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METALLURGICAL ANALYSIS FROM SARAZM, TADJIKISTAN SSR

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INTRODUCTION

This report consists of metallurgical analyses of objects from the Soviet Central Asian Bronze Age site of Sarazm. The settlement of Sarazm is situated 15 km west of Pendjikent on the second terrace of the Zeravshan River. It has been reported that the 'unobstructed or open part of the ancient settlement is equal to *c.* 35 hectares' making it one of the largest of central Asian Bronze Age communities (Isakov 1981 p. 273). The site has been excavated for eight seasons by Abdullah Isakov and the analysed samples came from these earlier excavations. In the summer of 1985 Kohl and Lamberg-Karlovsky undertook collaborative excavations at Sarazm under the auspices of a joint U.S.S.R./U.S.A. archaeological exchange program.

A series of radiocarbon determinations provide the basic chronological framework for Sarazm. Soundings and excavations have revealed that the site had at least four major occupational horizons. The following dates for Sarazm I–III were determined by radiocarbon. We have converted the furnished B.C. dates back to what must have been the original 5568 B.P. half-life determinations by adding 1950. We then calibrated them to the CRD 1δ B.C. dates as shown in table 1. The calibrations seem to indicate that Sarazm I dates to the early fourth and Sarazm II to the late fourth, early third millennia. The dates for Sarazm III suggest that some occupation at the site may have lasted into the last half of the third millennia. It should be emphasized that relative chronological parallels from sites in Iran (e.g. Shahr-i Sokhta), southern Afghanistan (Mundigak), and the Quetta valley with the Sarazm materials correlate far better with the uncorrected radiocarbon determinations. This problem of the absolute dating of Sarazm cannot be settled on present evidence, though a Late Aeneolithic to Early Bronze (late fourth to early third millennia B.C.) date for part of the site's occupation seems secure.

The unusually rich metal inventory recovered from Sarazm, most particularly from Periods II, III and IV, include numerous daggers, awls, chisels, a shaft-hole axe-adze, tweezers and a wide variety of decorative rings, pendants, beads and pins. The painted ceramics from Sarazm I have direct parallels to the upper levels of Geoksyur and Kara-depe in Southern Turkmenia where they are dated to the Namazga II–III periods. The recovery

Table 1 *Radiocarbon determinations from Sarazm*

Sarazm	*Exc.*	*Level*	*Laboratory reference No.*	*As furnished*	*5568 half-life*	*CRD 1δ B.C.*
			LE 2172	3100 ± 60 B.C.	5050 ± 60	3905–3775
			LE 2173	2930 ± 30 B.C.	4880 ± 30	3790–3645
	2		LE 2174	2990 ± 30 B.C.	4940 ± 30	3870–3660
II	3		LE 1806	2510 ± 50 B.C.	4460 ± 50	3365–3020
II	3	2	LE 1808	2280 ± 40 B.C.	4230 ± 40	2970–2795
III	2	3	LE 1807	1890 ± 40 B.C.	3840 ± 40	2415–2185
III	3	2	LE 1420	1840 ± 80 B.C.	3790 ± 80	2410–2115

Note LE, Leningrad.

of these ceramics at Sarazm indicate the most easterly distribution of these painted wares. Equally significant are the presence of limited quantities of ceramics with direct parallels to Mundigak, Nal and sites on the Iranian Plateau. The recovery of numerous stone weights further suggest the wide-ranging parallels of the Sarazm corpus. These disc-shaped weights with clearly defined handles are directly analogous to those recovered from Anau, Kara-depe, Sialk, Yahya and numerous sites from the Iranian–Afghan Seistan region. The materials recovered from Sarazm indicate a hitherto unsuspected large agricultural community in an area where Bronze Age agricultural communities were not previously known to exist. Furthermore, the material inventory suggests not only an indigenous propensity but wide-ranging cultural contacts with northern Baluchistan, the Iranian Plateau and Soviet Turkmenistan.

SARAZM METALS

The eight samples were mounted in a cold setting resin, ground and polished in the standard metallographic procedure. A variety of chemical etchants were tried and it was determined that a 1:1 mixture of ammonium hydroxide–hydrogen peroxide produced the microstructure most clearly. The microstructures were observed using both an optical microscope and an electron beam microanalysis apparatus (EBMA).

There appeared to be sufficient metal in four of the samples to permit reliable elemental analysis by atomic absorption (see table 2). These analyses show, as do the metallographic

Table 2 *Element analysis by atomic absorption* (wt%)*

		Sn	*As*	*Zn*	*Pb*	*Fe*	*Ni*	*Ag*
Sarazm 4	95.6	0.36	nd	100 ppm	0.99	0.01	0.03	0.03
Sarazm 5	95.9	nd	0.3	100 ppm	0.32	100 ppm	0.03	0.21
Sarazm 6	96.0	0.07	0.43	100 ppm	1.14	100 ppm	0.01	0.02
Sarazm 7	98.3	0.07	0.62	100 ppm	0.11	0.22	0.01	0.19

* Analyses obtained by J. Merkel, Peabody Museum, Harvard University, Cambridge, Massachusetts.
nd. not detected.

structures, these four to be essentially 'pure' copper. Sarazm 1, 2 and 3 also show the same metallographic structures and are of 'pure' copper. More will be said about these analyses following the discussion of the results of optical and EBMA observations.

Sarazm 1

This was part of a mirror. It shows (figure 1) a partially recrystallized structure. The coppersmith had fashioned his object to a degree where further shaping would have cracked the object. Hence, he attempted to heat the object to soften it and permit him to continue the shaping. This shaping causes the black particles to be aligned in rows produced by the hammering (in general, perpendicular to the direction of the hammering). Twins (parallel bands) are distorted indicating again the residual strain remaining from the last cold hammering. Observations using EBMA show the black particles to be holes considered to have been the sites of Pb particles torn out by the polishing. Light circles were identified as lead sulfate particles* (Yazawa 1974–1979). Analysis by EBMA shows a strong As peak. The samples were polished with alumina and it is most likely that some polishing grit remained in the holes after the Pb was removed. The presence of parallel bands in islands are indicative of copper that had been cold worked, i.e. hammered then subjected to a temperature of above 500 °C for an hour or so. If the copper had been fully recrystallized the parallel banding would be present throughout the micrograph and not just as islands. Complete recrystallization is dependent on the extent (and kind of) cold hammering, the

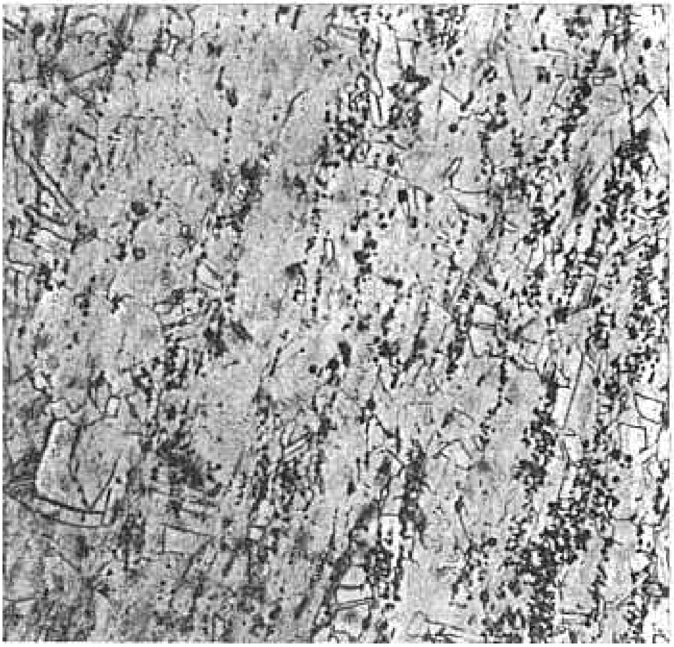

Figure 1 *Microstructure of Sarazm 1 (magnification, × 256). The small islands are new grains grown at the annealing temperature from the strained grains. If sufficient time had been permitted at these elevated temperatures, the entire sample would have been filled with similar grains. The black particles are holes that once held Pb or lead sulfate torn out by the metallographic polishing.*

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* While our EBMA measures Pb, S and O, we are more confident in the amounts of Pb and S and less certain about the amounts of the O.

temperature at which it is heated and the amount of time heated at that temperature. Complete recrystallization reduces the hardness but increases the ductility so that further deformation may be performed.

There was insufficient metal to permit elemental analysis. On the other hand, the microstructure is that of a 'pure' copper. The object was recovered from Period III.

Sarazm 2

This sample was taken from the blade of a knife. Insufficient metal remained to permit reliable results from elemental analysis. The grain structure, figure 2, shows a completely recrystallized copper but with residual strain. The recrystallization was either at a temperature higher than 500 °C or for a long time, as judged by the large grain size. The number of Pb particles is small compared with Sarazm 1. The object was recovered from Period II.

Sarazm 3

Sarazm 3 was derived from an unidentifiable 'lump' that had insufficient metal for reliable elemental analysis. It has essentially the same characteristics as Sarazm 1 showing the Pb particles aligned perpendicular to the direction of the hammering and in incomplete recrystallization (figure 3). The presence of Pb particles is also noted but the number is much fewer than in Sarazm 1. The presence of residual strain is not as apparent as in Sarazm 1 although some slightly curved twins can be detected indicative of casting.

EBMA (figure 4) shows an interesting effect. Within a background showing twins there are holes in which some Pb remains but from which most of the Pb was removed. Here the Pb is most likely in the form of a sulfate rather than metallic Pb. The objects date to Sarazm Period III.

Figure 2 *Sarazm 2 microstructure (magnification, × 256) showing recrystallized grains with some distortion due to further hammering after annealing. Note the curved twins*

Figure 3 *Sarazm 3 (magnification, × 256) showing the islands of the recrystallized grains and the large pits which formerly held Pb, lead sulfide and lead sulfate particles.*

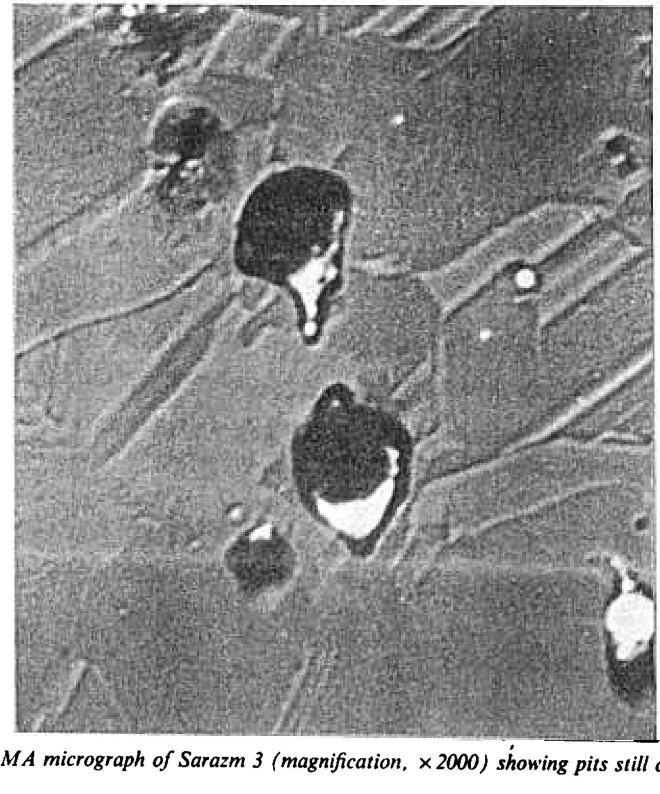

Figure 4 *EBMA micrograph of Sarazm 3 (magnification, × 2000) showing pits still containing some Pb.*

Sarazm 4

The object appears to be a fishhook about 3 mm on edge, and contained sufficient metal for elemental analysis (see table 2). The chemical composition is remarkably similar to that for Sarazm 6; both contain about the same amounts of Sn, Pb, Ni and Ag. Both samples show an absence of As, essentially an absence of Zn and Fe with about the same amount of Cu. The microconstituents in both samples are about the same although the mechanical treatment differs (more about this later). It may, therefore, be suggested that both these objects come from a similar smelting technology, perhaps even the same smelt. The ores from which these metals were smelted contained substantial amounts of Pb. Their chemical contents are sufficiently different from those for Sarazm 5 and Sarazm 7 to permit the suggestion that these latter objects came from different ores. In the smelting of Cu ores containing Pb in the form of PbS (as well as sulfates as these samples do), the lead sulfate is readily reduced to metallic Pb while the lead sulfide remains primarily as PbS or in an oxidized state and is partially reduced because of the sluggishness of the reaction (Yazawa 1974). Pb is insoluble in Cu both in the liquid as well as in the solid state. As the Cu solidifies from the liquid, the metallic Pb and the partially reduced PbS solidifies as droplets of Pb and the oxidized states of PbS as well as unreduced lead sulfate. These show in the micrograph as cylindrical particles of varying sizes (see figure 4).

The microstructures for Sarazm 4 are shown in figures 5 and 6. Figure 5 is from a cross-section of the object while figure 6 is from a longitudinal section. The cross-section shows a large cavity (figure 5). That this object was subjected to a large amount of cold hammering is noticeable in figure 6 from curvature of the small twins. The object was

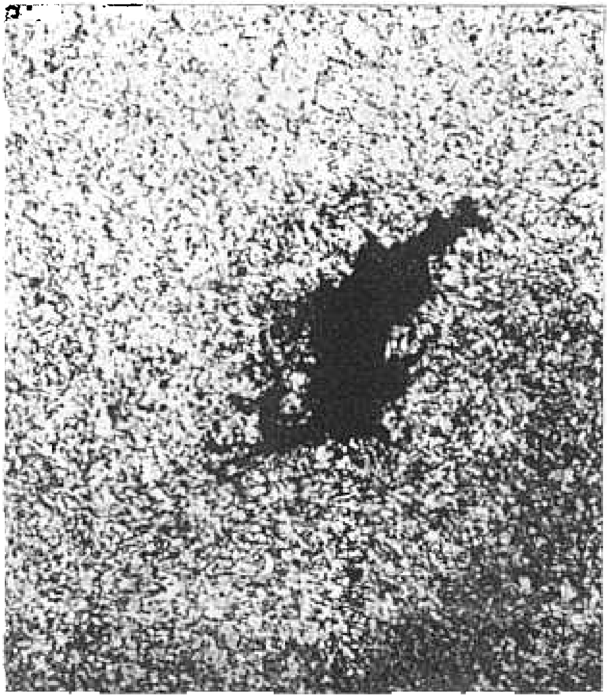

Figure 5 *Cross-section of Sarazm 4 showing a void in the center of the sample.*

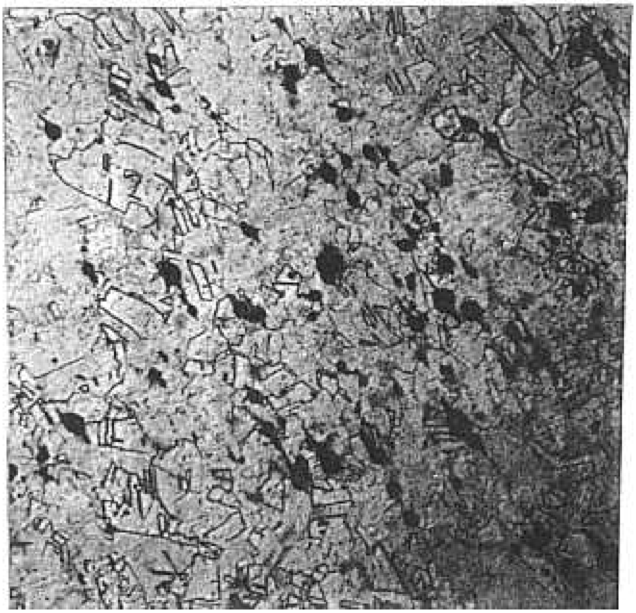

Figure 6 *Longitudinal section of Sarazm 4 (magnification, ×256). The microstructure is that of a partially recrystallized copper containing strain from hammering following the last recrystallization. Recrystallization is almost complete; the black particles are pits.*

annealed, probably at a relatively low temperature (about 500 °C) and for a short time, as judged by the small recrystallized grain size. The objects have considerable numbers of Pb particles. The Pb particles are aligned in the longitudinal direction of the bar.

The EBMA micrograph (figure 7) shows, in a background of recrystallized grains, smeared Pb. The Pb, originally in the holes, must have fallen out in polishing and was deformed into smears by the polishing. The strained nature of the twins may be seen in the background. The object dates to Sarazm Period IV.

Sarazm 5

Sarazm 5 is a fragment removed from the blade of a dagger. It was covered by a black surface layer applied by a conservator. The layer was easily removed during the initial grinding operation and was easily brushed off to obtain a sample for elemental analysis (table 2). The chemical content of this has some resemblance to that of Sarazm 7 but with enough differences to suggest they come from different smelts but not necessarily from different ores. The Sn contents are essentially the same, the As is twice as high in Sarazm 7 as in Sarazm 5, the Zn, Ni and Ag are about the same while the Pb is three times that in Sarazm 7. The major difference occurs in the Fe which is substantially free in Sarazm 5 but not so in Sarazm 7. Most of these differences may be explained by assuming that both metals were derived from the same ore but from different smelting operations. For example, twice the As in one case is not unusual since there was no way to control either the temperature or the atmosphere and, hence, the result in different As contents. The differences in the Pb occur simply from the sluggish kinetics of reducing the Pb minerals, as they

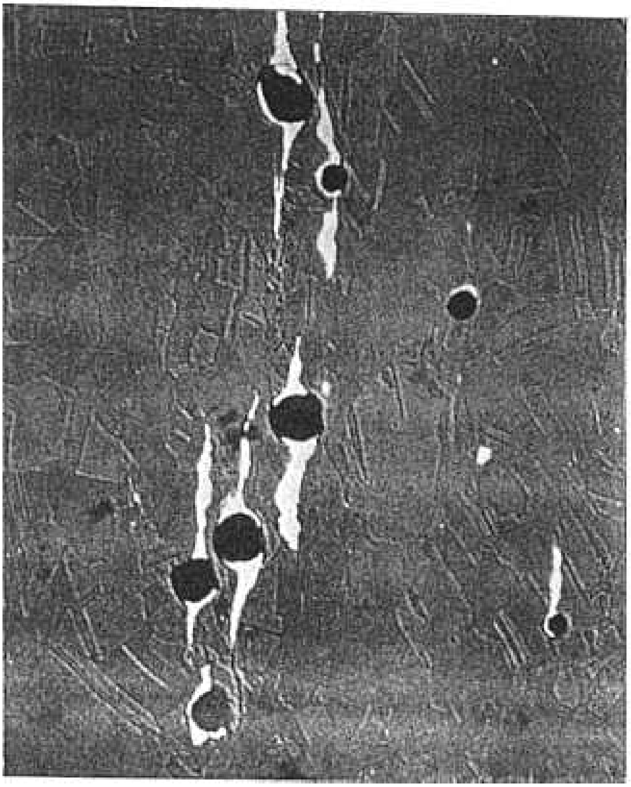

Figure 7 *EBMA micrograph of Sarazm 4 showing pits which contained the Pb (the white areas) smeared by the polishing (magnification, × 2000). Note the extensive and curved twinning.*

are dependent on conditions of temperature, size distribution of the Pb minerals and the oxygen potential in the immediate environment of the Pb minerals.

The flat section of the blade (figure 8) shows a partially recrystallized copper with an aligned distribution of large Pb particles (i.e. what had previously been Pb particles aligned perpendicular to the direction of the hammering). The recrystallization is heterogeneous in that the grains have grown to a fairly large size within a matrix that shows no recrystallization (particularly noticeable in figure 8). This may be due to a heterogeneous hammering followed by a long time at relatively low annealing temperature (*c.* 500 °C). In this case the distorted grains would have realigned and grown in this characteristic way. The abundant and large size $PbSO_4$ and other Pb would have reduced the malleability of the copper necessitating the annealing. The blade was left in a hammered state (see the curved twins in figure 8).

Sarazm 6

Sarazm 6 derived from a knife blade and like the other samples shows considerable numbers of large-size particles of Pb. As stated above, the chemical content of Sarazm 6 is similar to that in Sarazm 4, so much so that it may be said that the objects were made of the same smelted material. The grain structure is shown in figure 9. This micrograph shows a

Figure 8 *Flat section of Sarazm 5 (magnification, × 256). The structure is that of a partially recrystallized copper containing large pits. The recrystallized grains are large indicating a relatively high annealing temperature but an insufficient time at that temperature.*

Figure 9 *Flat section of Sarazm 6 (magnification, × 256) showing the distortion clearly. Here it is seen that the recrystallization is not complete.*

recrystallized microstructure with some alignment of the Pb particles. The object was left in a work hardened state as noted by the extensively distorted twins. Recrystallization occurred both at a relatively high temperature and for a time sufficient to develop a large grain size. Recrystallization appears to have been complete.

Sarazm 7

Sarazm 7 is a section from a blade (as in Sarazm 5) covered with the same surface layer as in Sarazm 5. The sample has a similar chemical content (as noted above) to that for Sarazm 5 so much so that it may have been made from copper from the same smelt. There are differences, however, that point to a somewhat different interpretation. The recrystallization appears more complete since the grain size is much larger with few areas not showing some recrystallization. The annealing probably occurred at both a higher temperature and for time long enough to permit substantial grain growth. These structures are shown in figure 10 (note the large grain size in figure 10 as compared with that in figure 8). Whereas the particles show a much more pronounced alignment in Sarazm 5, those in Sarazm 7, although showing some alignment, appear to have precipitated within the grain boundaries. The particles seen in figure 11 (EBMA × 4000) is lead sulfate containing a large amount of Sb (about 30%). A small piece (the black hole within the particle) held, at one time, some Pb which was removed during the polishing. The object was recovered from a Period II context.

Sarazm 8

This object was a small grayish bead without metallic luster but with a silvery grayish appearance too light in weight to be lead. Polished, it showed no metallic characteristics. The mounted sample was examined by microprobe equipment. It showed the sample to be silver chloride containing a marked bromine line. Hence, the conclusion could be made that

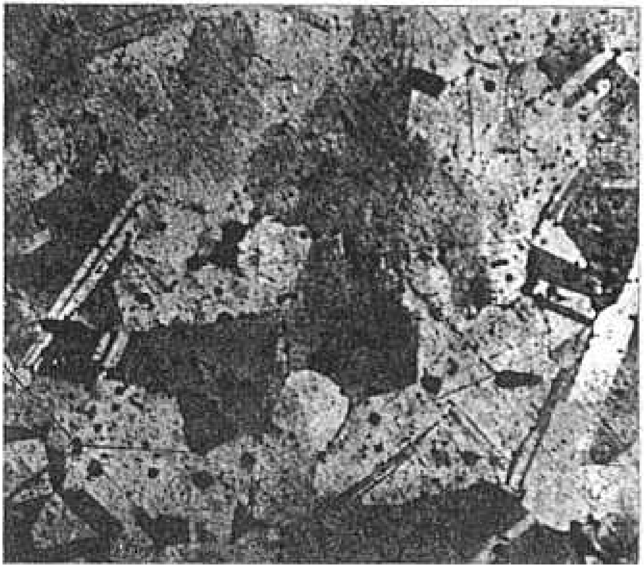

Figure 10 *Knife blade. Sarazm 7 (magnification, ×256). Here the pits appear to outline the copper grains*

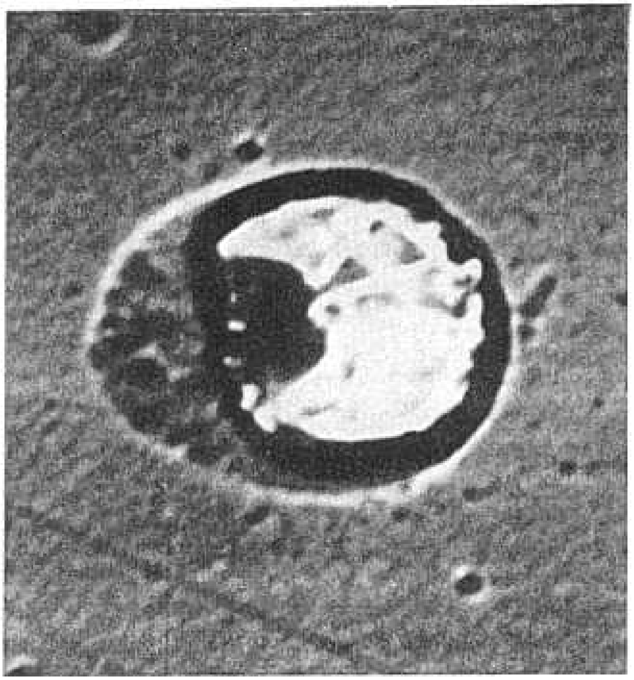

Figure 11 *Sarazm 7 (magnification, × 4000). A large pit as seen by EBMA. The white within the pit is Pb with about 30% Sb.*

the bead was made from the mineral cerargyrite (AgCl), a soft ductile but tough crystalline substance of moderate density. Cerargyrite is a secondary mineral found usually in the upper oxidized zone of silver deposits, especially in arid regions.

The hole in the bead was sharply defined giving little clue to the manner in which it may have been made. However, beads of this vintage were usually made by boring a small hole (probably with a flint or obsidian tool) which was then enlarged with a wet string containing grit. The hole was symmetrical (figure 12). This bead was taken from a necklace, dated to Period II, which contained 27 such beads alternating with beads of lapis lazuli. In the 1985 excavations a burial was recovered containing an entire string of beads of the type described above.

CONCLUSIONS

The ores from which these metals were smelted were, most likely, weathered ores such as malachite, cuprite or azurite. This conclusion is based upon the relative absence of Fe and the absence of CuS. The Cu is relatively 'pure' containing only small amounts of impurities except for Pb which was relatively high in two cases. The Pb probably entered the Cu as a combination of the sulfide and weathered and partially weathered products of the PbS, products such as lead sulfate and intermediate sulfur-containing Pb.

Analyses of the metal artifacts indicate that the smiths of Sarazm produced metal objects in much the same fashion as contemporaneous coppersmiths in Mesopotamia, the Iranian Plateau and the Indus Valley. These included the working to shape and harden objects,

Figure 12 *Sarazm 8 (magnification, ×64). Cerargyrite bead showing a sharply cut hole.*

annealing to soften and shape further, as well as casting in open and closed molds. Objects which were best left hard, e.g. knives (Sarazm 5 and 7) were left in the hardened condition.

That metal was worked directly at Sarazm is attested to in the excavations. Significant quantities of crucibles and slag were recovered from excavation 2 and dated to Sarazm III. Though the architectural association and function remain somewhat unclear the crucibles and slag were recovered from surfaces of floors that were burned red. From this floor were recovered holes of hearths that were 18–25 cm in diameter and 20–30 cm in depth. It is not unlikely that these were 'pot-furnaces' for the smelting of ores.

The fact that Sarazm produced its own metal inventory is further supported by the analysis of Sarazm 4 (a fishhook) and 6 (a knife) regarded as derived from the same smelt. It is interesting to note that very different objects were produced from a single smelt. Analysis of Sarazm 1 (a mirror) and Sarazm 3 (an amorphous lump) also suggest their derivation from the same smelt. The production of different type artifacts from a single smelt may argue against large scale production of a specialized nature. Thus it is suggestive of different behavior, (production, supply, demand) if one produces several identical pieces from a single smelt rather than a variety of different artifacts. The former is more indicative of large-scale specialized production, the latter a production to fill immediate needs.

Copper ores are reported to be present in the region of the Zeravshan and were most likely those exploited. That singular copper sources were exploited over a period of time is indicated by Sarazm 5 and 7, both are daggers from different periods but from the same ore deposit, and produced from different smelts. Almost certainly the cerargyrite bea (Sarazm 8) is a local resource. The bead was recovered from a burial which had alternatin beads of this mineral with lapis lazuli beads. In the 1985 excavation a single burial chamb of three individuals was recovered. A female in this tomb was interred with necklac including dozens of lapis, carnelian, turquoise, gold and cerargyrite beads.

Excavations in the third millennium levels at Sarazm have revealed a rich metallurgic inventory from a hitherto little-known archaeological region. Their metallurgical tec niques of production together with other categories of material inventory, e.g. cerami beads, architecture, mineral beads etc. indicate an unexpected wealth of indigenous produ tion which is, nevertheless, related to techniques of production and resources comparal with such distant centers as Mesopotamia and the Indus Valley. Further research w undoubtedly shed more light on the important relations that characterized the unity technological knowledge within the diversity of cultures in this large geographical expan Historically this region of central Asia has served for millennia as the corridor for weste contact with China. The materials from Sarazm have direct parallels with materials fr the west (Turkmenistan), the south (Baluchistan and Iran) and the north (the Steppes Kazakhstan). Is it too much to hope to recover materials reflecting a knowledge a communication with the more distant east? Finally, what precise meaning are we to der from an understanding of this emerging interconnectedness of technology and mate culture? What role did it play in the process toward the development of urban civilizati in these different regions?

REFERENCES

Isakov, A., 1981, Excavations of the Bronze Age settlement of Sarazm, in *The Bronze Age civilization of ce Asia* (ed. Philip L. Kohl), pp. 273–86, Armonk, NY: M. E. Sharpe.

Yazawa, A., 1974, Thermodynamic considerations of copper and smelting, *Canad. Metall. Q.* **13** (3), 443–

Yazawa, A., 1979, Thermodynamic evaluations of extractive metallurgical processes, *Trans. Met. Soc.* 307–321.