

# RESULTS OF AN EXAMINATION OF METAL SPECIMENS FROM AN EXCAVATION OF SHAMSHIR GHAR, AFGHANISTAN<sup>1</sup>

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The specimens discussed in this paper all came from the excavation of the cave site of Shamshir Ghar, Afghanistan, conducted by Dr. Louis Dupree of Harvard University. This site is situated in the Province of Kandahar, at 31° 35' N latitude and 65°30' E longitude, and is about 15 miles WNW of Kandahar city.

According to the findings of Dr. Dupree, this site was not occupied by man until after the beginning of the Christian Era. Four cultural levels were identified, all belonging to pre-Mongol invasions.

Seven specimens, all more or less corroded, were submitted by Dr. Dupree for examination. In four of them sufficient metal was present to provide samples for quantitative analyses. The descriptions of these specimens and the results of our examination now follow.

No. 1. *Bronze Coin*. Diameter=17-18 mm. Weight=2.37 g. Date=IX-X Cent. A. D. This coin was covered with such a dense and uniform layer of green corrosion products that no trace of a design could be distinguished before cleaning. After electrolysis, parts of a crude design were visible. For analysis the surface layers were filed away, and two samples of fairly clean metal were obtained. The results of the analysis are shown in table 1.

These results show that this coin was composed of a lead-tin bronze of rather high lead content. Because of lack of analyses no comparison with respect to composition can be made between this coin and other coins of similar provenance. However, it is interesting that bronze of about the same composition was used for late Greek coins struck in eastern provinces of the Roman Empire. In all probability the silver in the alloy was introduced as an accidental impurity in the lead made from argentiferous galena. Though the proportion of nickel present as an accidental impurity falls within the normal range for an ancient bronze, the proportion of cobalt is unusually high and may be indicative of copper from a particular source. There is nothing remarkable about the proportions of iron and zinc. The low summations are due to the presence of undetermined oxygen and other non-metallic impurities present in the form of corrosion products within the samples of metal.

No. 2. *Fragment of Thin Bronze*. Length=25 mm. Width=15 mm. maximum. Thickness=ca. 1 mm. Weight=2.00 g. Date=IX-X Cent. A. D. This appeared to be a segment of a disc, though the complete object could have had a different shape. Faint traces of an ornamental design were visible on the surface, which was covered with a thin layer of dirt and corrosion products. These were removed mechanically as far as practicable in preparing the two samples for analysis. The results of the analysis are shown in table 2.

These results show that this fragment was also composed of a lead-tin bronze, but one of lower tin content and even higher lead content than the metal of the coin. It is not surprising that the percentages of copper and lead in the two samples are not in agreement, for in bronze of such high lead content the lead

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is often irregularly distributed through the alloy. On comparing the figures of table 2 with those of table 1 it will be seen that both bronzes contained the same impurities and that all except nickel were present in higher proportion in the metal of the fragment. The parallelism between the percentages of silver and lead in all samples and the near constancy of the ratios of these percentages, shown in table 3, is a clear indication that the silver was introduced as an impurity

TABLE 1  
*Analysis of bronze coin*

Sample	Cu %	Sn %	Pb %	Ag %	Fe %	Ni %	Co %	Zn %	Total %
A	76.86	5.75	14.96	0.12	0.12	0.15	0.08	0.20	98.24
B	77.07	5.78	15.14	0.16	0.06	0.11	0.03	0.14	98.49

TABLE 2  
*Analysis of fragment of object composed of thin bronze*

Sample	Cu %	Sn %	Pb %	Ag %	Fe %	Ni %	Co %	Zn %	Total %
A	67.22	3.36	25.53	0.20	0.49	0.11	0.13	0.66	97.70
B	64.54	3.29	28.29	0.22	0.52	0.11	0.12	0.74	97.83

Table 3  
*Ratio of Silver to lead in bronzes*

Pb %	Ag %	Ag/Pb Ratio
14.96	0.12	0.008
15.14	0.16	0.011
25.53	0.20	0.008
28.29	0.22	0.008

along with the lead. The higher proportion of cobalt in the metal of this fragment as compared to the proportion of nickel is still more indicative of the use of copper ore from some particular source. As might have been expected, the summations of the results in table 2 are low because of the presence of corrosion products in the samples. In general, the analysis shows that the object from which this fragment came was composed of a kind of bronze suitable for ornaments but not for objects requiring hardness or strength.

No. 3. *Fragment of Pin or Clasp*. Length=32 mm. Weight=3.84 g. Date=ca. X Cent. A. D. This fragment appeared to be part of the shank of some sort of a pin or clasp. Mold marks on its sides indicated that this part of the original object had been formed by casting in a two-piece mold. The

fragment was coated with a thin, rather uniform layer of greyish-white corrosion products that contained stannic oxide and basic lead carbonate. The underlying metal was soft and white. Preliminary qualitative tests showed the presence of tin and lead as the major components of this metal. For quantitative analysis the surface layer of corrosion products was filed away, and two samples of rather clean metal were obtained. However, since the metal of this fragment had undergone extensive intergranular corrosion, it was not possible to obtain samples free from corrosion products. The results of the analysis are shown in table 4.

These results show that this fragment was composed of an alloy of tin and lead containing iron and zinc in small proportion as accidental impurities. This alloy is a kind of pewter in which the proportion of tin is close to twice that of lead. The closeness of the ratio seems to indicate that the alloy was not the result of the accidental or careless combination of the two component metals, but was the result of the deliberate combination of carefully measured amounts.

No. 4. *Broken Piece of Iron Pin or Shaft.* Length=69 mm. Weight=4.86 g. Date=VII-VIII Cent. A. D. This was a deeply rusted short length of straight rod that still contained some residual metal in its core as shown by tests with a magnet. On removal of the layers of rust mechanically a short, thin piece of metal was isolated. This iron was so soft that it could be easily filed,

TABLE 4  
*Analysis of fragment of pewter*

Sample	Sn %	Pb %	Zn %	Fe %	Total %
A	63.87	32.64	0.08	0.03	96.62
B	63.64	32.89	0.07	0.02	96.62

and so ductile that it could be flattened out easily by hammering. After heating it to bright redness and plunging it into cold water it still could be easily filed and was still so ductile that it could be hammered out without any sign of fracture. This behavior is characteristic of iron containing a very low proportion of carbon. The metal of this object must have been, therefore, wrought iron or a very mild steel.

No. 5. *Broken Piece of Iron Pin or Shaft.* Length=45 mm. Weight=4.37 g. Date=VII-VIII Cent. A. D. This was similar to No. 4 in appearance, though somewhat thicker, and it also contained a short, thin core of metal. This iron was noticeably more resistant to the file than the metal of No. 4, and much less ductile on hammering. After heating it to bright redness and plunging it into cold water it was still more resistant to the file, and on hammering it broke into small pieces. This behavior is characteristic of iron containing enough carbon to be classed as a steel. In view of the difference in behavior before and after heat treatment, it must be concluded that the metal of the object was a tempered steel.

No. 6. *Broken Piece of Iron Arrowhead.* Weight=2.11 g. Date=VII-VIII Cent. A. D. This was part of a bayonet-shaped arrowhead with three ribs. No residual metal could be detected by means of a magnet. The form of this fragment and the extent to which it had rusted clearly seemed to indicate that the arrowhead had been fashioned from either wrought iron or steel but not from cast iron.

No. 7. *Irregular Flat Piece of Cast Iron*. Thickness=3-5 mm. Weight=48.6 g. Date=X-XIII Cent. A. D. This piece of cast iron broke readily on being struck with a hammer and showed the bright crystalline structure characteristic of white cast iron. It also had the characteristic hardness of this variety of cast iron, for it could be neither drilled nor filed with tools of ordinary steel. The layer of rust on its surface was not more than a few tenths of a millimeter in thickness, which is not surprising in view of the known resistance of cast iron to corrosion under natural conditions. This specimen appeared to be a fragment from an iron plate, or possibly a piece from the bottom of a dish or pan. The fact that its thickness tapered regularly from 5 mm. at one end to 3 mm. at the other was perhaps an indication of the latter possibility. One side was smooth and the other slightly rough, which may indicate that the original object was cast in an open mold. A few small blowholes were present in the metal under the rough surface, and this also may be an indication of the use of this technique. Except for these blowholes the casting was sound. Separate samples were taken for the determination of the usual constituents of cast iron. The results of these determinations are show in table 5.

TABLE 5  
*Analysis of fragment of cast iron*

C	Si	P	S	Mn
%	%	%	%	%
4.25	0.13	0.11	trace	trace

These results fully confirm the previous observations indicating that this fragment was composed of white cast iron. The proportion of carbon is too high for steel, and is nearly the maximum that can occur in cast iron. Iron containing this particular proportion of combined carbon is the so-called eutectic alloy of iron and carbon, the one that melts or solidifies at a lower temperature than any other combination of iron and carbon. This minimum temperature is 1140°C, a temperature not difficult to reach even in a primitive furnace. The percentages of the other constituents are much lower than in modern cast iron. Iron of such high purity could have been produced by smelting a carefully selected, pure iron ore with charcoal in a blast furnace maintained at a relatively low temperature by the application of a regulated flow of unheated air. The higher percentages of impurities in modern cast iron arise from the use of unselected ore, coke as a fuel, and the higher temperature arising from the use of a blast of preheated air. From the standpoint of quality, the iron in this specimen is superior to modern white cast iron.

#### GENERAL CONCLUSIONS

A surprising variety of alloys and metallurgical techniques are represented by these few specimens. Such a variety of alloys and skills indicate an advanced stage in the art of metallurgy that could have been reached only on the basis of a long background of experience and practice.