energy Dispersive X Rays Fluorescence or EDXRF, in order of obtaining a semi-quantitative elemental characterisation. EDXRF was performed with a portable XRF system, adopting as irradiation standards 40 Kv and 0.8 mA. Later, a more restricted set of samples was prepared for metallographic analysis, embedding the sampled pieces in transoptical resins: the mounts were then polished with diamond pastes and fine abrasive tissues, and observed at the metallographic microscope with and without chemical attack for the enhancement of the inner micro-structures.[29] Finally, minimal fractions of some samples (an ore piece and a slag) were powdered and analysed by the means of XRD.

The analysed collection, in terms of types of metal objects, might fit the reductive description given by V.M. Masson of the ancient metallurgy attested in the settlement. In sequential order of technological transformation, the series included:

- 1 fragment of a thick unidentified Pb-based object, whose shape resembled an ingot or a plano-convex cast (AS2 846, see Figs. 6.19 and 8 left).
- 1 fragment of an ore rich in Pb;

[29] See Scott 1987; Leoni 1984.

- 3 slag pieces rich in Fe and Cu, having highly sintered silicatic bodies (CM19a, CM19b and AS2 571, this latter reproduced in Fig. 6.6);
- 12 possible copper/bronze prills spilled in the frame of various stages of the alloying process;
- 1 casting residue, in the form of the joint extremities of 2 casting canals cut after casting from a lost wax closed mould (Fig. 6.18);
- 2 fragments of small Cu-based ingots (AS 488, drafted in Fig. 6.22, and ASE 6, in Fig. 8 right);
- 1 fragment of a lead ingot (WM ES, Fig. 6.20);
- 4 fragments of small bars in Cu-based alloys (ASE 2, AS2 565, AS2 592, AS2 636: see Fig. 6.35-38);
- 1 fragment of copper/bronze sheet (AS2 559, Fig. 6.23);
- 2 possible vase fragments in Cu (AS2 488 and ASE 3, Fig. 6.24-25);
- 1 fragment of a cross-shaped compartmented bronze seal, very rich in Pb (Fig. 6-26);
- 1 fragment of a Cu-based pin terminating into an animal's body (this piece was not cut but only slightly polished at its lower end) (Fig. 6.27 and Fig. 10);
- 12 vitrified fragments of linings of kilns used to melt Cu alloys (Figs. 6.1 and 11).

The results of the chemical analyses by the means of EDXRF, for 7 principal elements, are summarised in Fig. 7a (metallic objects) and 7b (kiln linings).

Sample CM19a is composed by almost pure Pb, with traces of Sb and Cu. XRD analysis characterised this piece as a fragment of galena ore, probably associated to laurionite (Pb(OH)Cl) (Fig. 15). Galena might represent the raw material later transformed into items such as AS2 846. This latter, as well, is chemically composed of almost pure Pb (more than 98%), with secondary traces of Cu and Fe. Its inner structure is microstratified, with red and yellow alternating bands. XRD analysis characterised this material as lead oxide or litharge (PbO), and probably of cerussite (Pb carbonate, PbCO3) (Fig. 16). The spectrum had a strong amorphous component, a feature compatible with a pyrotechnological origin.

Three fragments having a slag-like appearance (CM19b, AS2-571, 3-ON) are distinguished by high percentages of Fe and Cu, and this suggests, at least for the latter artefact, the possibility that such slag was a by-product of a primary reduction of copper/iron bearing ores. Actually, XRD of sample CM19b showed the presence of magnetite (Fe3O4) and paracatamite (Cu(OH3)Cl), usually occurring on bronze objects as an alteration product. SEM-microprobe inspection of the same sample showed that the sintered matrix of the slag was composed by two different phases, a dark one similar to fayalite (Si, Ca, Fe, traces of K, Al, Mg) and a lighter one (Cl, Cu, Fe, Ca), perhaps bearing paracatamite. Cu is visible in form of segregated pellets embedded in the sintered matrix. CM19b was collected from the floor of one of he rooms excavated in the uppermost architectural levels of the Copper Mound. This find leaves open the possibility that local craftspeople performed a certain amount of ore reduction (chalcopirite? In CM19b Fe ranges around 45%). The find of fragments of galena ore in the same archaeological context (CM19a), as ascertained – as we have seen – through XRD, might support this view. On the other hand, it is also possible that slag was used as a raw material, to be crushed and recycled for recovering even the minimum residual amounts of copper. Furthermore, the first three samples contain other elements as well (Pb, As, Sn), thus suggesting the exploitation of polymetallic ores or, as an alternative, specific stages of intentional alloying. Fe-rich powders could also have been used as a flux in the smelting/melting stages.

Coming to the prills – we assumed they represented indicators of alloying processes – they show a rather recurrent, homogeneous chemical pattern, with Cu varying from 85 to 95%, a variable content in Pb (from 0 to 10%) and a As content equally variable (from 0 to 45%). Sn is rather rare, with the exception of the bronze spill AS2 549. The high content of Fe of prill ASE 5 also reminds one of the possibilities already discussed for the slag pieces. Three items (the pieces of casting canals and 2 ingot fragments) may be taken as indicators of some (preliminary?) stages of casting. All three (TMSEP, AS 488 and ASE 6) have no or little Sn content, and may be considered arsenical bronzes, thus matching the overall composition of the bulk of the over-spilled metal drops. WM ES is a fragment of an ingot composed of almost pure Pb, with faint traces of Sb and Cu.

As far as the finished products are concerned, the 4 fragments of small bars have a more variable composition, with Cu, in every case, being the main component. These bars may have been parts of undetermined finished objects, but also of tools, and this makes difficult their comparison with other sampled objects. ASE 2 is a heavily leaded alloy (Pb = 30.7%), with As and minor traces of other elements (Masson's alloy d.?). AS2 565 and AS2 636, in contrast, are very low in Pb. AS2 592 is one of the rare binary Cu-Sn bronzes. More homogeneous is the chemical composition of the 4 pieces of scalpels (thus identified because of the presence of the functional extremity): the Pb content ranges from 2.1% to 4%, As from 0.4% to 5.7%, with very scanty traces of Sn and Sb. The bronze sheet fragment AS2 559 has a similar composition. Scalpels with a flattened functional extremity (perhaps they were wood working tools) were apparently cast with Cu-As alloys, and not with Sn.

Two objects, most probably, were parts of copper/bronze vessels. AS2 488 turns out to be almost pure Cu, with As as secondary component (around 1%). ASE 3 is a binary arsenical bronze, as well as the fragment of zoomorphic pin AS5 WEST. While the use of pure Cu would have resulted in vessels having a strong reddish colour, the use of high percentages of As should have granted the objects a light-golden, shiny surface (still visible in the freshly cut surfaces). Finally, the fragment of compartmented stamp seal AS2 721 was cast with a percentage of Pb higher than 41%, and may be compared to ASE 2. Such high percentages of Pb would match well the technical constraints of the production of small objects with particularly elaborated shapes (thanks to the fluidification of the alloy). Analogous alloys have recently been reported for copper/bronze compartmented stamp seals excavated in Makran.[30]

Chemical analysis of kiln linings

12 fragments of kiln linings – fragments of highly sintered ceramic surfaces with evident drops and slag of copper – were collected after having being precisely mapped on the surface of AS 2. These lining fragments represent residues of the interior surface of medium-to-small furnaces originally erected on the surface of the "Copper Mound" and later abandoned to destruction, trampling and erosion. The analysis was carried out by pointing precisely the beam onto metallic droplets and encrustation most evident on the vitrified surface. It is difficult to state whether the metallic elements revealed in the spectra should be ascribed to a cumulative concentration following more firings, or rather to a single melting stage. The semiquantitative counts for the 12 cases are shown in Fig. 7b. Fe is the most common component in several cases, followed by Cu and Pb. Traces of Ag have been identified in a single case. It is interesting to observe that in this group of finds Sn is relatively common (5 cases) while As is rare (only 2 cases). In AS2 597 Sn was recorded as the most important element. In other words, the relative frequency of Sn and As, in the furnaces' walls, appears to be reversed. This might indicate that part of the sintered fragments were produced by a single episode of melting/alloying with Cu, Sn, Pb and that the surface scatter of vitrified material of the Copper Mound is, to a certain extent, a primary context of deposition (the presence of Fe and Sr in the spectra cannot be

[30] R. Besenval, information given at the SAA conference held in Leiden in 1999.

taken into account because it is obviously due to soil contamination). This might also be confirmed by the spatial distribution of the Cu-Sn-Pb bearing fragments, apparently belonging to a single loose cluster.

Metallographic analysis

In general, we found a reasonable agreement between the palaeo-technological field identification (for example through the labels of "slag", "prill", "fragment of finished object") and the inner microstructure of the metallic finds. Nonetheless, as we shall see, there were few noticeable exceptions.

ASE 1: a melting prill. Unmodified dendritic structure, with a strong corrosion on surface (both inter- and intra-dendritic).

ASE 5: a melting prill. The strong corrosion prevented the recording of any inner microstructure.

ASE 7: a melting prill. The section shows a dendritic structure, rather homogeneous, with a gradual transition from dendrites to isolated grains. Such changes may be explained to a further stage of heating rather than to mechanical processing.

AS2 527: a melting prill, with a strong corrosion on surface (both inter- and intra-dendritic) (Fig. 17). The section shows a unmodified dendritic structure, perhaps due to spilling from a crucible or a kiln with ensuing gradual cooling. Some dark inclusions are formed by copper sulphides.

AS2 644: a melting prill, equally affected by a strong corrosion. In this case the transition from the extremity of dendrites to isolated grains is more advanced, but always – we think – ascribable to spilling from a crucible.

AS5 S: a melting prill, strongly corroded (intra-dendritic process). The inner structure is dendritic and made compact by a further stage of heating.

EZC: a melting prill. The section shows an unmodified dendritic structure, still recognisable in spite of the intensity of corrosion processes.

GT: a melting prill. Similar to part of the described cases, this sample shows dendrites changing themselves into isolated rounded grains (Fig. 18). Below a thick corrosion layer, the inner structure suggests a simple casting residue.

ASE 4: originally interpreted as a melting prill, is probably a fragment of a semifinished item. It appears highly corroded. The inner structure shows the presence of polygonal grains with incipient formation of geminated planes (Figs. 19 and 20). It also shows the presence of flattened slag inclusions after some stage of hot hammering, impossible to recognise on the base of the object's shape.

AS 488: fragment of a small plano-convex ingot (drafted in Fig. 6.22). The inner microstructure shows distinctive sliding planes and twin-like features, due to an intensive hot hammering – hardly compatible with the palaeo-technological field definition of "ingot" (Figs. 21 and 22). It follows that, in this case, the plano-convex shape of the piece is not due, as usually assumed, to simple casting into a cavity. As a matter of fact, the inner microstructure would rather point to a tool (??).

ASE 6: a fragment of a copper ingot (see Fig. 8 right). This sample, strongly corroded, shows an inner dendritic structure, perhaps slightly modified by the effects of a further heating process.

ASE 2: a fragment of a small bar having a rectangular section. Another strongly corroded object. As the inner structure is dendritic, the piece might have been cast into an open mould.

AS2 520: a fragment of a scalpel. Although strongly corroded, the inner structure shows the presence of polygonal grains indicating a stage of intensive hammering.

AS2 693: a fragment of a scalpel (Fig. 6.39). The inner microstructure, distinguished by small-sized polygonal grains, is consistent with the hypothesis of an intensive cold or hot hammering, perhaps followed by a final stage of cold hammering (work hardening).

AS2 695: another fragment of a scalpel (Fig. 6.40). The inner structure, like in the previous cases, shows the indicators of an intensive cold and/or hot hammering.

TM: another fragment of a scalpel (Fig. 6.41). The inner structure of this artefact reflects the features expected for an efficient tool in arsenical bronze (Pb, in this case, has been counted 1.4%). The point of the scalpel has been hammered for a long time, as one may infer from the flattened shape and the developed twin-like features within the polygonal grains, all oriented according to the forging surface (Figs. 23 and 24).

AS2 488: a possible copper vessel fragment. Although the inner structure is almost completely hidden by intense corrosion, the surviving polygonal grains structure point to a strong hammering stage.

Metal processing patterns: a summary

In summary, the set of samples we analysed, in spite of Chernykh's generalisations, leaves open the possibility that the ancient craftspeople of Altyn-depe used to concentrate and process in their urban workshops not only scraps from finished objects to be re-melted, but (at least episodically) amounts of metal ores (among which sulphides, not mentioned or less common in the eastern and north-eastern source areas). This is also consistent with the mentioned discovery in a room of excavation 10 (belonging to a private dwelling) of the residues left by a ore-crushing operation.

Our research also indicates the co-occurrence at Altyn-depe of lead-based and copper-based technologies. Lead is present in form of unprocessed galena ore;[31] of a homogeneous block of lead oxide (litharge), possibly a by-product of galena smelting, silver-refining, or as a semiprocessed lump produced for the manufacture of red pigments; of a fragment of a cast ingot. Selected artefacts – among which compartmented stamp seals – could be cast with percentages of Pb reaching up to 30 and 40%. During the surface survey of Ilgynly depe, a 5th-4th millennium BC central settlement south-east of Altyn-depe, we recorded and sampled a wide scatter of copper/bronze manufacturing residues, among which range a series of possible Pb lumps or ingot fragments. These finds suggest a long, autonomous tradition of copper-lead production in the Chaacha-Meana region, and hopefully it will be studied and analysed in the next future.

The use of Ag by the urban *élites* was anyhow widespread: the list of silver objects found at Altyn-depe, in fact, includes complex artefacts such as a pin terminating in a goat's head, a stamp seal with the figure of a composite fantastic creature, a mirror, a small knife, finger rings, a hammered sheet showing a bird with spread wings. The absolute rarity of Ag in our metal samples is in contrast with what had been reported by the Russian scholars which evidently encountered some objects cast in intentional Ag-Cu alloys; this might be due to a simple sampling bias. But in our cases, even the artefacts composed in large part by Pb showed only faint traces of Ag. Given the apparent lack of correlation between the two elements, we ought to think that the processes for separating them were extremely efficient, or instead that Ag was not extracted from lead-bearing ores.

An important feature of the ancient metallurgy of Altyn-depe in the 3rd millennium BC already observed by the soviet scholars and confirmed by

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[31] It might have been traded and stored as a make-up pigments ingredient, a medicine, or a smelting raw material – see Bachmann 1993.

our preliminary research is the absolute prevalence of arsenical bronzes on Cu-Sn alloys. Cu-As alloys, in many cases doubtless intentionally produced, were commonly used for tools, vessels and ornaments, sometimes with limited amounts of Pb, while the use of Sn is present but much more limited (this is reflected both in the finished objects and in the spilled drops), but nonetheless attested. On the other hand, the anomalous content in Sn in the surface of the vitrified kiln linings we analysed shows at least a case of a purposeful alloying Cu-Sn-Pb on the top of the Copper Mound, during its last stages of occupation.

Finally, while the inner metallographic structure of the sampled objects (with two exceptions) conformed to our palaeo-technological expectations, there are no reasons to share our soviet collegues' opinion that copper/bronze artefacts were exclusively cold-hammered. On the contrary, the intensity of forging observed, as an example, in the fragments of 4 scalpels made in arsenical copper points to refined and labour-demanding stages of hammering, both in cold and hot conditions.

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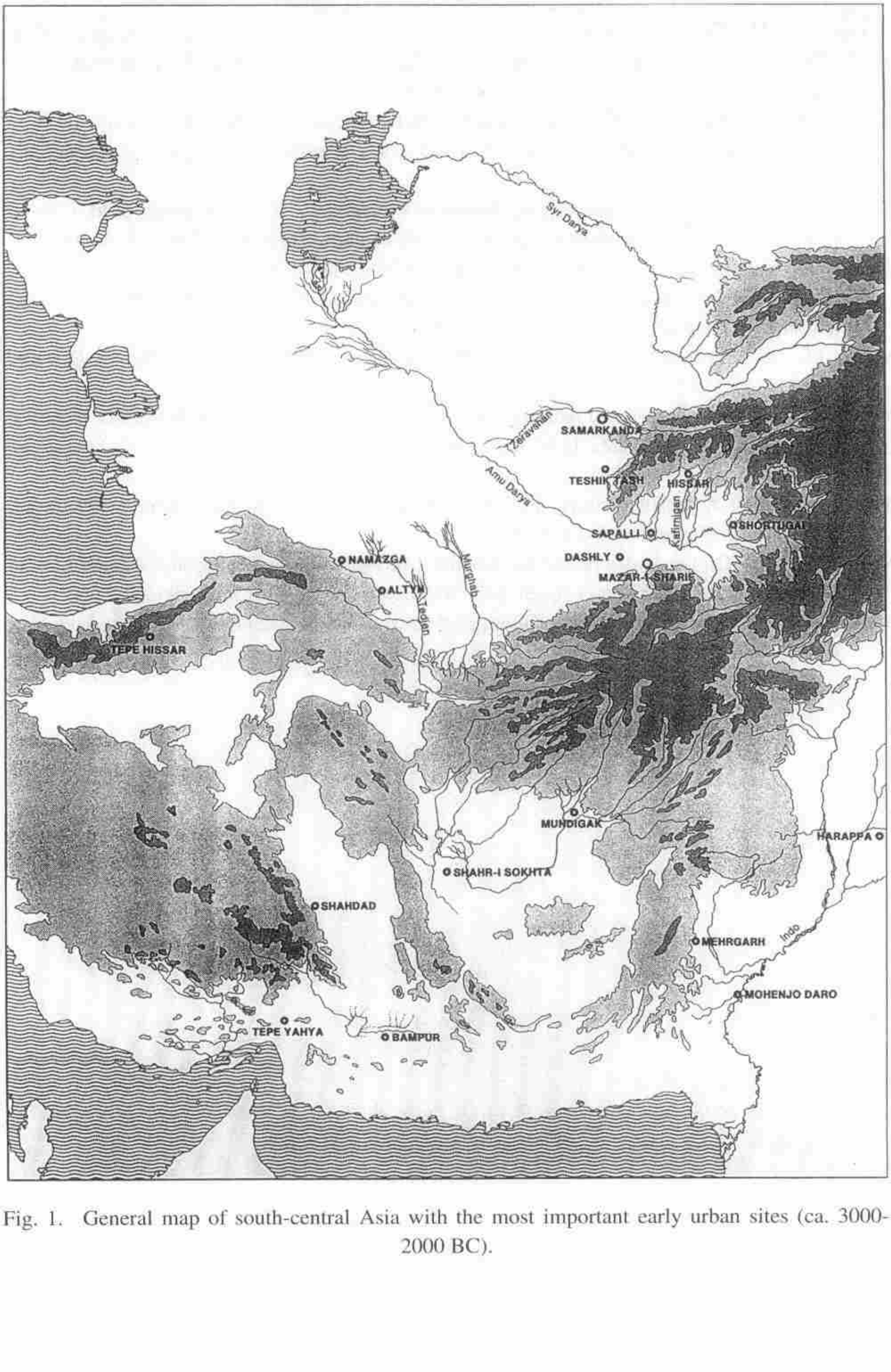

Fig. 1. General map of south-central Asia with the most important early urban sites (ca. 3000-2000 BC).

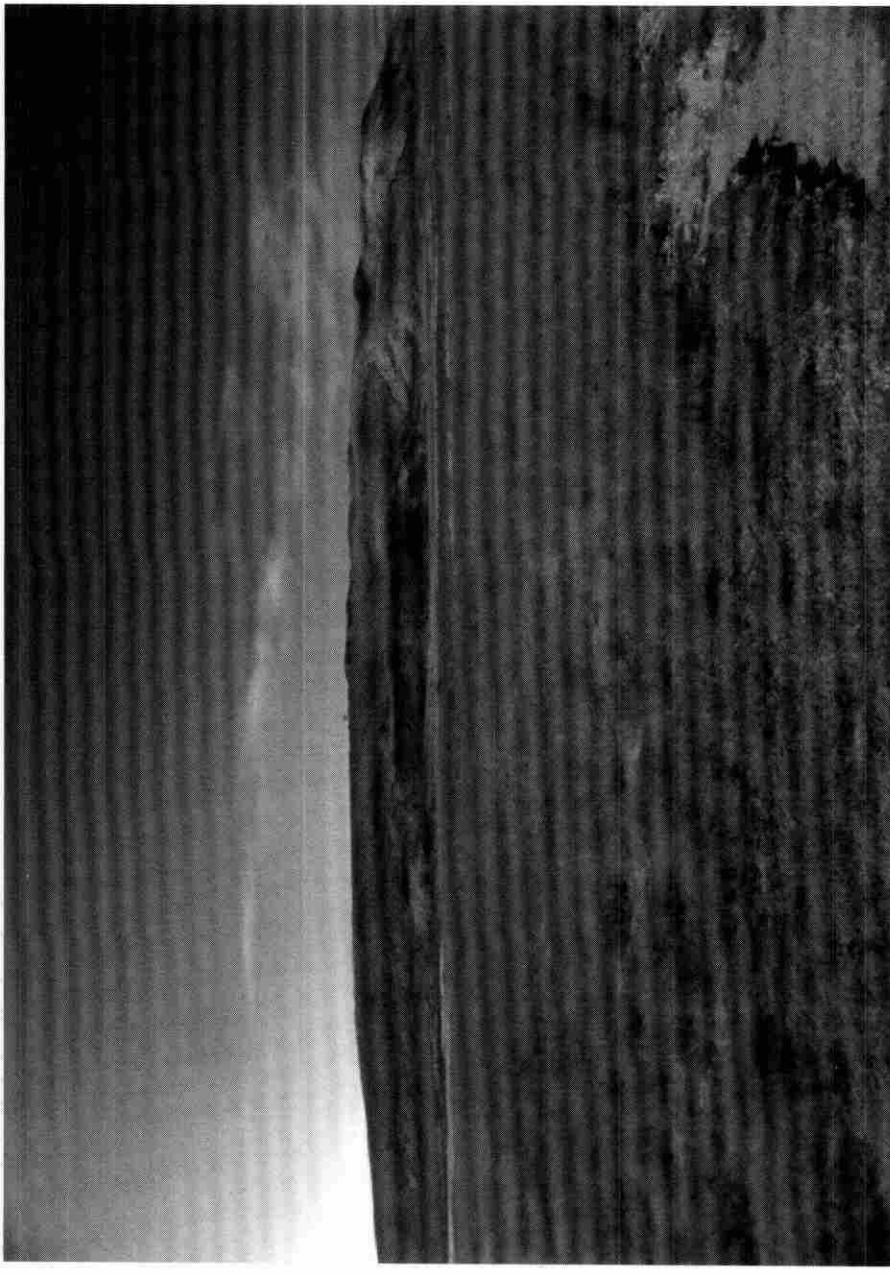

Fig. 2. A view of the slopes of the mound of Altyn-depe (Turkmenistan) from the present floodplain in autumn 1998.

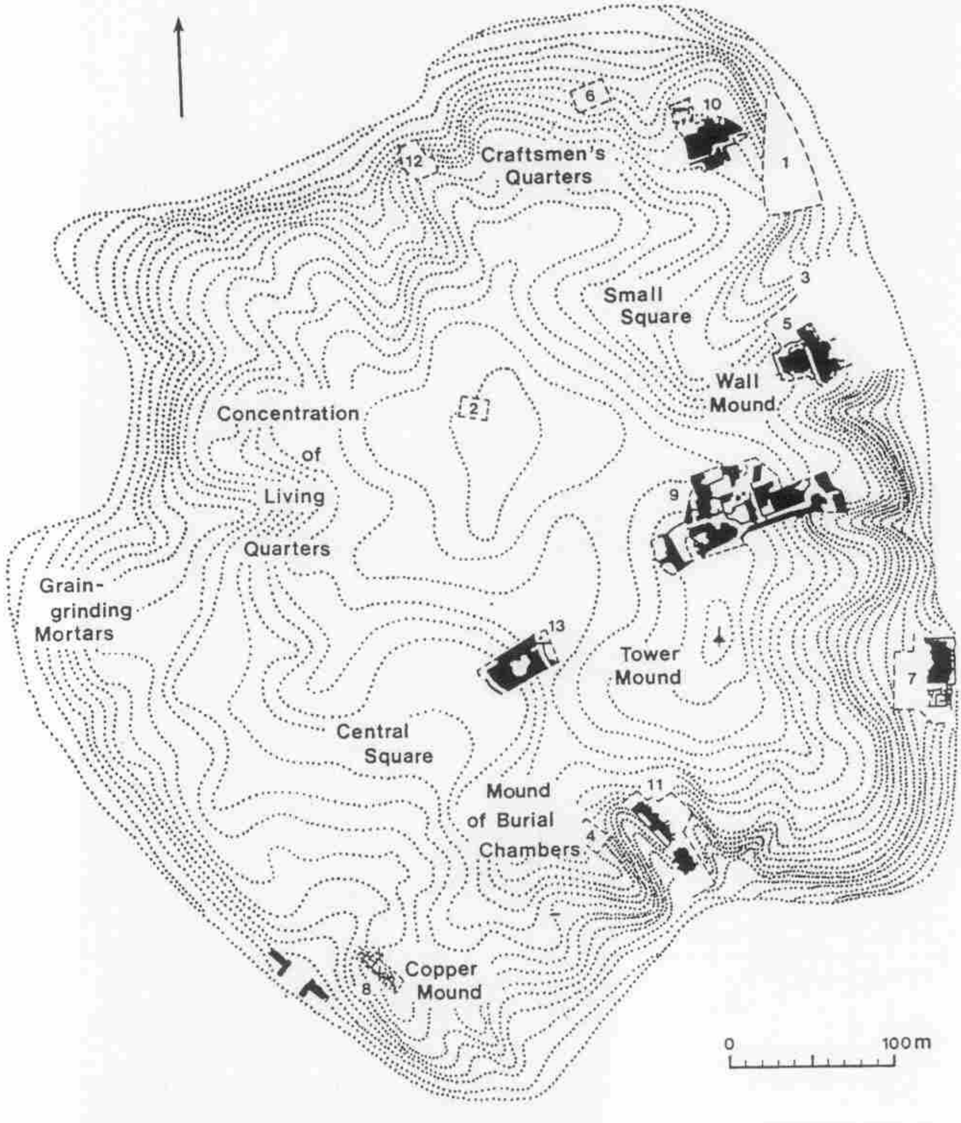

Fig. 3. The old map of the excavations of Altyn-depe (after Masson 1988). The Copper Mound is marked at the southermost tip of the mounded area.

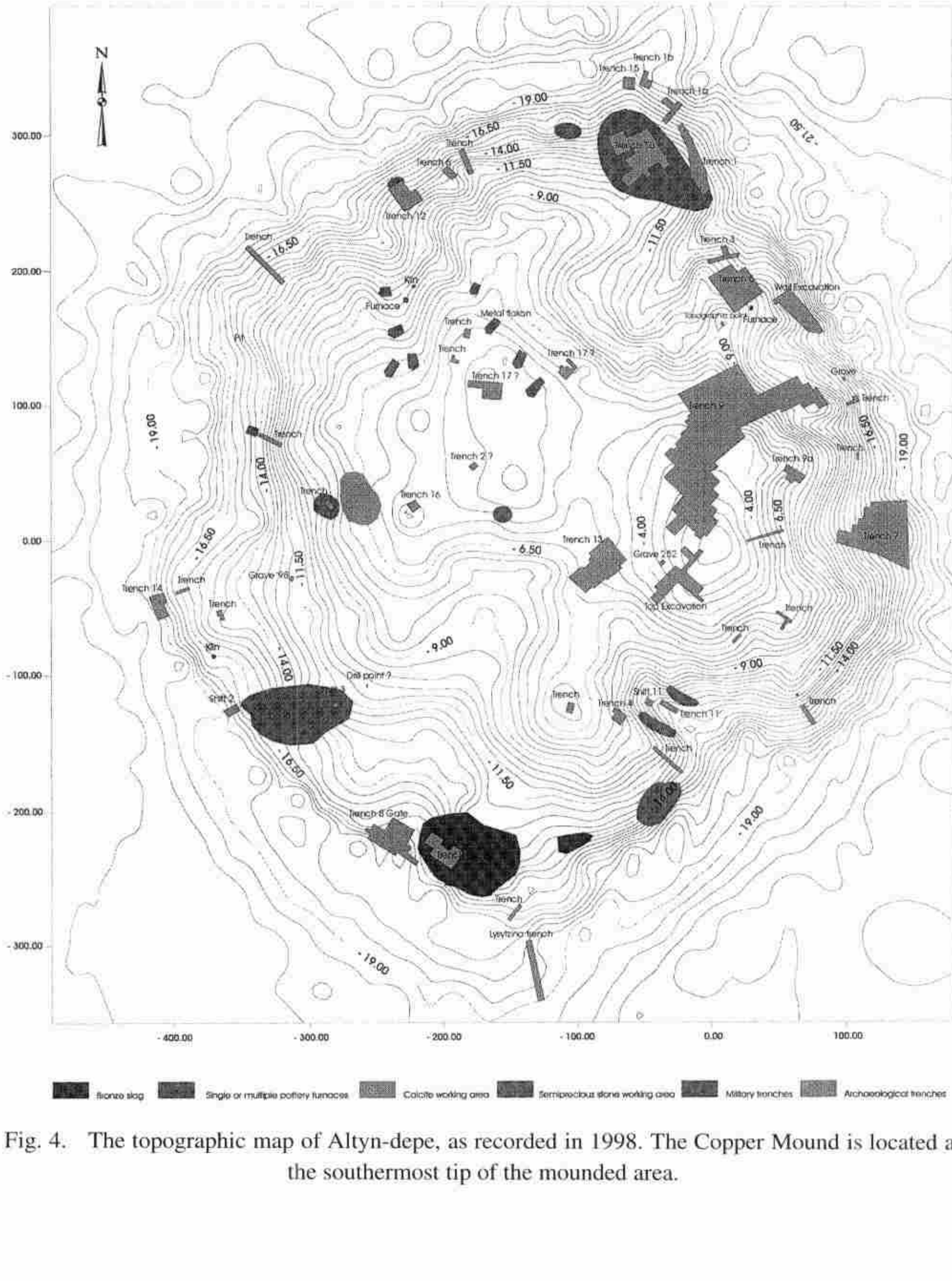

Fig. 4. The topographic map of Altyn-depe, as recorded in 1998. The Copper Mound is located at the southermost tip of the mounded area.

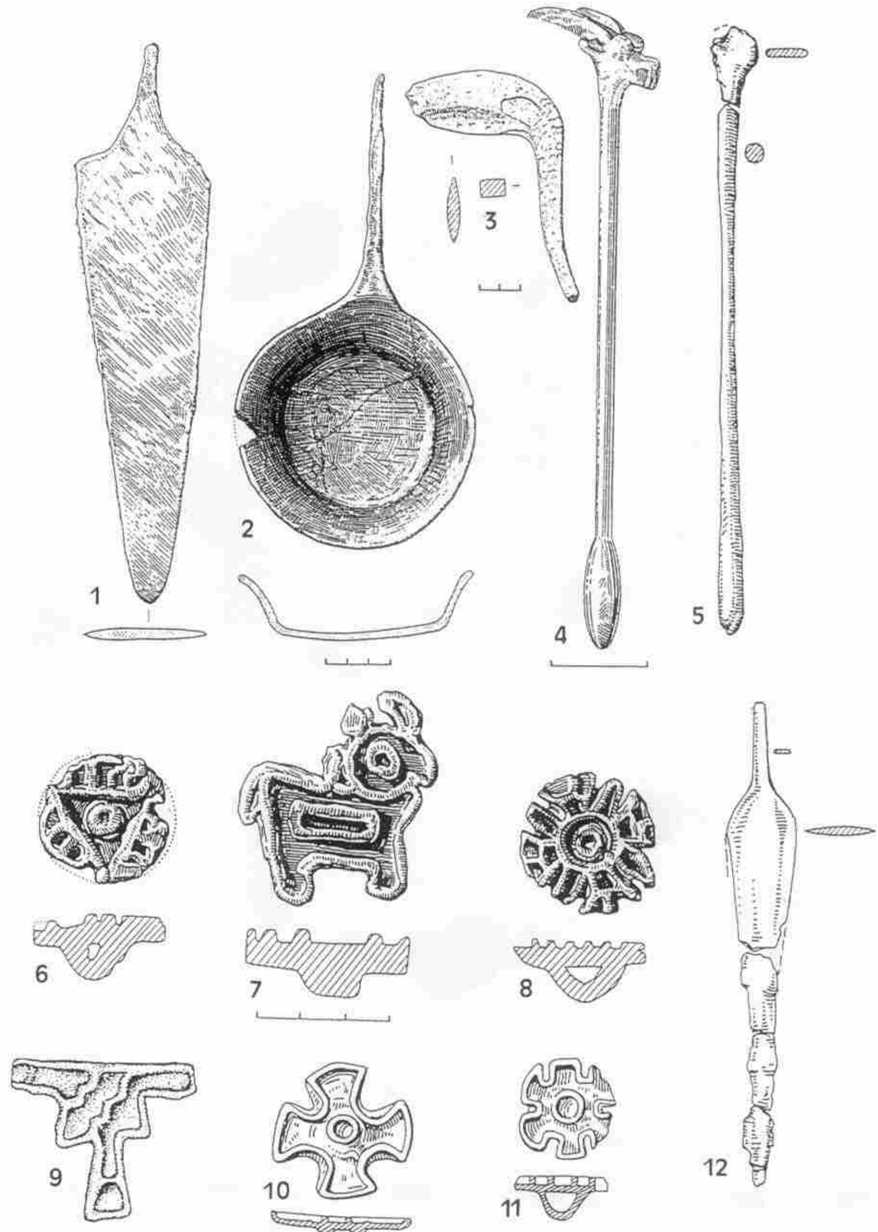

Fig. 5. Copper/bronze objects from various excavations at Altyn-depe (3rd millennium BC). 1, 12: tanged knives; 2: a copper pan with a long handle; 3: a fragmentary sickle blade; 4, 5: pins; 6-11: various types of stamp seals.

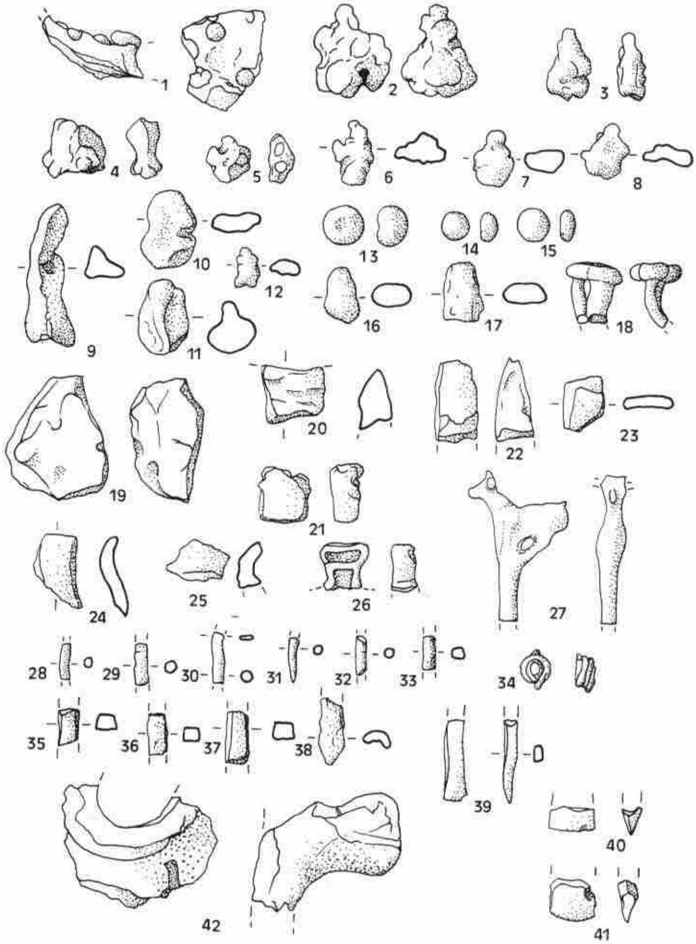

Fig. 6. Artefacts related to copper/lead metalworking from the surface of Altyn-depe (collected in 1998). When reported, the sample id refers to the list and the chemical analyses of Fig. 7a, b. 1: a fragment of a furnace lining with copper prills embedded in a glassy surface; 2-8: various types of slag-like or shapeless lumps; 9-12: spilled lumps; 13-16: small spherical lumps, originally classified as casting prills; 17: a fragment having a trapeze-shaped section; 18: a piece formed by the extremities of three casting funnels, a residue from a lost-wax closed mould (TM SEP); 19: a piece of litharge (lead oxide: AS2 846); 20: a possible pieces of a lead ingot from a semiprocessed casting (AS 488); 21: ASE 6, a piece of a copper ingot; 22: a fragment whose shape resembled the edge of a plano-convex ingot, WM ES (actually, the inner structure showed the signs of a heavy hammering); 23: a sheet folded and hammered for re-processing (AS2 559); 24, 25: possible fragments of copper vessels (AS2 488, ASE 3); 26: a piece of a broken cross-shaped seal in leaded bronze (AS2 721); 27: extremity of a zoomorphic pin in arsenical bronze (AS5 West). 28-38: various fragments of pins and small bars (34 is a broken spiral); 39-41: fragments of scalpels; 42: a spout from a coarse chaff-tempered container (a crucible?).

ALTYN DEPE - ANALYSIS OF METAL OBJECTS

SAMPLE	TYPE OF OBJECT	Cu%	Fe%	Pb%	Ag%	Sn%	Sb%	As%
AS2-846	LITHARGE BLOCK	0,6	0,6	98,2	0,0	0,1	0,0	0,0
CM19a	GALENA ORE	0,2	0,0	99,2	0,0	0,1	0,5	0,0
CM19b	SLAG	43,8	44,9	5,4	0,0	1,2	0,6	4,1
AS2-571	SLAG	86,4	2,2	0,6	0,0	4,9	0,2	5,7
3-ON	SLAG	11,9	82,9	4,4	0,0	0,1	0,2	0,0
ASE1	PRILL	86,3	1,2	9,9	0,0	0,1	0,0	2,5
ASE4	PRILL ?	98,4	0,2	0,0	0,0	0,0	0,0	1,4
ASE5	PRILL	85,5	10,8	0,0	0,0	0,6	0,2	3,0
ASE7	PRILL	97,2	0,7	0,0	0,0	0,1	0,0	2,0
AS2-525	PRILL	89,9	0,7	8,1	0,0	0,5	0,0	0,8
AS2-526	PRILL	98,5	0,0	0,1	0,0	0,1	0,0	1,1
AS2-527	PRILL	95,2	0,2	0,0	0,0	0,0	0,1	4,5
AS2-549	PRILL	92,1	0,9	1,3	0,1	3,3	0,1	2,2
AS2-644	PRILL	96,6	1,0	0,7	0,0	0,1	0,0	1,5
AS5-S	PRILL	97,7	0,5	0,8	0,0	0,2	0,0	0,8
EZC	PRILL	95,6	0,0	0,0	0,1	0,1	0,2	4,0
GT	PRILL	98,1	0,2	0,3	0,0	0,1	0,1	1,4
TMSEP	CASTING FUNNELS	97,1	0,0	0,6	0,0	0,0	0,0	2,2
AS488	INGOT FRAGMENT	95,8	0,0	0,8	0,0	0,0	0,1	3,2
ASE6	INGOT FRAGMENT	93,3	0,0	0,7	0,0	0,1	0,1	5,8
WM - ES	INGOT FRAGMENT	0,2	0,1	99,4	0,0	0,0	0,4	0,0
ASE2	BAR	67,3	0,1	30,7	0,0	0,0	0,1	1,8
AS2-565	BAR	95,0	0,1	3,4	0,0	0,0	0,0	1,5
AS2-592	BAR	87,4	0,6	0,8	0,0	6,6	0,0	4,5
AS2-636	BAR	98,6	0,1	0,6	0,1	0,0	0,0	0,7
AS2-520	SCALPEL	94,6	0,2	3,3	0,0	0,2	0,1	1,6
AS2-693	SCALPEL	89,8	0,0	3,8	0,0	0,5	0,2	5,6
AS2-695	SCALPEL	90,8	0,3	1,9	0,1	0,8	0,1	5,5
TM	SCALPEL	94,8	0,7	4,0	0,0	0,0	0,1	0,4
AS2-559	SHEET	95,8	0,6	1,2	0,0	0,0	0,1	2,2
AS2-488	VESSEL	98,6	0,0	0,3	0,1	0,0	0,0	1,0
ASE3	VESSEL	96,1	0,1	0,0	0,0	0,0	0,0	3,7
AS2-721	STAMP SEAL	51,5	0,0	41,3	0,0	0,0	0,1	7,1
AS5 WEST	PIN	91,0	0,1	0,0	0,0	0,0	0,2	8,7

ALTYN DEPE - ANALYSIS OF FURNACE LININGS

SAMPLE	TYPE OF OBJECT	Cu	Fe	Pb	Ag	Sn	Sb	As
AS2-845	KILN LINING	Cu	Fe	Pb				
AS2-844	KILN LINING	Cu	Fe	Pb	Ag	Sn		
AS2-728	KILN LINING	Cu	Fe	Pb		Sn		
AS2-714	KILN LINING	Cu	Fe	Pb				
AS2-707	KILN LINING	Cu	Fe	Pb		Sn		As?
AS2-697	KILN LINING	Cu	Fe	Pb		Sn		
AS2-692a	KILN LINING	Cu	Fe	Pb				
AS2-692	KILN LINING	Cu	Fe	Pb	Ag			
AS2-684	KILN LINING	Cu	Fe	Pb		Sn		
AS2-621	KILN LINING	Cu	Fe	Pb				
AS2-605	KILN LINING	Cu	Fe	Pb			Sb	As
AS2-589	KILN LINING	Cu	Fe	Pb		Sn		

Fig. 7. Results of the chemical analyses (EDXRF) carried out in the frame of the present study. 7a: metallic artefacts. 7b: vitrified linings from the interior of metal melting furnaces.

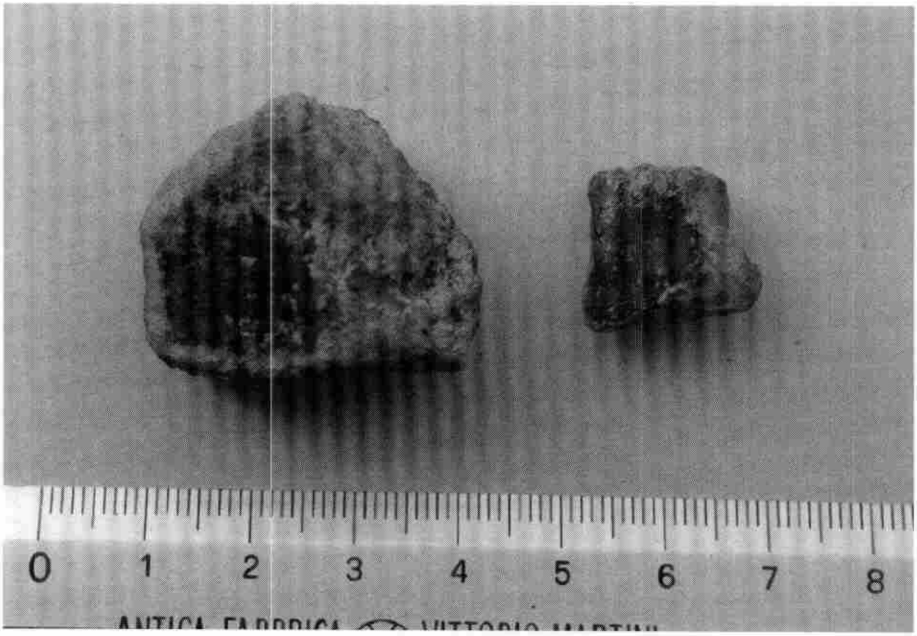

Fig. 8. A block of litharge, AS2 846 (left) and a piece of a copper ingot, ASE 6 (right) (see also Fig. 6, 19 and 21).

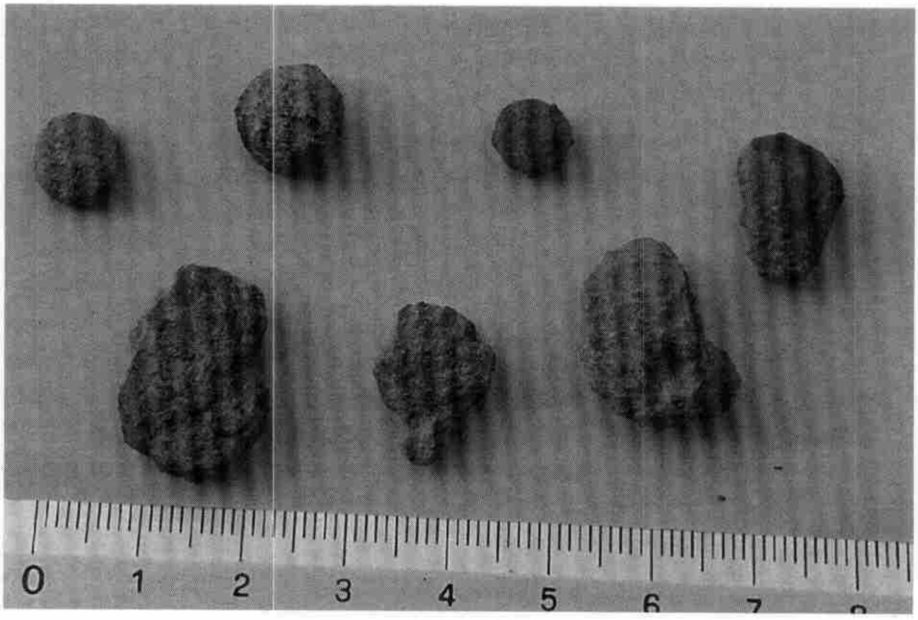

Fig. 9. A group of copper/bronze prills (see also Fig. 6, 13-16; see also Fig. 7, prills).

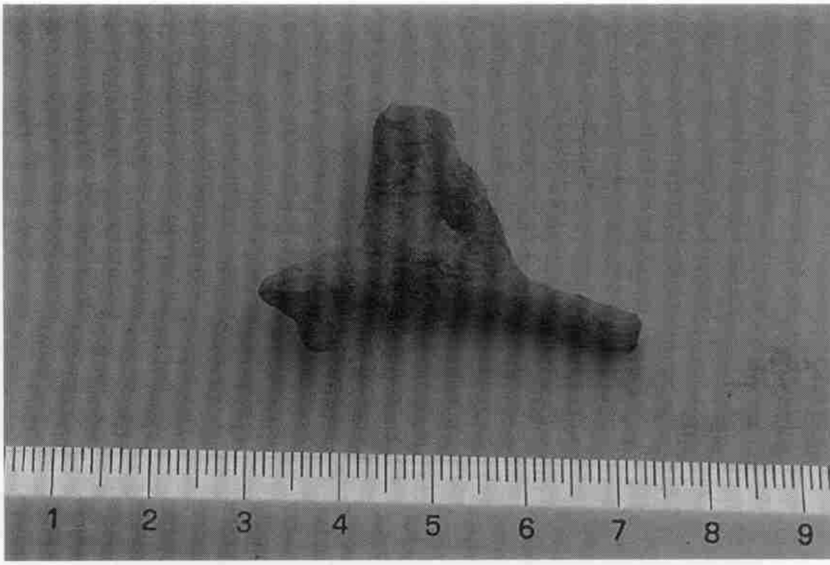

Fig. 10. Extremity of a copper/bronze pin terminating with a stag (or possibly a bovine), AS5 West (see also Fig. 6, 27).

Fig. 11. A group of kiln linings with traces of copper slag (see also Fig. 6, 1, and for the chemical results Fig. 7b).

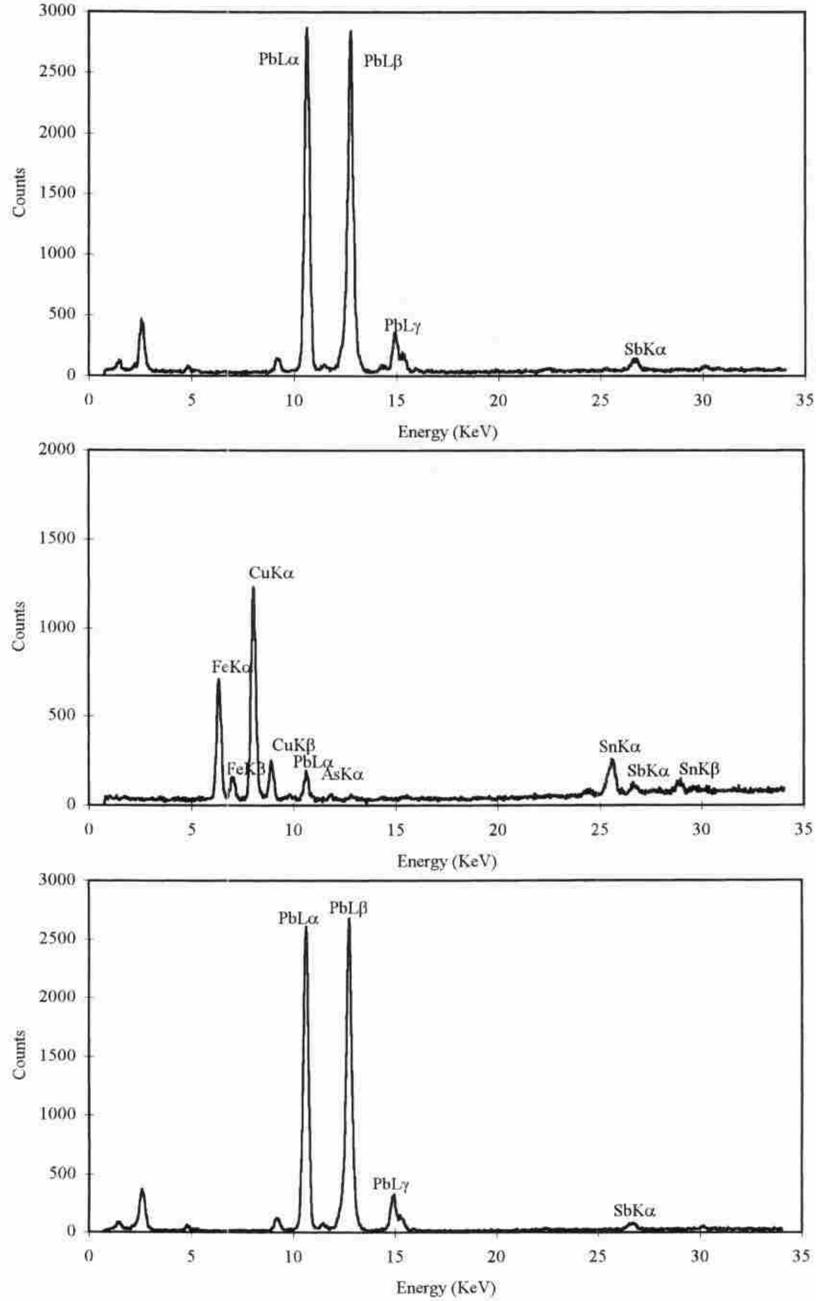

Fig. 12. EDXRF patterns for samples CM19a (a), a piece of unprocessed galena ore; CM19b (b), a slag piece; WM-ES (c), a heavily hammered fragment of a possible ingot.

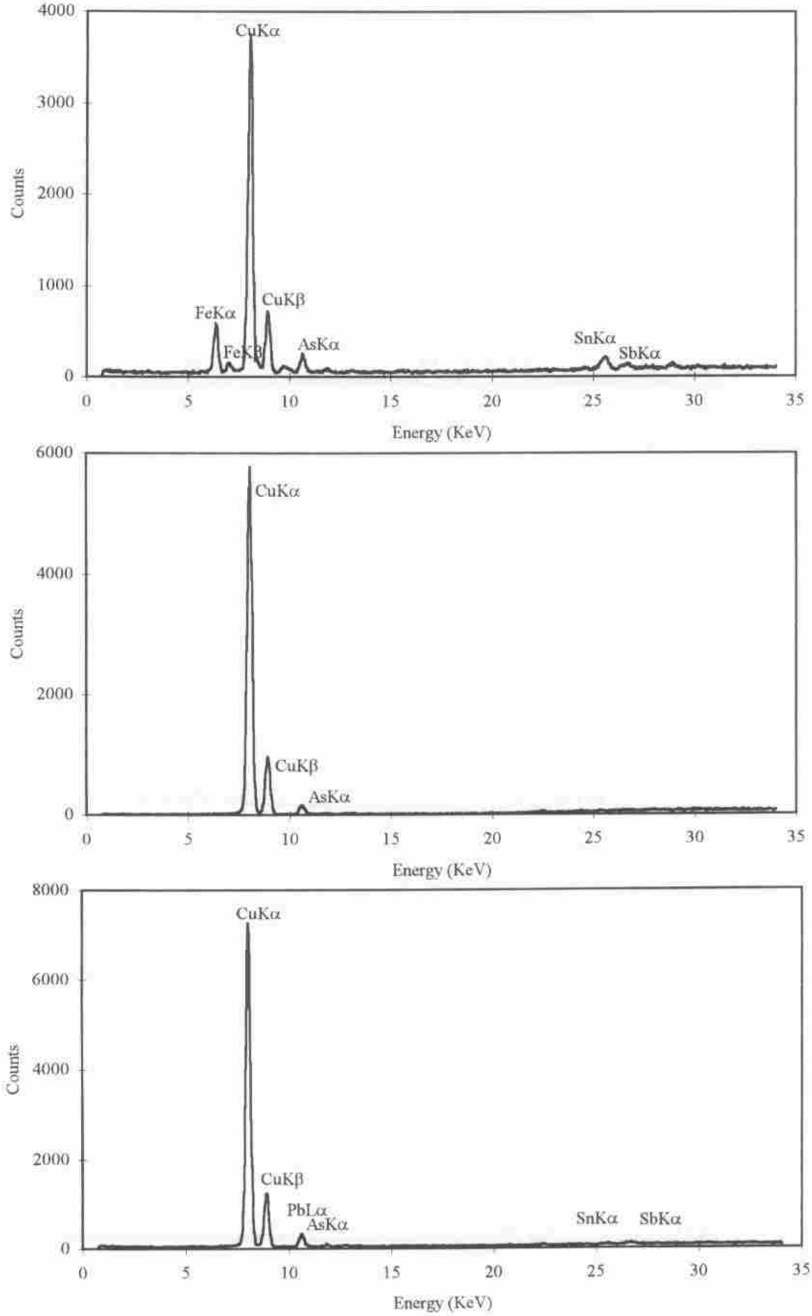

Fig. 13. EDXRF patterns for samples ASE 5 (a), a casting prill; AS2 527 (b), another casting prill; ASE 6 (c), a fragment of a copper ingot.

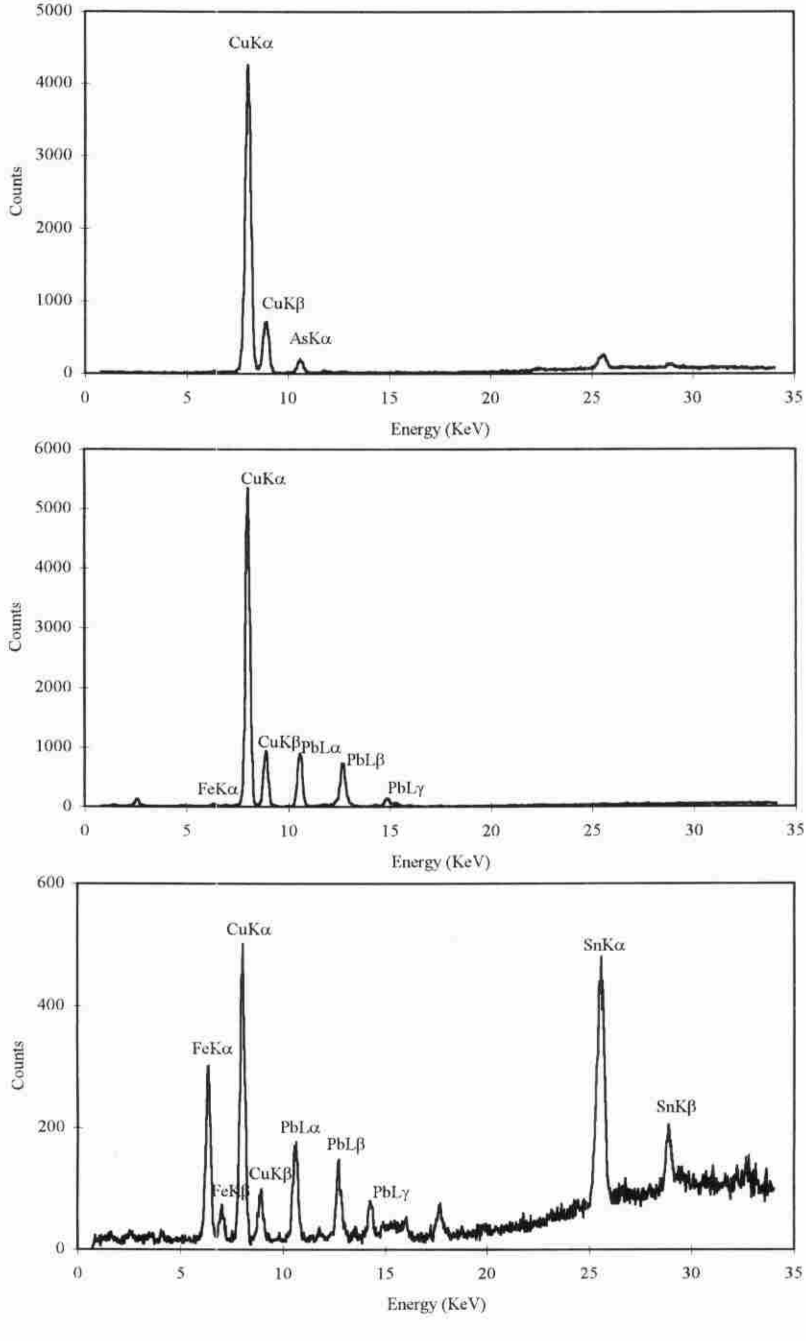

Fig. 14. EDXRF patterns for samples AS2 695 (a), a fragment of a scalpel; AS2 721 (b), a piece of a cross-shaped stamp seal; AS2 707 (c), a piece of a furnace lining.

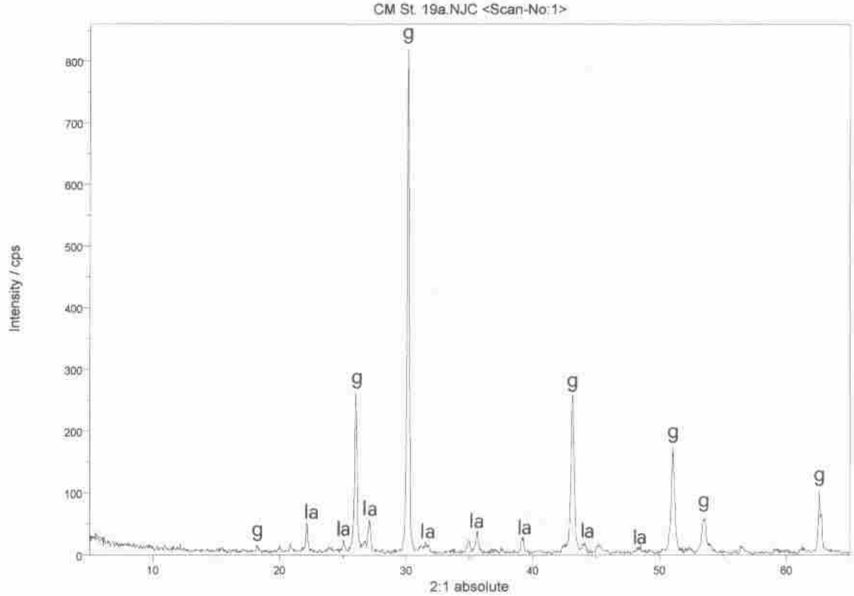

Fig. 15. XRD pattern for sample CM19a, a piece of unprocessed galena ore (g) with a minor component of laurionite (la).

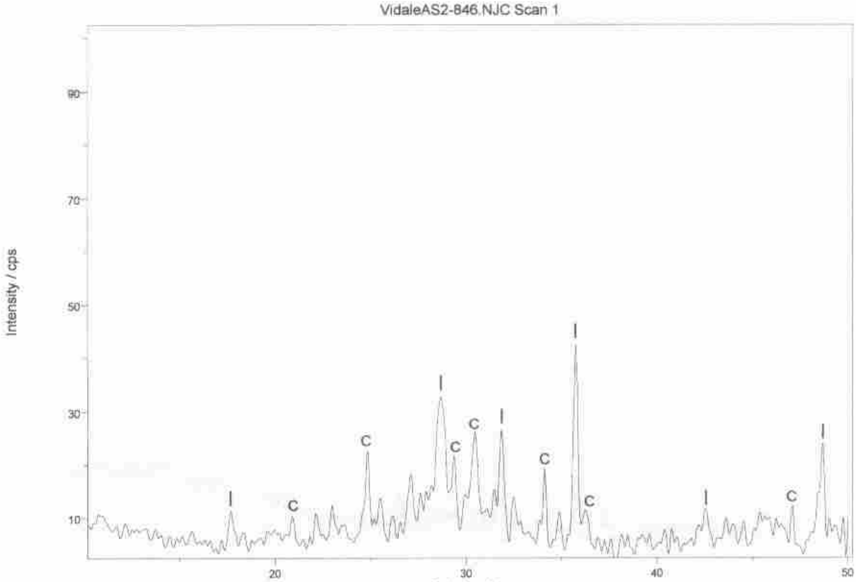

Fig. 16. XRD pattern for sample AS2 846, a block of litharge (l) with a minor component of cerussite (c).

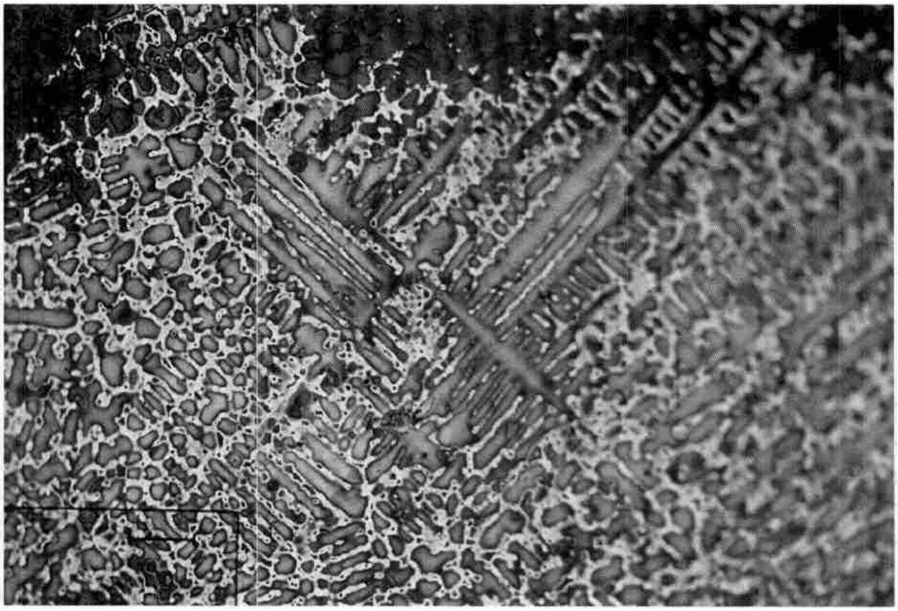

Fig. 17. Metallographic section of sample AS2 527, a casting prill, showing a well preserved dendritic structure typical of an unmodified cast object (10×X).

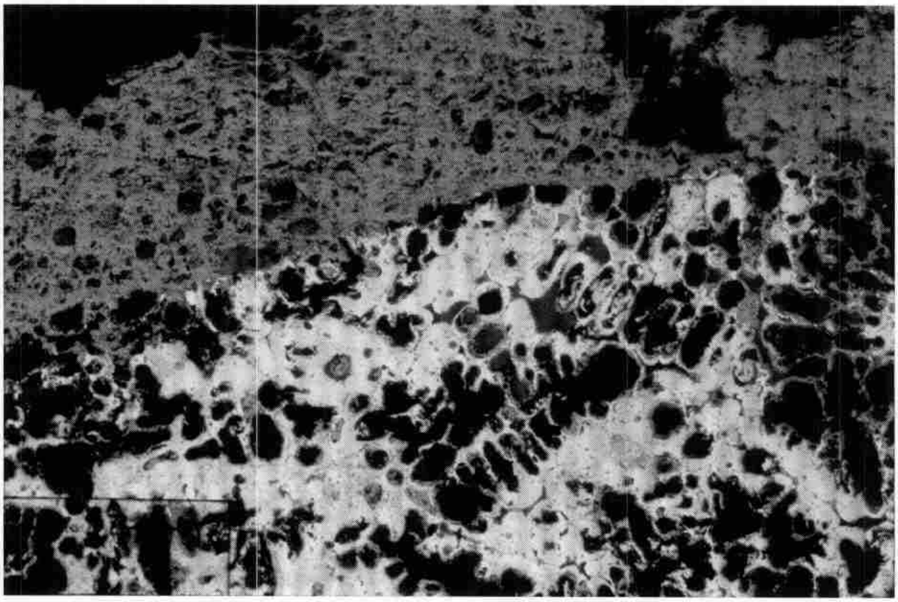

Fig. 18. Metallographic section of sample GT, showing a dendritic structure affected by a strong corrosion, compatible with a casting prill (5×).

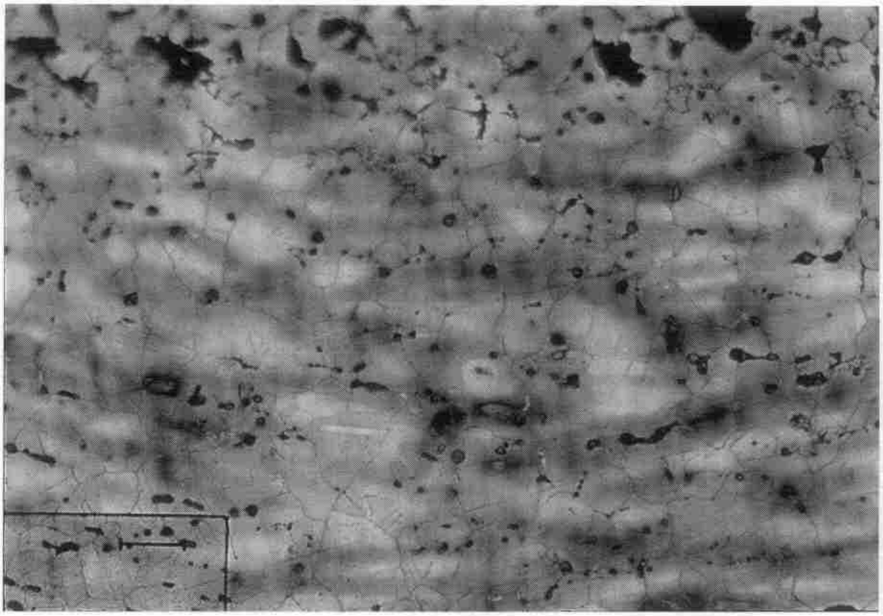

Fig. 19. Metallographic section of sample ASE 4, possibly a casting prill, showing a dendritic structure affected by a slight modification, with some isolated grains (20×).

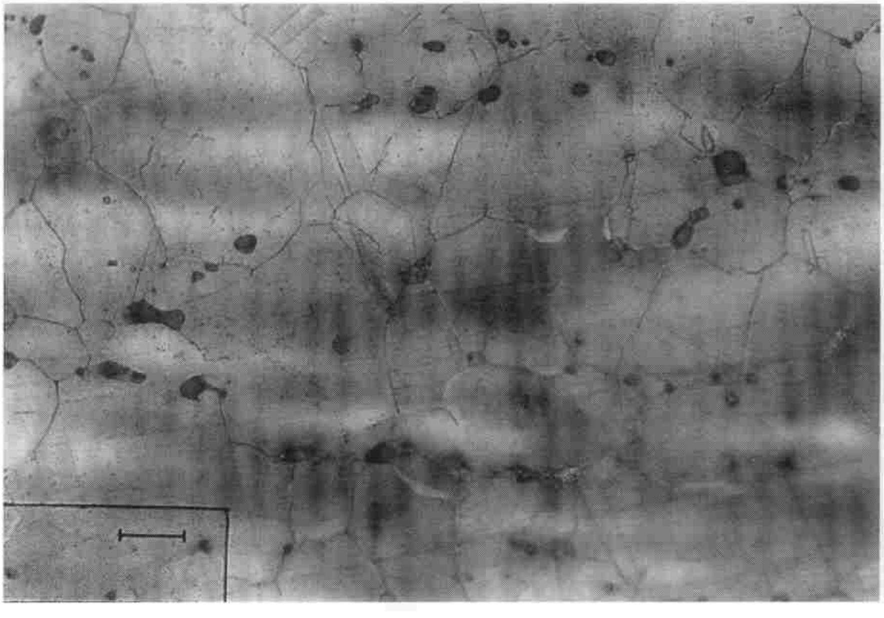

Fig. 20. Metallographic section of sample ASE 4, showing a dendritic structure affected by a slight modification, with some isolated grains (50×).

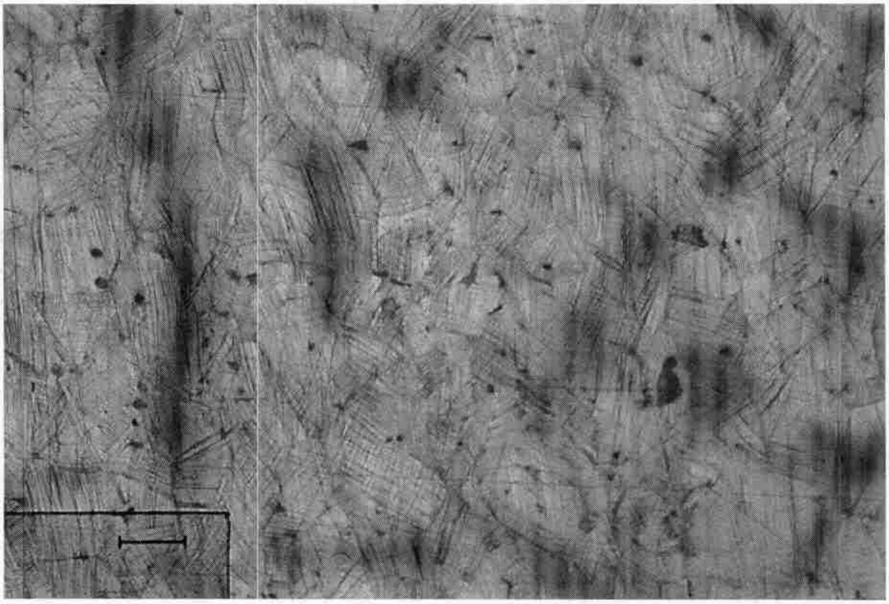

Fig. 21. Metallographic section of sample AS 488, possibly a fragment of a vessel, showing the signs of an intensive hammering (polygonal grains with inner geminated planes).

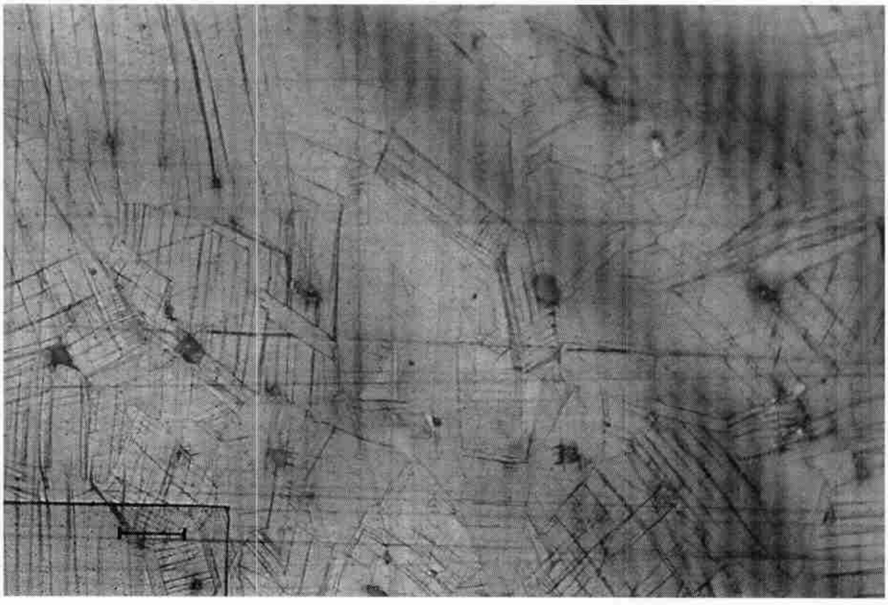

Fig. 22. Metallographic section of sample AS 488, possibly a fragment of a vessel, showing the signs of an intensive hammering (polygonal grains with inner geminated planes).

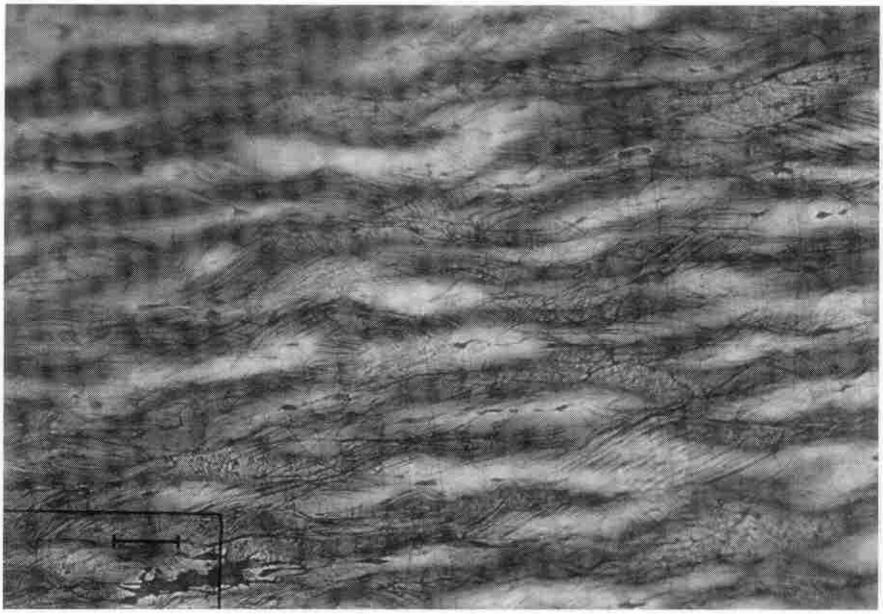

Fig. 23. Metallographic section of sample TM, a scalpel in arsenical copper, showing the signs of an intensive hammering (polygonal flattened grains with inner geminated planes).

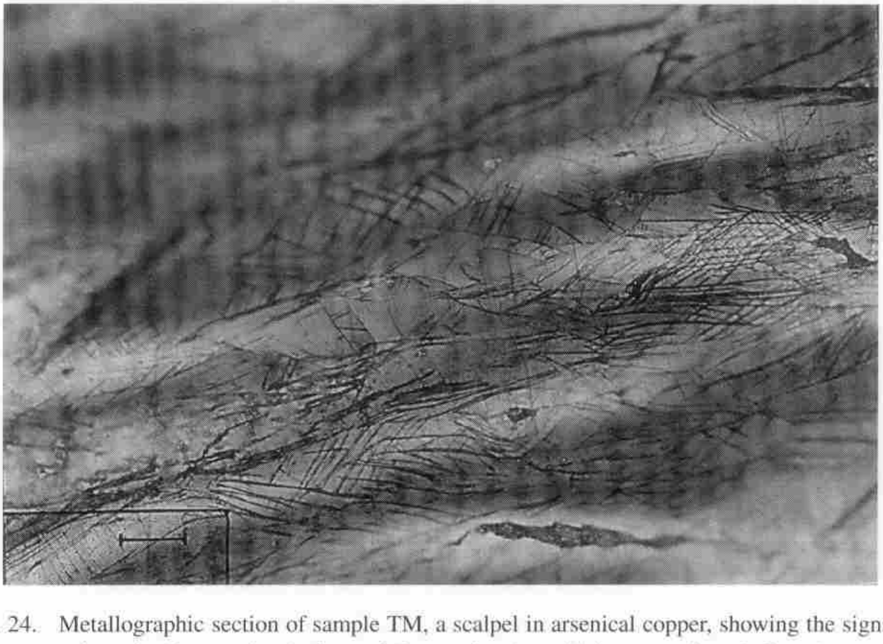

Fig. 24. Metallographic section of sample TM, a scalpel in arsenical copper, showing the signs of an intensive hammering (polygonal flattened grains with inner geminated planes).