

IR 62-34  
**FOR REFERENCE**  
NOT TO BE TAKEN FROM THIS ROOM  
CAT. NO. 4 L.-M.CO.

Basement

*Dr. J. Conway*

This document was produced by scanning the original publication.  
Ce document est le produit d'une numérisation par balayage de la publication originale.

**CANADA**

**DEPARTMENT OF MINES AND TECHNICAL SURVEYS**

**OTTAWA**

CANMET LIBRARY  
555 BOOTH ST.  
OTTAWA ONT. CANADA  
K1A 0G1

**MINES BRANCH INVESTIGATION REPORT IR 62-34**

**EXAMINATION OF CANADIAN PACIFIC  
COAST INDIAN "COPPERS"**

by

**A. COUTURE & J. O. EDWARDS**

**PHYSICAL METALLURGY DIVISION**

*45P*

*1-1055*

Mines Branch Investigation Report IR 62-34

EXAMINATION OF CANADIAN PACIFIC COAST  
INDIAN "COPPERS"

by

A. Couture\* and J.O. Edwards\*\*

- - - -

SYNOPSIS

"Coppers" specimens selected from the collection of the National Museum of Canada were investigated in order to determine whether they were of European or of American Indian origin. The evidence presented in the following report indicates that the "coppers" examined are of European or white North American origin. Their thickness evenness, their surface smoothness and, in certain cases, their size suggest that the original copper pieces were fabricated with heavy equipment. Furthermore, the presence and distribution of cuprous oxide in the microstructure are strong indications that the metal had been melted, and, since it is generally accepted that the North American Indian did not know how to melt, this fact supports the conclusions derived from visual examination.

---

\*Senior Scientific Officer and \*\*Head, Non-Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

Direction des mines

Rapport d'investigation IR 62-34

EXPERTISE SUR DES ARTICLES EN CUIVRE PROVENANT DU  
LITTORAL CANADIEN DU PACIFIQUE

par

A. Couture\* et J.O. Edwards\*\*

RÉSUMÉ

Ce rapport est consacré à l'étude d'échantillons prélevés sur des objets en cuivre, qui sont tirés de la collection du Musée national canadien. Le but de cette étude était de déterminer si les pièces représentées par ces échantillons ont été fabriquées par des Européens ou par les Indigènes vivant sur le littoral de l'océan Pacifique. Les données recueillies au cours de ce travail permettent aux auteurs de conclure que les objets de cuivre examinés ont dû être façonnés par les Européens ou les Blancs de l'Amérique du Nord, à l'aide de machines lourdes. Vu le peu de variation dans l'épaisseur des pièces étudiées, leur fini et, dans certains cas, leurs dimensions, il est peu probable qu'elles aient été fabriquées à partir de morceaux de cuivre natif avec les moyens de fortune dont disposaient les Indigènes. De plus, la présence et la répartition de particules d'oxyde de cuivre, révélées par l'examen de la microstructure de ces échantillons, font croire à la fusion du cuivre qui a servi à fabriquer ces articles. Si nous admettons, avec l'opinion générale, que les Indigènes de l'Amérique du Nord ignoraient les procédés de fusion du cuivre, nous devons conclure, comme l'examen visuel l'avait déjà indiqué, que les pièces en question n'ont pas été ouvrées à partir du métal brut par les Indigènes de la côte du Pacifique.

---

\*Chargé de recherches principal, et \*\* chef, Section des métaux non ferreux, Division de la métallurgie physique, Direction des mines, ministère des Mines et des Relevés techniques, Ottawa (Canada).



## INTRODUCTION

At the request of Dr. L.S. Russell, Director, Natural History Branch, National Museum of Canada, Department of Northern Affairs and National Resources, Ottawa, Mr. J.O. Edwards and Dr. K. Winterton of this Division and Dr. A.H. Gillieson and Mr. A.E. Larochelle of the Mineral Sciences Division visited Dr. Russell on March 28, 1961, to study the possibility of carrying out tests on the metallic copper used by the Indians of the Canadian Pacific coast in preparing peculiar ornamental plaques known as "coppers".

Help was therefore requested from the Mines Branch by Dr. Russell, in his letter of April 12, 1961, to Dr. John Convey, Director, Mines Branch, in the form of a study and analysis of small samples taken from six such ornamental plaques selected as being representative of several different types of plaques in the Museum's collection. These samples were received by this Division on October 2, 1961.

As requested, a specimen of known native copper was sent to this Division on December 14, 1961, by Mr. H.S. Stacey, Petrological Sciences Division, Geological Survey of Canada Branch, Ottawa. This specimen had been collected by Dr. E.D. Kindle on Beloud Creek in Dezadeash map-area, Yukon Territory, and was to be used for comparison purposes.

Also included in this report for comparison purposes is a brief account of an investigation carried out at the same time on a specimen (C54-5193) of copper sent to this Division on December 13, 1961, by Mr. J.V. Wright, archaeologist with the National Museum of Canada. This specimen had been submitted to Mr. Wright by Mr. E.R. Channen, curator of the Strathaven Indian Museum, Anten Mills, Ontario, and had been recovered from a large Huron site near Barrie, Ontario. As mentioned in Mr. Wright's letter of December 13, "archaeologically, the specimen should be native copper, although there is an outside chance of it being a French trade piece". It was therefore requested that its origin be determined. The findings of that investigation were reported to Messrs. Wright and Channen on March 26, 1962, in Test Report PM-62-15, Mines Branch, Department of Mines and Technical Surveys, Ottawa.

#### MATERIALS

The sources and dates of recovery of the six plaques selected are shown in the first six lines of Table 1. The last three specimens, selected in April 1962, were added to the plaques previously studied, in order to give a broader picture of the Indian "coppers" found on the Canadian Pacific coast.

## EXAMINATION

### Visual Examination

The first six "coppers" mentioned in Table 1 were photographed; they are shown in Figures 1 to 6, inclusive, with their weights and approximate dimensions. The collection of "coppers" from which these specimens were drawn offers a large variety of sizes, their length varying from approximately  $1\frac{1}{2}$  inches to 4 feet. However, most of them have a characteristic shape of which specimen V11.D.406 (Figure 1) is representative. Several plaques, especially among the larger ones, had been cut before their discovery, but the remaining sections, specimens V11.E.430 (Figure 3) and V11.E.436 (Figure 4), strongly suggest that their original shape was as presented in Figure 1.

Some of the "coppers" examined were made of more than one piece, held together by means of solder or rivets; specimens V11.E.438 (Figure 5) and V11.E.603 (Figure 6) are representative of this group. Specimen V11.E.425 (Figure 2) is in one piece, but two of its sides show a layer of solder, indicating that this piece had been originally joined to a larger piece. The rivets of specimens V11.E.438 and V11.E.603 were closely examined and it was found that their heads are circular, very regular, and smooth where not damaged by corrosion.

One large shield, carrying number VII.C.361 and being approximately 18 inches wide and 44 inches long, showed evidence of melting in one corner. It was suggested by Mr. C.C. Perry, who collected this "copper" in 1911, that the shield had been damaged in a fire at Metlakatla, British Columbia.

Some of the specimens examined were so severely damaged or corroded that they hardly held together, whereas others were in an excellent state of preservation. Most of the specimens were coated with resin, or other unidentified substances.

Parts of the larger shields have a very smooth and even surface, whereas other portions of the same specimens have been deformed by a heating operation and, in some cases, damaged by indentation. Examination of the edges of incomplete plaques, particularly the thicker ones, suggests that the absent portions were cut out with a sharp tool like a chisel.

#### Thickness Measurements

The thickness of the first six plaques, mentioned in Table I, was measured with a  $\frac{1}{4}$ -inch ball-end micrometer where the surface did not seem to be too rough. However, it was not always possible to do these measurements in smooth areas and, consequently, some of the variation in



the results presented below are due to surface irregularities. All determinations were taken within 5/8 inch from the edges of the plaques.

Thirty measurements were taken around plaque number VII.D.406, and the thickness was found to vary between 0.017 and 0.025 inch. It was noticed that in certain areas there was a thick coat of resin on the metal surface, whereas in others it was difficult to determine whether resin was present or not. Also, the surface of the shield was quite irregular. It is possible that these two factors might account for some of the variation found in the thickness.

As mentioned earlier, specimen VII.E.425 had been soldered along two of its sides. Consequently, only eight thickness determinations were made along the other sides; results ranged from 0.037 to 0.048 inch. Again, this variation may be partly due to the specimen coating, which shows evidence of peeling in certain areas, and to the specimen roughness.

The thickness of specimen VII.E.430 was determined in thirty different locations. Results ranged from 0.063 to 0.068 inch. This "copper" showed the smallest thickness variation of all the specimens measured, probably because the surface condition is much better and smoother than that of the other specimens. However, such a small

thickness variation is remarkable in view of the relatively large size of this piece, whose overall dimensions are approximately 21 by  $10\frac{1}{4}$  inches.

Thirty-nine thickness determinations were made on specimen number Vll.E.436, which is the largest of all the "coppers" examined (its dimensions being approximately 47 by 20 inches). Thickness results varied from 0.174 to 0.207 inch. The piece is thickest near the middle and gradually tapers down towards both ends. Its surface was relatively smooth.

The surface of specimen Vll.E.438 was so rough that thickness results would be meaningless.

Similarly, specimen Vll.E.603, which is made of six separate pieces, was in general too rough to permit of thickness determinations. However, one of the pieces, which is approximately 8 inches long, had a thickness of 0.024 to 0.025 inch.

#### Metallographic Examination

The specimens sent to this Division by Dr. Russell were mounted in lucite and prepared for metallographic examination, together with the native copper specimen supplied by Mr. Stacey and the specimen sent by Mr. Channen. Three of the specimens, Vll.E.425, Vll.E.438 and Vll.E.603, were sectioned in areas that contained solder.

(1) Copper Specimens

In the "as-polished" condition the specimen of native copper supplied by Mr. Stacey shows a clean and homogeneous structure in massive copper areas. In less sound areas, however, the structure appears, as shown in Figure 7, to be a network of copper bordered, in general, by a fringe which appears light blue under the microscope using unfiltered incident light and which probably consists of cuprous oxide. This network surrounds areas of gangue and other unidentified material appearing black in the photomicrograph.

Etching the specimen with dilute alcoholic ferric chloride reveals a homogeneous microstructure (Figures 8 and 9) which consists of very large grains (average diameter 0.2 mm as shown in Table 2). However, the grain size varies appreciably from one area to another, going from 0.015 mm to 1.8 mm. In most cases the grain boundaries are well defined, but some grains (Figure 9) show evidence of grain boundary migration, a phenomenon which has been noticed by other investigators in the microstructure of native copper. A few grains also show annealing twins, which indicates that the specimen was annealed after being strained, or strained at an elevated temperature. Since this phenomenon is dependent on both time and temperature, it should be remembered that the time factor is that of

geological age, and hence is very long indeed, when compared with technological processes. This grain boundary migration, annealing twins, etc., may occur at relatively low temperatures in consideration of this very large time factor.

The specimen supplied by Mr. E.R. Channen and numbered C54-5193 appears very much like the native copper specimen in that, in the "as-polished" condition (Figure 10), no compound or structure can be seen even at the relatively high magnification of 500 times. The specimen is coated with a layer of cuprous oxide, seen on the upper surface of the specimen in Figure 10.

In the etched condition (Figure 11) the microstructure appears as fully recrystallized, with numerous annealing twins which have originated during the annealing of the previously strained specimen or during straining at an elevated temperature. Grain boundaries are sharp and straight, which suggests that recrystallization took place at a higher temperature than the previously described native copper specimen. The grain size varies from about 0.050 to 0.12 mm.

All the "copper" specimens sent by the National Museum of Canada have basically the same structure. In the "as-polished" condition they all show abundant cuprous oxide particles of different sizes and orientations in different specimens (Figures 12, 14, 16, 18, 20 and 22).

The oxide particles are randomly distributed and relatively small in specimens #406 (Figure 12) and #438 (Figure 20). In specimens #425 (Figure 14), #430 (Figure 16) and #436 (Figure 18), the oxide particles are large and elongated; in specimen #430 (Figure 16) the particles tend to be lined up. Many oxide particles of specimen #436 (Figure 18) are cracked in several places. Specimens #406 and #438 are sound, whereas specimens #425, #430 and #436 contain numerous voids, which may be pores or, less likely, holes left by a compound that was removed during the polishing operation. In specimen #603, oxide particles are small (Figure 22) and concentrated in the middle part of the copper section (Figures 24 and 25).

In the etched condition all specimens show a fully recrystallized microstructure -- they are represented in Figures 13, 15, 17, 19, 21 and 23. Grain size varies from specimen to specimen, as shown in Table 2. Copper oxide particles have been removed by the etching solution to leave holes. In specimen #425 (Figure 15), dark striations are seen that run in the same direction as the long axis of the elongated copper oxide particles. Several attempts to remove these striations were unsuccessful, and it is presumed that they represent traces of segregation.

Figures 24 and 25 show not only that copper oxide particles are concentrated in the middle of specimen #603, but also that those areas that are depleted in oxide

particles contain fine cracks. Some of these are full of a compound (Figure 26) which has the same appearance as cuprous oxide. It was also noticed (Figure 22) that the areas that are low in oxide particles contain, also, numerous holes, together with cracks.

The significance of these various observations, as well as of those in the following sections, is examined in detail in the Discussion.

## (2) Solder Specimens

Figures 26 and 27 are from the same field, taken partly in the copper-base metal and partly in the solder of specimen VII.E.603. These two photomicrographs were given different printing times to reveal all the compounds shown in this section. Figure 26 was under-printed to show the constituent seen in the cracks, and also the dark, textured particles in the solder material that have the appearance of lead particles. In Figure 27, which was over-printed, the copper oxide and lead particles are black and a eutectic (or eutectoid) compound is seen in the solder. Figure 27 shows that the solder and copper joined excellently but that there is no intermetallic layer between them. Instead, a narrow diffusion zone is apparent.

Additional photomicrographs of the solder found in specimen VII.E.603 are presented in Figure 28 (in the "as-polished" condition) and Figures 29 and 30 (in the

etched condition). Figure 28, like Figure 26, indicates the presence of a phase that is probably lead and occupies from 10 to 15% of the area studied. Etching in alcoholic  $\text{FeCl}_3$  pitted out the lead phase but revealed an intermetallic phase (Figures 29 and 30) which appears similar to the delta eutectoid of bronzes. Strain lines seen in certain grains present evidence of cold working.

The solder found in specimen VII.E.425 appears as shown in Figures 31, 32 and 33. Figure 31 shows that in the copper areas adjacent to the solder the oxide particles were unaffected. Also, in contrast to specimen VII.E.603, an alloy layer is seen at the copper-solder interface. Figures 32 and 33 show the general distribution and the details of the various phases present in the microstructure. Figure 32 indicates that the alloy consists of two main phases (white and grey, in the as-polished condition) which exist in approximately equal amounts, and a very fine and hard phase which polished in relief and is equally distributed in the other phases. Figure 33 indicates that the white phase of Figure 32 is a structureless grey constituent after etching, whereas the other main phase varies from white to dark grey, depending on the orientation of the crystal to the surface. This latter phase has a textured surface similar to that of lead or a very fine eutectic. In other parts of this solder specimen, small pieces of copper are completely surrounded by solder. The small hard crystals in this solder have a

habit similar to that of crystals of copper-containing, tin-antimony bearing alloys, and in general the structure is more typical of common lead-tin solders than is the structure of specimen #603.

The microstructure of the solder found on specimen VII.E.438 is shown in Figures 34 and 35. Etching does not stain the background as it did in specimen VII.E.425. The phase that appears white before etching remains white after etching. The dark phase, which occupies approximately 50 per cent of the area studied, was pitted out. A third phase is apparent, mainly in the white areas, and is harder than the other phases as it has polished in relief; this phase may correspond to the hard phase in specimen VII.E.425.

### (3) Additional Specimens

As mentioned earlier, three specimens were added to the previously studied ones in order to obtain a broader picture of the "coppers" found on the West Coast.

A metallographic examination of these specimens revealed that their structure is similar to those described earlier. The microstructure consists of copper oxide particles of different sizes and shapes in a copper matrix and, consequently, it was felt that a comprehensive study on these additional specimens was not necessary.



## Hardness Measurements

### (1) Copper Specimens

As the copper specimens supplied by the National Museum were very small, their hardness was determined on a Vickers diamond pyramid hardness tester. The results so obtained were later converted into Rockwell F hardness values, and the original and converted values are reported in Table 2. Although the limitations of hardness conversions from one scale to another are well known, it is thought that Rockwell F values would be more useful in establishing comparisons with ASTM specifications. The last column of Table 2 gives the equivalent temper conditions of each specimen as determined from Standard Specification for Copper Sheet, Strip, Plate and Rolled Bar, ASTM Designation: B152-55. This is used only to give an indication of the amount of cold work in the various specimens.

It is seen that the native copper specimen and the specimen sent by Mr. Channen are soft enough to be in the soft-anneal or, less likely, in a condition equivalent to a light cold-rolled temper. All the others have hardness values corresponding to the light cold-rolled to the spring temper conditions. This indicates that all the specimens supplied by the National Museum were cold-worked to a certain extent after being annealed (or that they contain relatively large amounts of soluble impurities that would increase

their hardness in the fully annealed condition).

Since there appeared to be a diffusion zone at the copper-solder interface of specimen VII.E.603, a hardness survey was carried out in the copper specimen from approximately  $\frac{1}{2}$  mm from the interface towards the solder. Four series of fifteen hardness determinations were made and did not show any consistent variation as the interface was approached.

(2) Solder Specimens

A similar survey was attempted in the solder of specimen VII.E.603 but results were too inconsistent to reveal any trend. However, the relative hardness of the various compounds can be appreciated from the following results. The diamond pyramid hardness number of the phase thought to be lead in Figures 26 and 28 is approximately 30, that of the matrix is approximately 140, and that of the eutectoid compound is approximately 350.

An attempt was made to measure the hardness of the other two solder specimens: VII.E.425 and VII.E.438. It was not possible to determine the hardness of the various constituents as the impressions were too large even with a 10-g load, the general hardness being in both cases less than 5 DPH.

## Spectrographic Analysis

### (1) Copper Specimens

Pieces of tough pitch copper, oxygen-free high-conductivity copper, the native copper specimen supplied by Mr. Stacey, the specimen sent by Mr. Channen, and the first six National Museum "coppers" listed in Table 2, were all analysed by the Mines Branch Spectrographic Laboratory and the results were reported to the Physical Metallurgy Division in Report No. SL-62-106.\* Unfortunately, it is not possible to detect any systematic trends or differences between the samples so analysed. This may be due to the very small samples used or to the absence of suitable metal standards. Two specimens, V11.E.425 and V11.E.603, show higher lead and tin contents than do the other specimens but this may come from contamination of the copper with solder that was present on the copper surface. However, in spite of certain inconsistencies, these results show that all the specimens investigated are reasonably pure copper.

### (2) Solder Specimens

Specimens were taken from the solder found on "coppers" V11.E.425, V11.E.438 and V11.E.603, for analysis by the Mines Branch Spectrographic Laboratory. Results are reported in SL-62-106.

---

\*Issued May 14, 1962.

their hardness. Solder specimens from "coppers" VII.E.425 and

VII.E.438 are lead-tin solders containing around 60% lead,

with copper and iron as impurities. It is then possible  
copper-solder interface of specimen VII.E.603, a hardness

survey was carried out in the copper specimen from approx-  
particles of intermetallic compound involving these two  
mainly came from the interface towards the solder. Four

impurity elements. This alloy has a liquidus temperature  
series of fifteen hardness determinations were made and  
in the vicinity of 250°C (480°F).

did not show any consistent variation as the interface was

approached. The composition of solder from specimen VII.E.603

is quite different from that of the other ones, as it

(Copper Solder Specimens)

consists of approximately 70% copper, 15% lead, 10% tin,

and 5% zinc, with some iron. Although some copper contami-

nation may come from the copper specimen from which the

solder was recovered, it is interesting to note that the

liquidus of such an alloy would be about 975°C (1785°F),

which is only 100°C below the melting point of the copper.

Also, these results help in interpreting the microstructure

of the alloy, since lead will come out as lead globules, as

shown in Figure 28. The intermetallic phase of Figures 29

and 30 is probably the delta eutectoid of the copper-tin

An attempt was made to measure the hardness of the

system. Thus, this "solder" is in fact a bronze.

other two solder specimens: VII.E.425 and VII.E.438. It

Special Tests to determine the hardness of the various

constituents as the impression size was large even with a

A number of experiments were carried out in an

attempt to elucidate or synthesize observed structures.

(1) Melting

A small specimen cut from the piece of native copper supplied by Mr. Stacey, and containing both copper oxide and gangue, was melted in a crucible under a borax cover to exclude air from the operation. This was kept at 1200°C for  $\frac{1}{2}$  hour and furnace-cooled. In Figure 36 is shown a section of the button so obtained, in which an excess of oxygen presumably coming from the oxidized areas in the native copper caused the presence of large cuprous oxide particles. It is therefore conceivable that native copper containing a smaller amount of oxide would yield, upon melting and hammering, a structure that would be quite close to those found in the Museum's specimens.

(2) Forging

Two other specimens from the same native copper piece were covered with graphite to exclude or limit air reaction and heated at 850°C for twenty-four hours. One specimen was pulled out after this treatment and examined. The other specimen was forged flat, being returned to the furnace and repacked in graphite for reannealing when it became too hard to forge easily. This specimen was also examined metallographically.

These heated and heated-and-forged specimens were found to have essentially the same microstructure. The

bulk of the specimens present no structure at all in the "as-polished" condition, whereas the oxide-containing areas show a fine precipitate associated with the large oxide inclusions (Figure 37). These large copper oxide inclusions came from the original native copper specimens from which the rocky material or gangue broke away during forging. Although, in general, the fine precipitate is dispersed at random in the zone adjacent to oxide pools, it is occasionally lined up in stringers that appear to correspond to grain boundaries, as shown in Figure 37. It is thought that the heat treatment at 850°C for 24 hours dissolved some oxide which later precipitated at a lower temperature, and it is apparent that this type of oxide distribution is quite different from that observed in the Indian "coppers".

Another forging test was carried out on a specimen of oxygen-free high-conductivity copper after heating for  $\frac{1}{2}$  hour at 850°C in air. The specimen was hot-hammered flat and folded several times in an attempt to introduce oxide particles into an originally oxide-free structure, the specimen being returned to the furnace and reheated when it became too hard to deform easily. Another specimen was kept in the furnace during this forging operation, again for comparison purposes. When this latter specimen was examined under the microscope, its structure did not contain any oxide except for a thin oxide layer formed on the surface of the specimen. The forged specimen contains layers of oxide,

as shown in Figure 38. This oxide was formed during heating at high temperature; when the flattened specimen was folded and hammered, this oxide layer was trapped in the otherwise oxide-free copper matrix. The copper oxide may appear, as shown in the bottom part of Figure 38, as a very thick and continuous stringer or, as in the upper part of the same figure, as separate but lined-up small globules. Generally speaking, however, where the oxide layer is so broken it appears as only one line of globules instead of several as in Figure 38. It is also noticed that in several places the two surfaces are perfectly welded by the hot-hammering operation, the only indication of a weld being the presence of stringers of oxide globules which can only come from the folded oxidized specimen. Again, this oxide distribution is very different from that found in the Indian "coppers".

### (3) Soldering

As the melting point of the so-called solder found on specimen VII.E.603 is relatively close to that of the base metal — an alloy of such composition would melt around 975°C (1785°F), whereas the melting point of copper is 1083°C (1980°F) — it is unlikely that such a material was used for joining copper. Consequently, solder tests were carried out on copper, using tin and an alloy containing 70% tin and 30% lead as joining materials. After soldering in the usual manner, the specimens were held for 24 hours at 600°C (1110°F) in a reducing atmosphere.

The "as-soldered" specimens showed a thin layer of delta phase at the copper-solder interface, with lead in the tin-lead solder forming a eutectic phase with tin. In the specimens held for 24 hours at 600°C, however, the structure was quite different. The solder has been replaced by a structure consisting of copper and large quantities of the delta copper-tin eutectoid, with lead globules distributed throughout. It is apparent that solution or diffusion of copper in the tin has occurred, to form a bronze. These structures are sufficiently similar to that found in specimen Vll.E.603 to suggest that such results might have been obtained with similar methods.

#### DISCUSSION

The previous sections of the report have outlined the various tests made on the Indian "coppers" that were supplied by the National Museum of Canada for a determination of whether the material used was of native origin. For comparison, a native copper nugget, along with an Indian piece thought to be of native copper, was included in this examination. Metallographic examination showed that both of these comparison pieces had a similar structure, the copper matrix being substantially free of oxide. However, all the West Coast Indian pieces, irrespective of original location, were essentially different from the comparison pieces in that they contained substantial amounts of copper oxide distributed through their structure and could thus be classified as tough pitch copper.



The presence and distribution of the copper oxide particles suggest (in agreement with Hofman<sup>(1)</sup> and Kroll<sup>(2)</sup>) that the objects had been made from cast copper that had subsequently been worked down into sheet form. While a few authors<sup>(3, 4)</sup> claim that the North American Indian knew how to melt and cast copper, the majority<sup>(5-14)</sup> have felt that this was not one of his attainments. It is concluded, therefore, that in this case the copper from which the West Coast Indian made his pieces was manufactured by Europeans or white Americans, and was not hand-beaten from nuggets of native copper. In support of this, the surfaces of many of the plaques are relatively smooth and free from the marks of beating, and the thickness of many of the plaques is remarkably uniform, the variation being less than 0.01 inch over large areas. Both of these observations suggest that the copper was rolled or stamped by machine rather than hand-beaten.

The methods used to join the pieces to form composite plaques are of interest. The rivets used in specimen V11.E.603, for example, are remarkably uniform and well-formed, and again indicate machine fabrication. Wilson<sup>(15)</sup> suggests that the Indian was unaware of soldering methods, and that the joints on specimens V11.E.425 and V11.E.438 therefore indicate white contact. The joint on specimen V11.E.603 is most unusual, in that the joining material is bronze; with such a material, in order to obtain a good

bond, adequate fluxing or other measures would have to be taken to prevent oxidation. In addition, as the melting point of the bronze is only 100°C below that of the copper being joined, careful technique would be required to prevent overheating, resulting in the melting of the copper. The presence of a deoxidized zone at the surface of this specimen, and the cracks in this zone, both suggest that it was heated in a reducing atmosphere containing substantial quantities of hydrogen. All these factors indicate a sophistication of technique unlikely in the West Coast Indian and, indeed, in all but highly skilled white craftsmen. Additional soldering tests carried out in this investigation indicate that a similar type of structure can be obtained by overheating a normal soldering joint for an appreciable time in a reducing atmosphere. From a consideration of all the factors, it is believed that this was the cause of the observed structures.

Finally, attempts were made to duplicate the structures observed in the Indian "coppers", which are essentially those of cast tough pitch copper subsequently broken down by hot working, or cold working and annealing, followed in certain cases by further small amounts of cold work. Working on the assumption that the Indian did not know how to melt and cast copper, forging experiments were carried out on both native and oxygen-free copper. While it was possible to introduce oxides into the copper

matrix without melting (in contrast to McLeod<sup>(16)</sup>), the distribution was such that they in no way duplicated the structure of the Indian "coppers". It was considered that these structures could be duplicated, without melting, by similar forging operations, but the treatments would be so complex, and so far from the primary requirement of forming a sheet from a lump, that they cannot be seriously considered as possible fabrication methods. A cast structure containing well-formed oxide particles was obtained by melting parts of the nugget of native copper, even under reducing conditions such as may exist at the heart of a wood fire. However, as mentioned, the Indians were thought to be unfamiliar with the art of melting and casting, whereas the size and uniformity of some of the 'coppers' suggest a refined casting and fabrication technique.

Because of the nature of the samples, and the lack of appropriate standards, spectrographic analysis could give no information as to the origin of the samples other than to indicate that all were substantially pure copper and that there was no deliberate alloying.

Thus, while it is not impossible that the West Coast "coppers" were made by the Indian from native copper, the great weight of evidence suggests that all the material examined was of white manufacture, and that it had subsequently been fabricated by the Indian (possibly with white assistance, in the case of the soldered joints) into the final characteristic shapes.

### CONCLUSIONS

It is believed that the specimens of "coppers" that were supplied by the National Museum of Canada are of European or white American origin, for two main reasons:

1. The presence and distribution of copper oxide particles found in the microstructure almost certainly indicate that the copper was melted, and it is generally believed that the North American Indians did not know how to melt copper.
2. The surface and thickness of the largest plaques are too even to have been produced with crude tools.

It must be concluded, therefore, that the copper plates from which these "coppers" were cut were originally fabricated by Europeans or white North Americans, who had the equipment necessary to produce such sheets.

REFERENCES

1. H.O. Hofman - "Metallurgy of Copper" - 2nd Ed., McGraw-Hill (New York), 1924.
2. W.S. Kroll - "Report on the Composition of Indian Beads Found at the McNary Dam, Oregon" - River Basin Surveys Papers No. 8, Bur. American Ethnology, Bull. 166, 227-231 (1957).
3. F.S. Perkins - "Fabrication of Ancient Copper Implements" - Wisconsin Hist. Collections 8, 168 (1908).
4. E.F. Slafter - "Prehistoric Copper Implements" - Wisconsin Hist. Collections 8, 152-164 (1908).
5. P. Bergsoe - "The Gilding Process and the Metallurgy of Copper and Lead Among the Pre-Columbian Indians" - transl. from the Danish by C.F. Reynolds, Danmarks Naturvidenskabelige Samfund, Copenhagen, 12-20 (1938).
6. "First Use of Copper" - Mineralogist 14, p. 58 (1946).
7. P.R. Hoy - "Fabrication of Ancient Copper Implements" - Wisconsin Hist. Collections 8, 169-173 (1908).
8. E. Lilly - "The Use of Copper by the American Aborigines" - Proc. Indiana Academy of Sciences 46, 53-56 (1936).
9. "Metallic Implements of the New York Indians" - New York State Museum, Bull. 55 (1901).
10. G.B. Phillips - "The Primitive Copper Industry of America" - J. Inst. Metals 34, 261-270 (1925).
11. G.B. Phillips - "The Primitive Copper Industry of America. Part 2" - J. Inst. Metals 36, 99-106 (1926).
12. T.A. Rickard - "A History of American Mining, Chapter X - The Copper of Lake Superior" - McGraw-Hill Book Co. (New York), 1932, pp. 222-248.
13. R.T. Rolfe - "The Story of Early Metallurgy - II: The Use of Native Metals" - Met. Ind. (London) 32, 321-322, 369-370 (1928).

14. C. Whittlesey - "Fabrication of Ancient Copper Implements" - Wisconsin Hist. Collections 8, 169 (1908).
15. D. Wilson - "The Ancient Miners of Lake Superior" - The Canadian Journal 1(3), 225-237 (1856).
16. B.H. McLeod - "Examination of Copper Artifacts from the McNary Site, Oregon" - River Basin Surveys Papers No. 8, Bur. American Ethnology, Bull. 166, 232-234 (1957).

= =

AC: JOE: (PES) ls

TABLE 1

Sources and Recovery Dates of Plaques Studied

Specimen Identification	Source	Recovery Date
V11.D.406	Bella Coola, B.C.	1923
V11.E.425	Alert Bay, B.C.	1922
V11.E.430	" " "	"
V11.E.436	" " "	"
V11.E.438	" " "	"
V11.E.603	" " "	"
V11.B.274	Graham Island, Queen Charlotte Islands, B.C.	1895-1901
V11.C.362	Metlakatla, B.C.	1911
V11.E.345	Blunden Harbour, Vancouver Island, B.C.	1885

TABLE 2  
Grain Size and Hardness Results

Specimen Identification	Grain size, (Average grain diam.) mm	Hardness		Equivalent Temper Condition in B152-55
		Measured DPH Number	Converted to Rockwell "F" scale (x)	
Native copper	0.200	56	59	( Soft anneal Light cold-rolled
C54-5193	0.050-0.120	51	53	( Soft anneal Light cold-rolled
VII D - 406	0.035	82	80	( Light cold-rolled Half hard
VII E - 425	0.050	83	81	( Light cold-rolled Half hard
430	0.025	97	88	( Half hard Hard
436	0.025	88	83	Half hard
438	0.050	96	87	( Half hard Hard
603	0.025	104	91	( Hard Spring

(x) The weakness of converting hardness results from one scale to another is well known. However, the converted values can be used to estimate the equivalent temper conditions of the specimen.



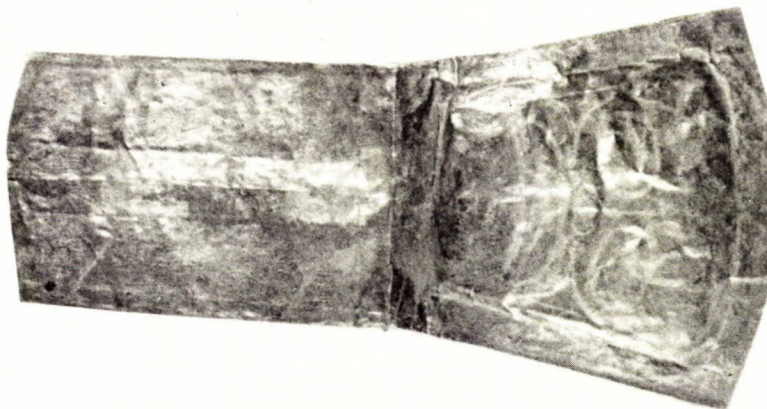


Figure 1. Specimen: V11.D.406  
Size:  $24\frac{1}{2}$  in. by  $13\frac{1}{2}$  in.  
Thickness: 0.017 in. to 0.025 in.  
Weight: 1 lb 12 oz



Figure 2. Specimen: V11.E.425  
Size:  $10\frac{1}{2}$  in. by  $8\frac{1}{4}$  in.  
Thickness: 0.037 in. to 0.048 in.  
Weight: 13 oz

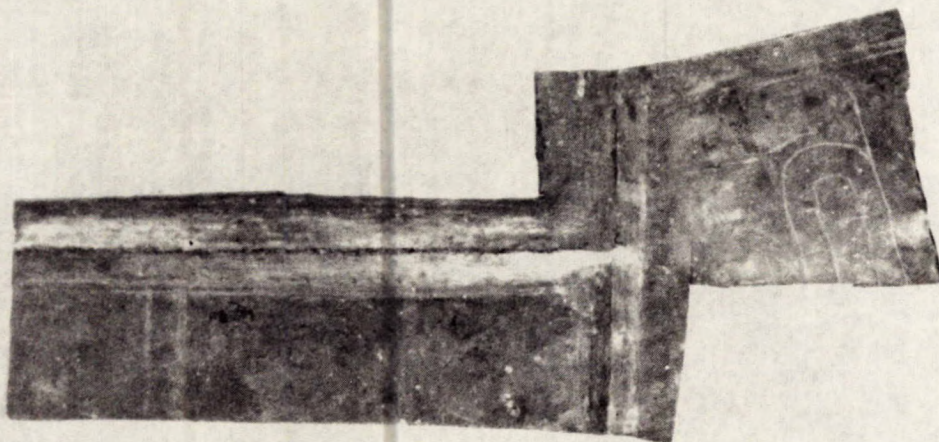


Figure 3. Specimen: V11.E.430  
Size: 21 in. by 10 $\frac{1}{4}$  in.  
Thickness: 0.063 in. to 0.068 in.  
Weight: 2 lb 11 oz

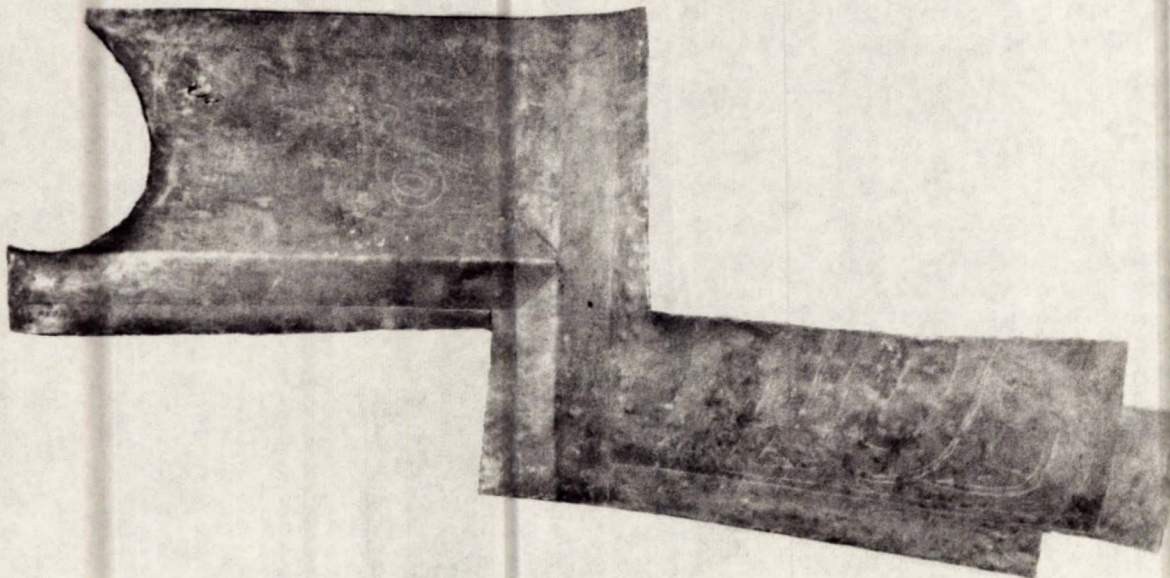


Figure 4. Specimen: V11.E.436  
Size: 47 in. by 20 in.  
Thickness: 0.174 in. to 0.207 in.  
Weight: 29 lb 4 oz



Figure 5. Specimen: V11.E.438  
Size:  $12\frac{1}{4}$  in. by  $4\frac{1}{4}$  in.  
Thickness: Not measured  
Weight: 12 oz

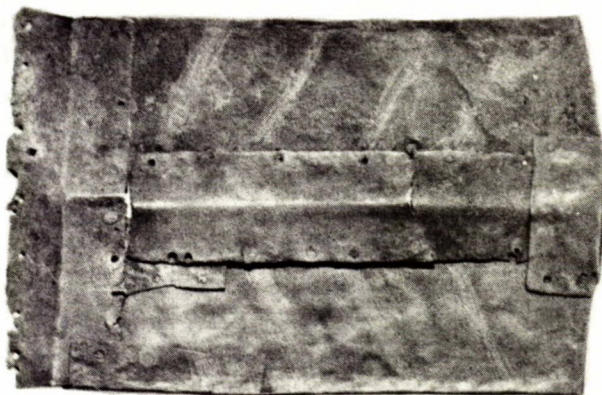


Figure 6. Specimen: V11.E.603  
Size:  $12\frac{1}{4}$  in. by 8 in.  
Thickness of right panel: 0.024 in. to  
0.025 in.  
Weight: 1 lb 10 oz



Figure 7 X250  
Native copper specimen.  
As-polished. The white  
areas (copper) are  
surrounded by a grey  
(light blue under the  
microscope) layer,  
probably cuprous oxide.  
The metallic network  
contains a rocky  
substance (dark areas).



Figure 8 X250  
Same specimen as in  
Figure 7. Etched for  
2 sec in alcoholic  
 $\text{FeCl}_3$ . Homogeneous  
solid solution showing  
a few annealing twins.  
Large grains (0.2 mm).

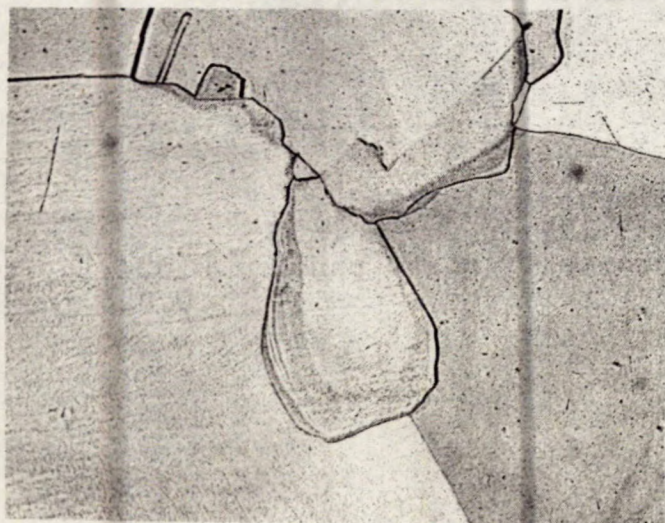


Figure 9 X250  
Same specimen and con-  
dition as in Figure 8.  
This area shows grain  
boundary migration.

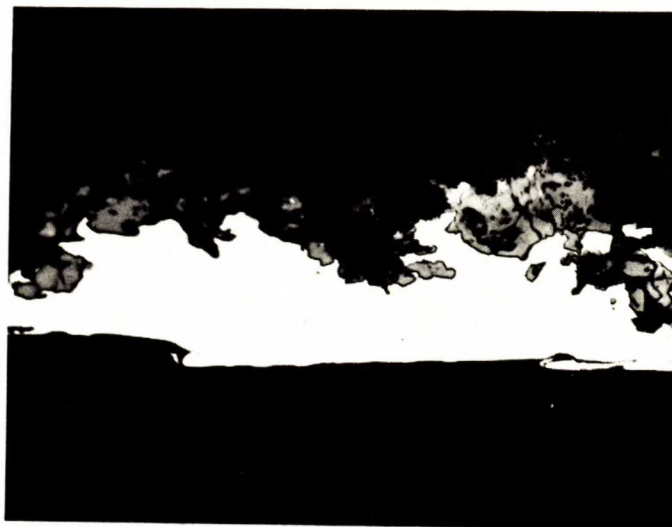


Figure 10 X500  
Specimen: C54-5193. As-polished.  
Probably pure copper specimen coated  
with cuprous oxide (upper part of  
specimen). No oxide particle in  
underlying copper.



Figure 11. X250  
Other section of same specimen  
as in Figure 10. Etched for 2 sec  
in alcoholic  $\text{FeCl}_3$ . Recrystallized  
microstructure showing numerous  
annealing twins. Grain size varies  
from 0.05 to 0.12 mm.



Figure 12 X250  
Specimen: V11.D.406. As-polished.  
Small cuprous oxide particles  
randomly distributed in a copper  
solid solution matrix.



Figure 13 X250  
Same specimen as in Figure 12.  
Etched in alcoholic  $\text{FeCl}_3$ .  
Recrystallized microstructure.  
Grain size is 0.035 mm. Oxide  
particles were etched out.



Figure 14 X250  
Specimen: V11.E.425. As-polished.  
Large elongated cuprous oxide particles in  
a copper solid solution matrix. Black areas  
at the end of some particles may be voids left  
during the forming process or by an etched-  
out substance.

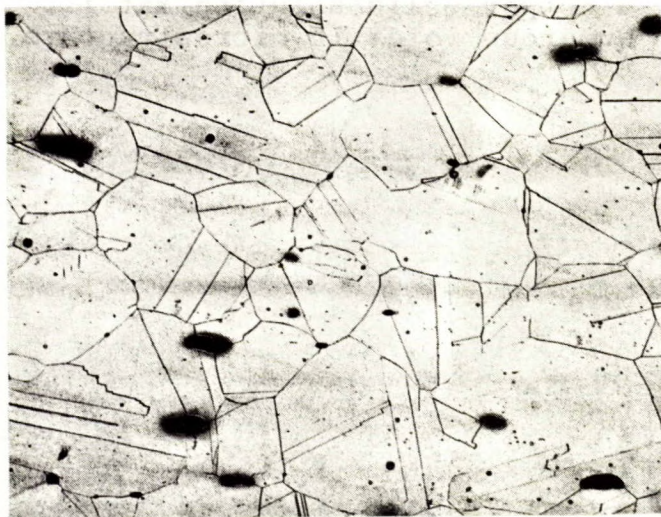


Figure 15 X250  
Same specimen as in Figure 14. Etched for  
10 sec in alcoholic  $\text{FeCl}_3$ . Recrystallized  
microstructure. Striations across several  
grains. Grain size is 0.050 mm.

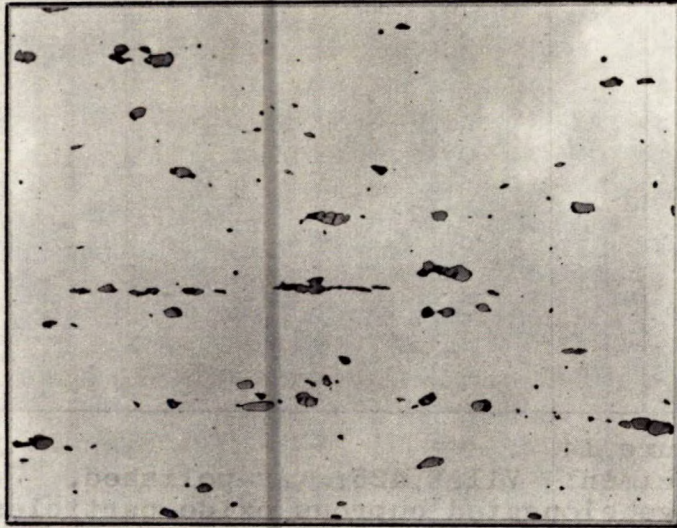


Figure 16 X250  
Specimen: V11.E.430. As-polished.  
Large elongated and occasionally  
lined-up cuprous oxide particles in  
a copper solid solution matrix.  
Numerous voids in microstructure.

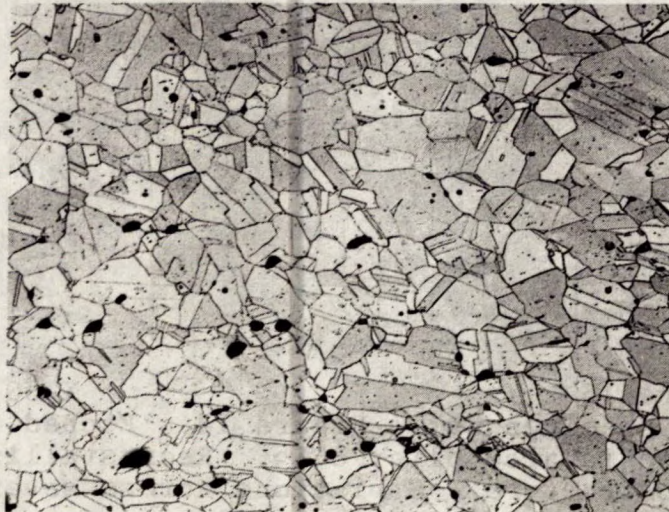


Figure 17 X250  
Same specimen as in Figure 16.  
Etched in alcoholic  $\text{FeCl}_3$ .  
Recrystallized microstructure. Grain  
size is 0.025 mm.





Figure 18 X250  
Specimen: Vll.E.436. As-polished.  
Large cracked and elongated cuprous  
oxide particles in a copper solid  
solution matrix. Numerous voids in  
microstructure.



Figure 19 X250  
Same specimen as in Figure 18.  
Etched for 2 sec in alcoholic  $\text{FeCl}_3$ .  
Recrystallized microstructure. Grain  
size is 0.025 mm.



Figure 20 X250  
Specimen: Vll.E.438. As-polished.  
Small cuprous oxide particles  
randomly distributed in a copper  
solid solution matrix. Material is  
sound.

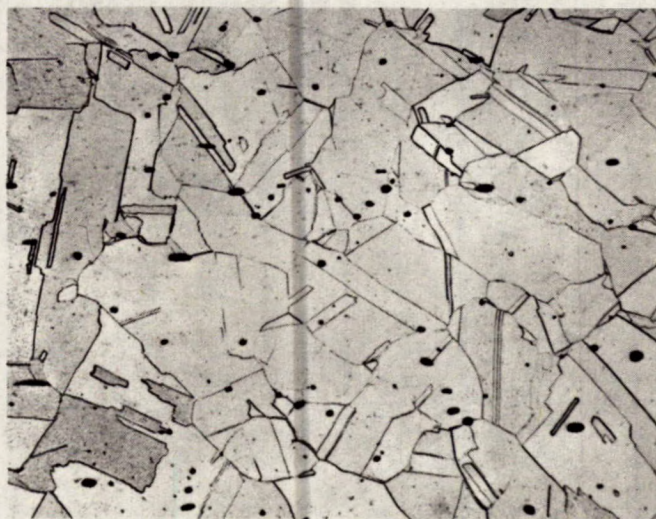


Figure 21 X250  
Same specimen as in Figure 20.  
Etched for 2 sec in alcoholic  $\text{FeCl}_3$ .  
Recrystallized microstructure. Grain  
size is 0.050 mm.



Figure 22 X250  
Specimen: V11.E.603. As-polished.  
Small cuprous oxide particles in a copper  
solid solution matrix. Voids in micro-  
structure are more numerous near the  
soldered surface (bottom) which contains  
practically no oxide.



Figure 23 X250  
Same specimen as in Figure 22.  
Etched for 2 sec in alcoholic  $\text{FeCl}_3$ .  
Recrystallized microstructure. Average  
grain size is 0.025 mm; it is apparently  
a little smaller near the soldered surface  
(lower part of figure).

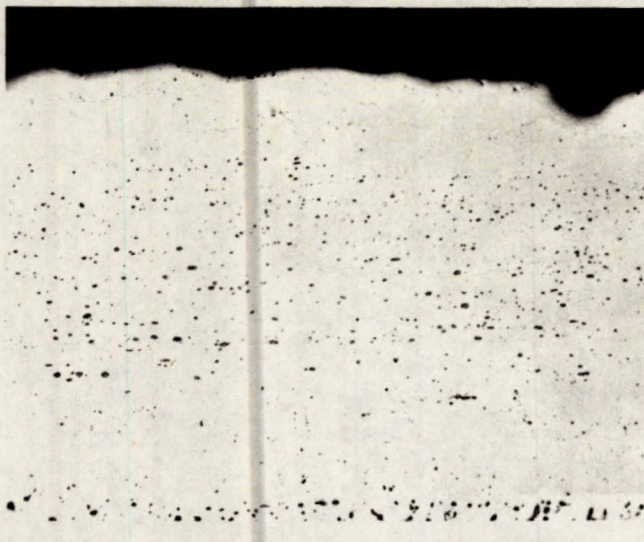


Figure 24 X100  
Specimen: Vll.E.603. As-polished.  
Cuprous oxide is concentrated in the  
neutral part of specimen and practically  
non-existent near the edges. Cracks near  
outside edge are faintly revealed. Solder  
in lower part of photomicrograph.

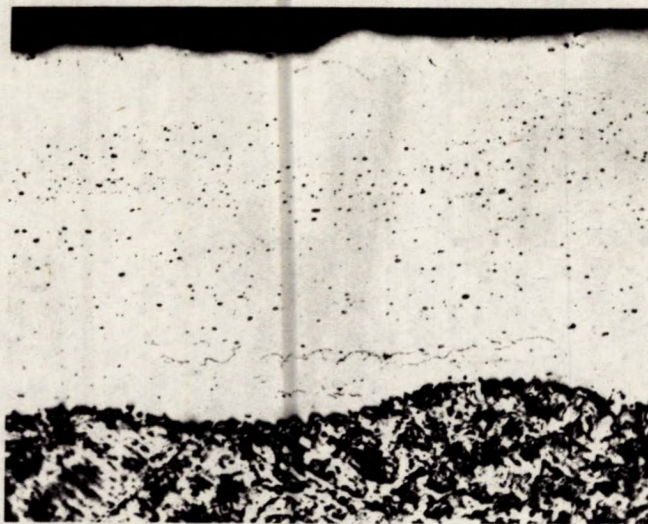


Figure 25 X100  
Same specimen as in Figure 24 but a  
different field. As-polished. Oxide  
particles are concentrated in the  
central part of specimen. Cracks are  
clearly visible near the soldered  
surface (bottom part of photomicrograph)  
of specimen.

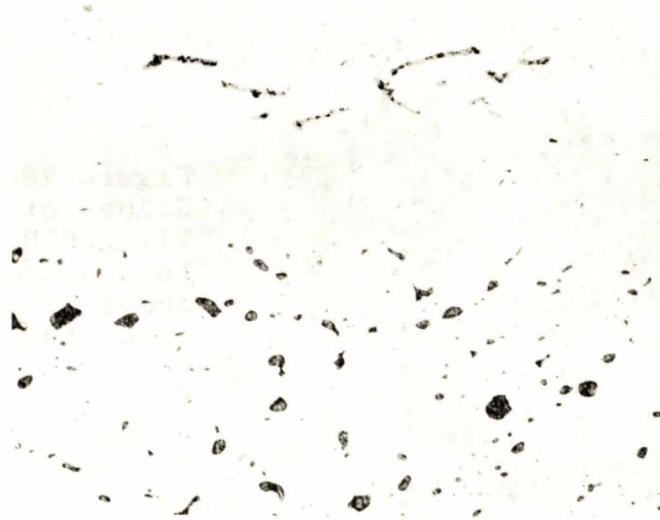


Figure 26 X250  
Specimen: Vll.E.603. As-polished.  
Upper part of photomicrograph is  
copper, lower part solder. Cracks are  
partially filled with probably cuprous  
oxide. Presence in solder of numerous  
particles that appear to be lead.

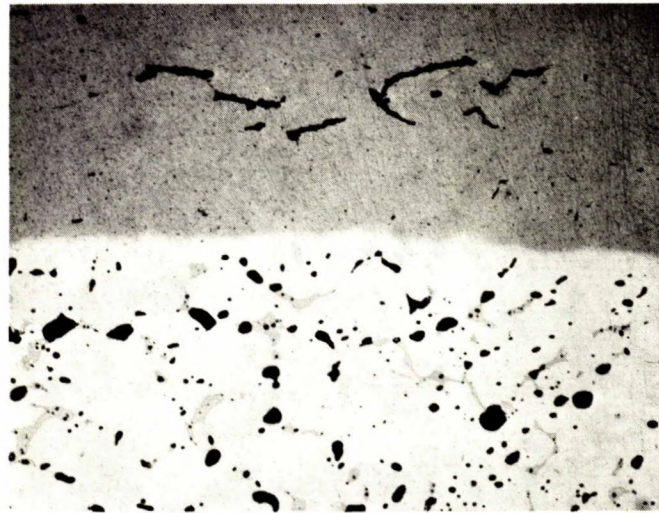


Figure 27 X250  
Same field as for Figure 26 but over-  
exposed to reveal the light grey or  
blue phase of the solder. Cuprous  
oxide and lead particles are now black.  
Note the absence of an alloy layer at  
the copper-solder interface.



Figure 28 X250  
Solder of specimen  
Vll.E.603. As-polished.  
Lead phase occupies  
about 10 to 15% of the  
area studied.



Figure 29 X250  
Same specimen as in  
Figure 28. Etched for  
2 sec in dilute alcoholic  
 $\text{FeCl}_3$ . Lead phase is  
pitted out but inter-  
metallic phase is clearly  
shown.

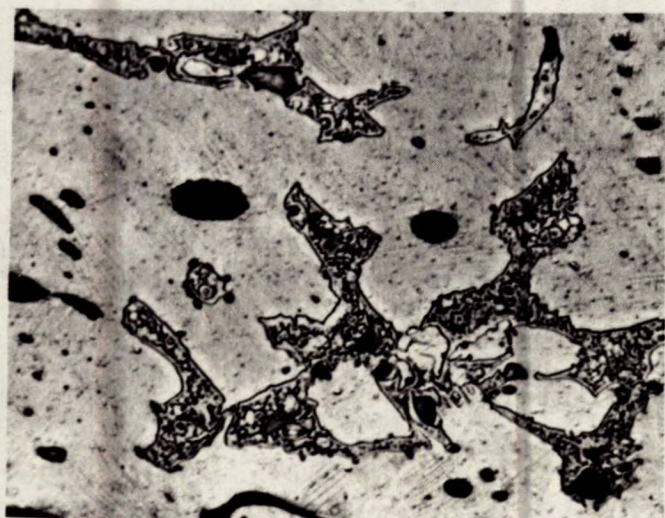


Figure 30 X1000  
Same specimen and con-  
dition as in Figure 29.  
Details of intermetallic  
phase.

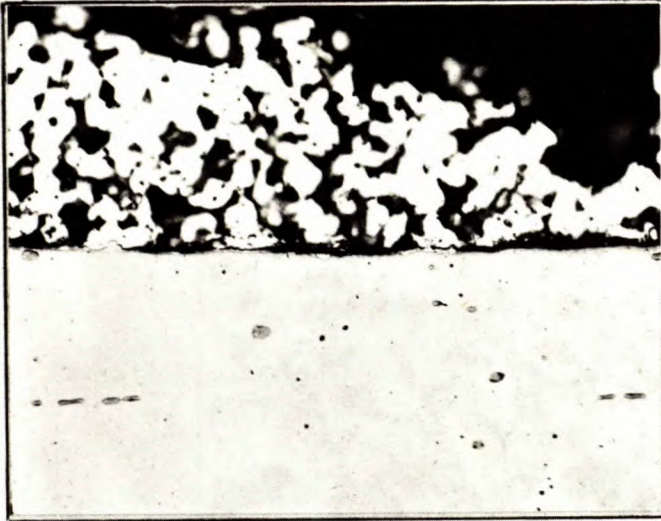


Figure 31 X250  
Specimen: V11.E.425.  
As-polished. Copper  
oxide particles near  
solder have not been  
reduced. Alloy layer  
between copper and solder  
may indicate that the  
solder is a tin-rich  
alloy.

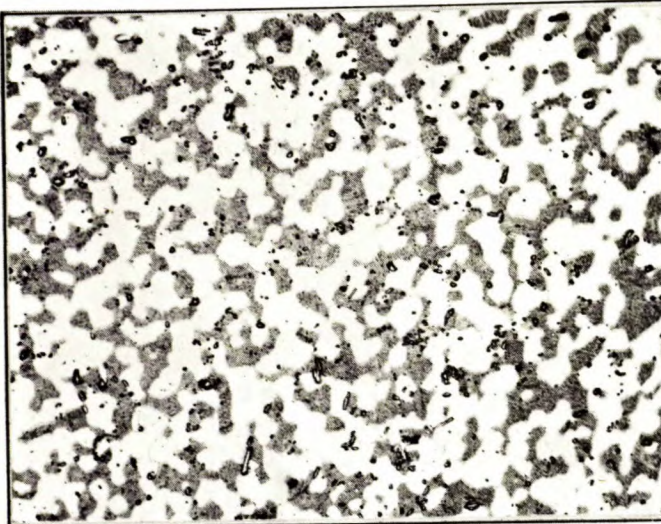


Figure 32 X250  
Solder from specimen  
V11.E.425. As-polished.  
Structure probably con-  
sists of three phases: a  
white phase (about 50%  
of the area), a grey phase,  
and a fine hard phase  
which polished in relief  
and is distributed in  
the other two phases.



Figure 33 X750  
Same specimen as in  
Figure 32. Etched in  
dilute alcoholic  $\text{FeCl}_3$ .  
The phase, which appears  
white in Figure 32, is  
revealed as a structureless  
grey constituent. Hard  
particles. Remainder con-  
sists of crystals varying  
in colour from white to  
dark grey, probably  
depending on the crystal  
orientation.

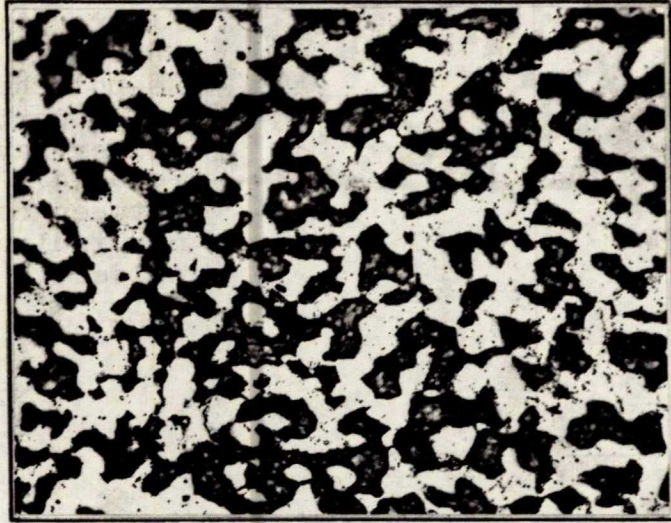


Figure 34 X250  
Solder from specimen V11.E.438.  
Etched in dilute alcoholic  $\text{FeCl}_3$ .  
White and dark phases in equal amounts.  
Also a very fine hard phase, mainly  
obvious in the white constituent.

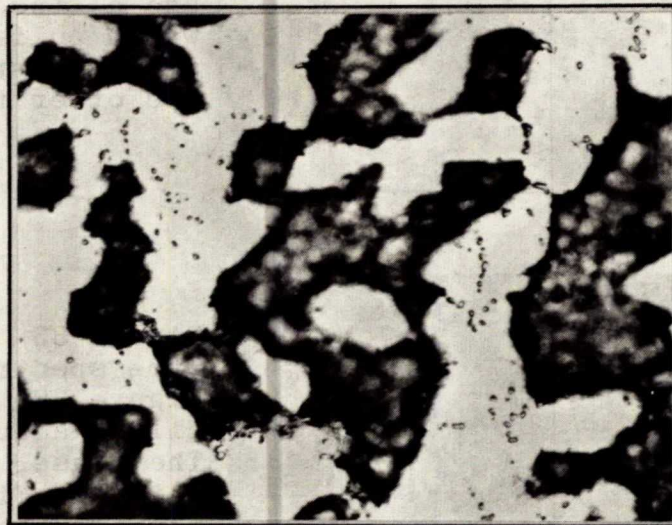


Figure 35 X750  
Same specimen and condition as in  
Figure 34. Dark phase is etched out.



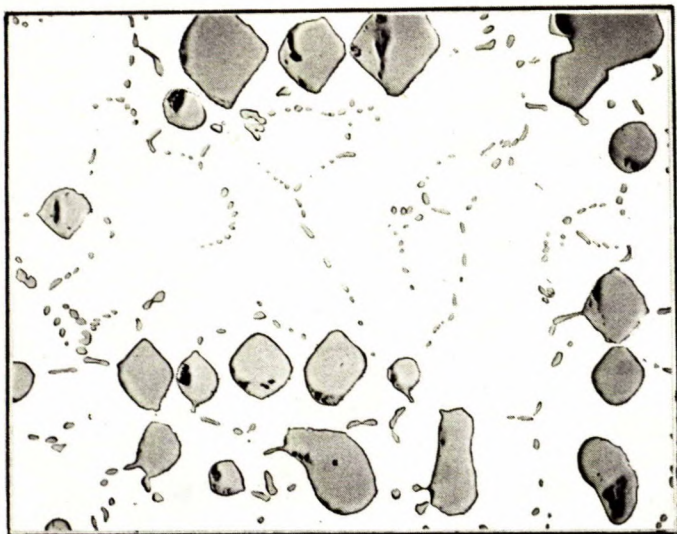


Figure 36 X250  
Specimen melted under borax cover. As-polished. Large oxide particles. Small oxide particles apparently disposed along grain boundaries.

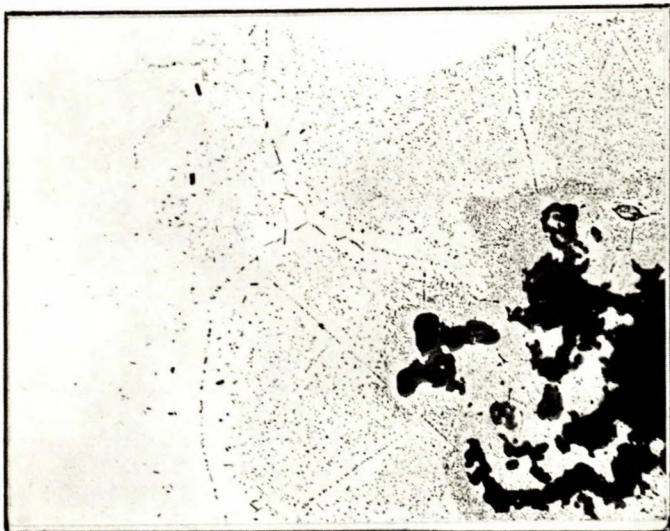


Figure 37 X250  
Forged native copper specimen. As-polished. Precipitate of fine copper oxide particles in areas adjacent to large copper oxide pools. In certain areas the precipitated particles appear to follow grain boundaries.

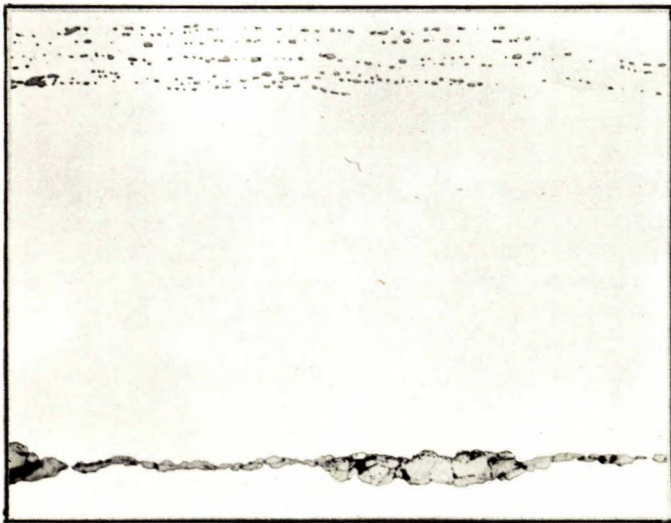


Figure 38 X250  
Forged OFHC specimen. As-polished. Oxide layers are continuous or broken up. In the latter case the oxide globules are lined-up at the joint between two surfaces. Note perfect weld between folds.