July 6, 1965

Dr. William C. Root
Department of Chemistry
Bowdoin College
Brunswick, Maine

Dear Dr. Root:

With a small grant from the National Science Foundation, we are starting a program in the combined fields of archaeology and metallurgy with the hope of learning more about the fabrication of metal artifacts and of contributing some information to the history of metallurgy. Dr. Robert Maddin, Chairman of the Department of Metallurgy at the University of Pennsylvania is the principal investigator.

We plan to have a team, or teams, of students in archaeology and in metallurgy working together on specific projects. Dr. Linton Satterthwaite suggested that you might be able to offer us helpful guidance. To get started we need to find both the appropriate graduate students and plans for projects.

I have enclosed a copy of our A.S.C.A. Newsletter in which some of our other activities are described.

Sincerely yours,

Elizabeth K. Ralph

EKR/mr

July 6, 1965

Dr. Dudley Easby, Jr., Secretary
Metropolitan Museum of Art
Fifth Avenue and 82nd Street
New York, New York

Dear Dr. Easby:

With a small grant from the National Science Foundation, we are starting a program in the combined fields of archaeology and metallurgy with the hope of learning more about the fabrication of metal artifacts and of contributing some information to the history of metallurgy. Dr. Robert Maddin, Chairman of the Department of Metallurgy at the University of Pennsylvania is the principal investigator.

We plan to have a team, or teams, of students in archaeology and in metallurgy working together on specific projects. Dr. Linton Satterthwaite suggested that you might be able to offer us helpful guidance. To get started we need to find both the appropriate graduate students and plans for projects. If you happen to come to Philadelphia, I hope that you will have time to discuss these matters with me. If not, I shall be glad to come to New York.

May I trouble you also for a copy of your reprint entitled "Pre-Hispanic Metallurgy and Metalworking in the New World," Proceedings of the American Philosophical Society, Vol. 109, No. 2 (April, 1965)?

I have enclosed a copy of our A.S.C.A. Newsletter in which some of our other activities are described.

Sincerely yours,

Elizabeth K. Ralph

EKR/mr

July 7, 1965

Dr. George Bass
c/o American Consulate
Izmir, Turkey

Dear George:

The metallurgical proposal which we wrote two years ago has now bwwn awarded by the NSF. We plan to start with teams of students in archaeology and in metallurgy working together on specific projects which will contribute information about certain artifacts and their fabrication and/or to the history of metallurgy.

If you expect to have a student in the fall who would be interested in this program or if you have some specific problems in mind, could you please send me this information as soon as possible. There are funds available for part-time student support, if needed.

Anne may have written to you about my questions in regard to your present NSF grant. These came about because Dr. Rainey instructed me to try to get a comprehensive grant from the NSF which would include both A.S.C.A. and Underwater Archaeology. The problem was not to conflict with your present grant. I don't think that there is much hope for the comprehensive grant, but I guess it is worth the effort.

I hope that your experiments are going well.

With best regards,

Beth Ralph

EKR/mr

~~July 7, 1965~~

~~Dr. Robert Dyson~~
~~Harvard University~~

July 7, 1965

Dr. Robert Dyson
Adams House
Harvard University
Cambridge 38
Massachusetts

Dear Bob:

After consultation with Dr. Maddin, we hope to get our metallurgical grant started with teams of graduate students (archaeologist and metallurgist in each) with archaeologist to present the problem, look up related references, make sure that it is carried out in such a way to give useful information, and metallurgist to do the experimental work. Then, together they write a report, pronto.

Do you expect to have a student who would be interested and do you have time to outline your spear head problem in specific terms? There are funds for part-time student support.

With best regards,

Beth Ralph

EKR/mr

July 7, 1965

Dr. C. C. Lamberg-Karlovsky
Department of Anthropology
Franklin and Marshall College
Lancaster, Pennsylvania

Dear Dr. Lamberg-Karlovsky:

With a small grant from the National Science Foundation, we are now starting the program in the combined fields of archaeology and metallurgy which we proposed several years ago.

We plan to have a team, or teams, of students in archaeology and metallurgy working together on specific projects. Do you have any suggestions for possible graduate students who would be interested in this program? Suggestions for projects would also be appreciated.

Sincerely yours,

Elizabeth K. Ralph

EKR/mr

July 8, 1965

Mr. Major McCullough
c/o Association for Cultural Exchange
Archaeological Seminar
Oxford University
Oxford, England

Dear Mr. McCullough:

With a small grant from the National Science Foundation, we are starting a program in the combined fields of archaeology and metallurgy with the hope of learning more about the fabrication of metal artifacts and of contributing some information to the history of metallurgy. Dr. Robert Maddin, Chairman of the Department of Metallurgy at the University of Pennsylvania is the principal investigator.

Mr. Wailes has suggested that you might be interested in this program. If so, may I trouble you to let me know as soon as possible. Will you tell me too how much time you will be able to contribute and when you expect to return. There aresalary funds available, if needed. If you have ideas for specific projects associated with Near- and Mideastern archaeology, that information would also be appreciated.

Sincerely yours,

Elizabeth K. Ralph

PHYSICS DEPARTMENT

July 30, 1965

COPY

Dr. R. Maddin, Chairman
Department of Metallurgy
Room 201, LRSM

Dear Dr. Maddin:

A few specific proposals for the metallurgical-archaeological project are attached. They are as follows:

1) R. Dyson - objects from Iran
2) S. Kramer - study of the history and technology of metals and metallurgy as revealed from cuneiform documents
3) L. Alpers - a study of the glaze industry in the Ancient Near East
4) D. O'Connor - research on Egyptian metals (being sent to you directly)

Possible starting times and funds required with respect to Museum staff and students are:

1) September (none unless student is found)
2) " ($2000 per year for two years)
3) November (none during academic year, possibly summer support
4) now (none)

Sincerely yours,

Elizabeth K. Ralph

EKR:rm

THE UNIVERSITY MUSEUM
UNIVERSITY OF PENNSYLVANIA
THIRTY-THIRD AND SPRUCE STREETS
PHILADELPHIA, PENNSYLVANIA 19104
CABLE ADDRESS "ANTIQUE"
TELEPHONE: EVERGREEN 6-7400
(AREA CODE 215)

August 4, 1965
Bodrum, Turkey

Dear Beth:

I just got your letter of July 7, addressed to the American Consulate in Izmir; we were at sea before, and only this week did anyone get up to Izmir. I leave for home tomorrow, but do want to answer your question regarding the metallurgical project. I do not have any great project at this time, but one of our students, Michael Katzev (transferring from Columbia this fall) is going to make a complete study of our iron objects from the Byzantine shipwreck. He has already gone into the problems of corrosion underwater to some extent and has written a number of papers on his preliminary results, but this seems like just the thing for him to spend some time on with a student of metallurgy. Mike should be around the museum from time to time, for he has been living in our house this summer while taking a German course at the Univ.

I didn't know about the comprehensive grant proposal for NSF, and, personally, would hope that it not come through - unless this is a sacriligemous thought. Our program is so new and experimental and its needs changing so from year to year, that it would, I think only confuse the issue to try to get it under the same heading as ASCA. I should think that both projects should stand and fall on their own merits. After this summer, for examole, it may be a bit harder for me to find funds unless our luck changes after my departure. We have tried proton magnetometer (Dr. Hall was here), underwater TV (I have two EE's here), and are just starting with a towed observation capsule (the inventer was here from Australia, and the manufacuterer is here now). But we have not found ANYTHING of note. Dr. Edgerton from MIT still hopes to come with his mud-penetrating sonar, but I don't even know if that will work. The sea is, as they found when looking for the Thresher, simply too damned big ! But a way MUST be found for locating these things underwater, and we are trying. We are agreed here that side-looking sonar might be best, but only if the wreck forms a mound which sticks up above an absolutely level seabed; in this case the two wrecks m we are after do happen to be ~~onto~~ on absolutely flat, snady bottoms that vary almost not at all from 250 feet.

Best wishes,

George

George F. Bass

RSY — metal from Gordion

UNIVERSITY INTRAMURAL CORRESPONDENCE

TO: Professor James B. Pritchard, Curator
Biblical Archaeology, The University Museum

FROM: Dr. Robert Maddin, Director
School of Metallurgical Engineering

DATE: October 26, 1965

Dear Professor Pritchard,

We have reserved a position for Miss Ruth Matson and note that she will begin work some time in May of 1966.

The work she intends to do is most interesting and fits in well with what the other students are doing (Miss Carol Kramer and Mr. Michael Katzev). Miss Matson should be acquainted with the work of Lamberg-Karlovsky submitted for a Ph.D. degree to Dr. Dyson in 1965. At the same time, it would be interesting to see how many of each type of specimen Miss Matson can obtain. If we can examine the specimens under the metallurgical microscope, as well as examine their chemistry, we should be able to deduce something about the history of the manufacture as well as the possible source of the ore from which the metals were derived.

Robert Maddin
Robert Maddin

RM:aj

cc: Miss Elizabeth K. Ralph

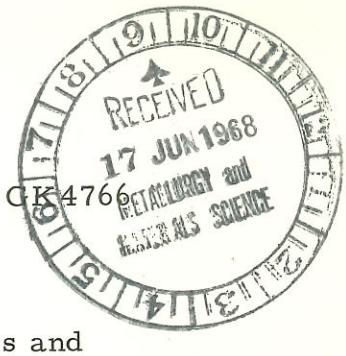
10/14/66

During the autumn semester 1965 Mr. Michael Katzev, who is a graduate student in Classical Archaeology at the Univiversity of Pennsylvania, received a National Science Foundation grant administered jointly by the Department of Metallurgical Engineering and the Allied Science Center for Archaeology at the University Museum. Mr. Katzev's project was to study some 150 concretions of iron objects, which were recovered between 1961-1964 in the course of the Museum's underwater excavations of a Byzantine shipwreck off the island of Yassi Ada, Turkey.

The experiment performed by the Department of Metallurgical Engineering was done on a concreted iron nail. A section was taken at the head of the nail, was mounted, and polished by Mr. Alfred Spitalieri. Dr. Robert Maddin analyzed this specimen through a microscope and determined that the original had decomposed into iron oxides, particularly magnetite. Mr. Henry Katz performed X-ray diffraction and fluorescence analyses of the sample. He positively identified additional iron compounds, as well as aragonite, calcite, and αSiO_2 crystals. Mr. Katzev continued his archaeological study of the identification and significance of the iron objects.

A preliminary report, including in part the finds of this study, has been accepted for publication in a forthcoming issue of Studies in Conservation.

Where did this
come from?
Hopefully, Near East



Subject: Metallurgical-Archeological Project NSF Grant GK 4766

A representative number of samples from three ages and locations were given to the Metallography Department, to be prepared for microscopic examination.

These samples were carefully sectioned to represent the entire sample; when possible the entire sample was prepared. The examination of the microstructure revealed a history of the mechanical and thermal treatment of each sample.

A micro-hardness survey of each sample was made for a correlation of the analysis.

Photomicrographs were taken of the samples, these and the micro-structure information were given to the principle investigator.

THE UNIVERSITY MUSEUM
UNIVERSITY OF PENNSYLVANIA
THIRTY-THIRD AND SPRUCE STREETS
PHILADELPHIA, PA. 19104
CABLE ADDRESS "ANTIQUE"
TELEPHONE: EVERGREEN 6-7400
(AREA CODE 215)

April 17, 1967

To: Dr. Elizabeth K. Ralph
Subject: Metallurgy Project
From: Carol Kramer

Since the most recent meeting of the personnel involved in the joint University Museum-Metallurgy Department project to investigate ancient metallurgical technologies, the following work has been done on the sample of thirty-seven artifacts from ancient Mesopotamia:

1. In November of 1966 I submitted to Dr. Robert Maddin a summary of relevant archaeological and bibliographic data for each artifact, along with the qualitative spectrographic analyses made by W.C. Coleman Company, Dr. Maddin's descriptions of the microscopic condition of each mounted sample and his interpretations.

2. The sample was submitted to Coleman for quantitative spectrographic analyses.

3. The sample has been submitted to the Metallurgy laboratory for hardness tests; I have not seen the results.

4. Twelve artifacts have been selected, and fragments sent for experimentation to Dr. Brill at the Corning Glass Works; he will forward to Dr. Dyson the results of his own quantitative spectrographic analysis.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY CAMBRIDGE 39, MASSACHUSETTS
Room 14N-321

9 July 1963

Professor Robert Maddin, Director
School of Metallurgical Engineering
University of Pennsylvania
Philadelphia 4, Pennsylvania

Dear Bob

Knowing that you are interested in the application of chemical and metallographic methods for the study of archaeological objects and works of art, I am passing on to you some information about a young lady who has recently expressed interest in doing just that. Miss Katharine Clapp, whose vita is attached, got her degree in art history but for the past three years has been working as a metallographer at the Wakefield Bearing Company. She seems to be a person of well-above average competence and, though not formally trained in metallurgy, has learned a great deal on her own initiative. She expresses a strong desire to get into the field of scientific study of museum material--a rare characteristic that should be encouraged.

If by any chance you have an opening, I think it would be worth your while to get in touch with Miss Clapp.

Yours sincerely,

Cyril Stanley Smith
Institute Professor

CSS:mk
Encl.

Name: Katharine P. Clapp

Address: 13 Shepard Street
Cambridge, Mass.
University 4-4464

Personal Data:

Age:	26	Date of Birth:	May 8, 1937
Height:	5'7"	Marital Status:	Single
Weight:	125	Social Security Number:	034-30-4671

Education:

1959-60 University of Florence, Italy.
1955-59 Vassar College. A.B. degree.
1952-55 Shipley School, Bryn Mawr, Pa.

Major Field of Study: History of Art, minors in English and Chemistry.

Work Experience:

1960-Present Metallographer, Wakefield Gearing Co. Wakefield, Mass.
Summer, 1958&59 Volunteer, Peabody Museum, Salem, Mass.
Summer, 1957&58 Laboratory Technician, Wakefield Gearing Co.

Foreign Languages: French, Italian, some German.

Travel: Summer, 1962 Travel in Mexico
Winter, 1959-60 Living in Florence, Italy, with travel to Austria, Belgium, France, England, Turkey and Greece.
Summer, 1955 Tour of Italy, France, and England.

References:

Mr. Donald G. Barnett, Vice President, Wakefield Gearing Corp. Wakefield, Mass.
Dr. J. H. Brophy, Massachusetts Institute of Technology, Cambridge, Mass.
Mr. Ernest Dodge, Director, Peabody Museum, Salem, Mass.
Vassar College Vocational Bureau, Poughkeepsie, N.Y.

UNIVERSITY of PENNSYLVANIA
PHILADELPHIA 4

The School of Metallurgical Engineering

PROFESSOR R. MADDIN, *Director*

July 29, 1963

Dr. Cyril Stanley Smith
Room 14N-321
Massachusetts Institute of Technology
Cambridge 39, Massachusetts

Dear Cyril:

The vita you sent through on Miss Katherine Clapp is most interesting. She looks like just the sort of person we would want for our laboratory directed by Miss Elizabeth Ralph. Miss Ralph, Fred Rainey and I must get together soon to discuss where we shall go to get support. Right now there is no money to hire Miss Clapp but there may be some by the middle of September, once Rainey, Ralph and I decide how to get the money. Can you stall Miss Clapp off by suggesting to her that she visit us some time during the middle of September. By then we should have the situation well in hand, at least I hope so.

As you know, we are carrying Reed Knox completely through our materials science program and are permitting him to devote a portion of his time to work with the applied science laboratory.

With very best regards.

Sincerely yours,

R. Maddin

/h

cc: Miss E. Ralph

UNIVERSITY INTRAMURAL CORRESPONDENCE

TO: Dr. Elizabeth K. Ralph, BW4, DRL

FROM: Paul C. Shumaker, 201 LRSM

DATE: October 6, 1966

SUBJECT: NSF Grant GP 4766, Metallurgy of Archaeological Specimens

As you requested this date, a review of subject grant funding is presented below:

Total Amount of Grant			$23,600
I. Salaries/Stipends Budgeted:			$14,400
Salaries/stipends paid or obligated:			
Katzev, M. (completed)	$500		
Kingston, Judy (active)	1875		
Kramer, Carol (completed)	1000		
Matson, Ruth (active)	2000		
Weinstein, James (completed)	500		
Total			$ 5,875
Balance salary funds available for use			$ 8,525
II. Material/Expense funds budgeted:			$ 9,200
Expended or obligated to date			5,675
Balance Material/expense funds available for use.		*	$ 3,525
Total Funds available			$12,050

* If it is planned to utilize all of the remaining budgeted salary funds for salaries, that is, $8,525; please deduct $700. from the $3,525. expense funding available to cover 8.4% university employee benefits charges against these salaries. There are no other known hidden-type costs.

A reasonable reallocation of budgeted funds from salaries to expenses and vice versa is permissible. The grant expires on 30 June 1967. Usually, however, an extension of time can be obtained by a letter request to the National Science Foundation.

Paul C. Shumaker

PCS/gts

UNIVERSITY OF PENNSYLVANIA MATHEMATICAL AND PHYSICAL SCIENCES

MADDIN

TWENTY FOUR MONTH BUDGET

A. SALARIES

Senior Personnel:		
(1) Principal Investigator MADDIN	$- - -	
(2) Faculty Associate RAINEY, RALPH.	- - -	
(3) Staff Associate, Visitor (20 days each summer)	4,000	$ 4,000
Other Personnel:		
(4) Research Assistant (1/2 time academic years, full time 3 months summers)		9,000
Fringe Benefits		756
		$13,756
B. EXPENDABLE EQUIPMENT AND SUPPLIES		4,000
C. TRAVEL		
Domestic		
(1) Visitor, 5 trips/Yr., Boston to Philadelphia	$ 500	
(2) Other	900	1,400
D. PUBLICATIONS COSTS		500
TOTAL DIRECT COSTS		$19,656
Indirect Costs (20% of Direct)		3,931
TOTAL		$23,587
ROUNDED TO		$23,600

P-17186

NSF-GP-4766

Fund 4-06225-3-6391

Metallurgy calls it NSF-5

FINANCIAL STATEMENT

Contract: NSF GK 4766 (Archaeology) **Period of Report:** 7/1/67-2/28/68

Budget Administrator: Dr. Robert Maddin **Expiration Date:** 6/30/68

	BUDGET	EXPENDITURES & OBLIGATIONS	BALANCE
SALARIES			
A-1			
A-2	$7,000.	$3,748.	$3,252. (2)
A-3, A-4			
Total Salaries	$7,000.	$3,748.	$3,252.
Current Expenses	2,549.	522.	2,027. (1)
Equipment			
TOTAL	$9,549.	$4,270.	$5,279.

(1) Current expenses:

of this balance, approximately $150. available for travel.

(2) Salaries:

Salary of Miss Ruth Matson through May 1968 obligated. Balance shown is wholly available.

Salaries paid or obligated since 7/1/67:

Mr. John Witthoft	$833.	July 1967
Mrs. Judy Bjorkman	625.	Sept-Dec. 1967
Miss Ruth Matson	2,000.	Sept. 1967-May 19
A-3 (Shop) Charges	290.	
	$3,748.	

NSF Grant GP-4776 ✓

Metallurgy of Archaeological Specimens

Progress Report

April 17, 1967

The research conducted so far in the combined fields of metallurgy and archaeology has been done mostly by graduate students in archaeology and anthropology. Each one, under the direction of a faculty member, has selected a study that we hope, will contribute to the knowledge of metal fabrication from the archaeological point of view as well as to the history of metallurgy. For some of the studies, samples have been mounted and polished and preliminary metallurgical examinations have been made.

The particular studies which have been undertaken are summarized under the following captions:

Egypt

Near East

Biblical Archaeology

Cuneiform Documents

Underwater Archaeology

EGYPT

Material available in the Egyptian Collection, University Museum, provides a good chronological and geographic coverage of Dynastic and Graeco-Roman Egypt. It provides a basis for a systematic study of the evidence presented by Egyptian copper and bronze objects concerning the processes involved in their manufacture. Such a systematic study has not been attempted previously.

The purpose of this research is:

i) to assess the complexity and sophistication of the metallurgical techniques practised in Egypt.

ii) to trace chronologically any improvments in techniques

iii) to observe any possible regional variation in techniques

iv) to observe differences in manufacturing processes dictated by the varying functions of the objects made

v) to date if possible the earliest appearance of bronze in Egypt

vi) to relate the evidence of the objects themselves to the other available evidence (mines, copper working sites, depictions of copper working and lexigraphical study).

Mr. David O'Connor and Mr. James Weinstein, after careful study, selected 58 Egyptian bronze and copper objects for the initial work. Samples of these objects have been mounted and polished for metallurgical examination. To aid the metallurgical interpretation, all samples have been analyzed by X-ray fluorescence for copper, tin, lead, and zinc. Since it was not possible to obtain ideal surfaces for many of them

(necessary for this type of analysis), more than half of these analyzes give only a rough estimate of the percentages of these elements present (Total percentages are less than 90%). Therefore, seven of the same samples were analyzed also by emission spectroscopy, and it may be necessary to do more by this technique.

The following results have been obtained up to this point:

(1) Egyptian metal-working techniques were not significantly improved through the course of pharaonic history. This is not to be construed as implying some innate Egyptian conservatism, however, but rather as indicating that metallurgical techniques had developed as far as was practical and necessary at the time.

(2) The Egyptians never fully understood the exact details of the annealing process, as can be seen by the fact that metal objects were rarely annealed for the proper length of time. In this connection it should be noted that the metal objects were most often under-annealed.

(3) The removal of all of the impurities from the copper ore was rarely attempted, or at least this is a possible explanation of the situation whereby only a handful of objects were considered as "clean" by the metallurgist. On the other hand it is also possible that the Egyptian smelting techniques were not good enough to remove all the impurities.

(4) The Egyptians differentiated in their metal-working techniques between those objects which would be subject to

heavy stress in normal use, and those objects which would encounter much less stress. For example, mirrors were almost invariably only cast, hammered, and annealed, while axeheads were cast, hammered, annealed, and then re-hammered.

Near East

The purpose of this part of the project is to learn more about the history of manufacture of metal objects from the Near East, especially from Iran and southeastern Turkey. Miss Carol Kramer, under the direction of Dr. Robert Dyson, selected 37 objects to be studied, and has made a summary of relevant archaeological and bibliographical data for each antifact. Samples of these have been mounted and polished for metallurgical examination, and preliminary interpretations have been made. All samples have been analyzed by x-ray fluorescence for copper, tin, lead, and zinc. Because of poor or undersized surfaces, most of these analyses were qualitative only. As a check, one sample was analyzed by emission spectroscopy.

Fragments of 12 artifacts have been sent for experimentation to Dr. Robert Brill (Corning Museum of Glass). Included in the experiments are more precise quantitative spectrographic analyses.

BIBLICAL ARCHAEOLOGY

Under the direction of Dr. James Pritchard, Miss Ruth Matson is planning a study of bronze objects from Syria and Palestine. Miss Matson is now in the field collecting samples for this study.

The aim of the project is to arrange a typology of bronze weapons, tools, utensils, vessels etc. found in this area and covering the period through the end of the Bronze Age. From this typology, it will be interesting to see if one can trace the chronological and geographical spread of forms, decorations, and techniques. This in turn may lead to answers to problems relating to trade and commerce in the Eastern Mediterranean, cultural origins and influences among the various peoples of Western Asia and the Aegean, development and spread of technology.

Cuneiform Documents

The ancient cuneiform documents run into the thousands and not a few of them are revelant to the history and technology of metals and metallurgy. But, very little has been done to collect and evaluate this widely diffused source material. There is a need, therefore, to collect all of the cuneiform contexts in which metals and metalworkers are mentioned in the translated cuneiform texts in order to lay the groundwork for a better understanding of ancient metallurgy.

Under the direction of Dr. Samuel Kramer, Mrs. Judith Kingston Bjorkman has started with diversified reading on the practical, archaeological, and philological aspects of metallurgy. She is making file cards of all references to metals found in the Chicago Assyrian Dictionary, Limet's Le travail du metal au pays de Sumer, and C. Hillen's 1955 doctoral dissertation, The Early Development of Metal-Working in the Ancient Near East (Univ. of Chicago Press).

Mrs. Bjorkman is planning to continue this general reading until the summer term; then, she plans to write a Master's thesis on a specific topic.

UNDERWATER ARCHAEOLOGY

A study of concretions surrounding decomposed iron objects found in a sunken Byzantine ship, and reconstruction of the original forms of the objects by means of molds was made by members and students in the Department of Classical Archaeology. This work is described by M. L. Katzev and F. H. van Doorninck, Jr. in an article entitled "Replicas of Iron Tools from a Byzantine Shipwreck" (Studies in Conservation, v. 2, 1966). (Four reprints are enclosed.)

As one of the projects in this grant, Mr. Katzev made a detailed study of a concreted iron nail from the wreck. Metallurgical examination revealed that the original nail had decomposed into iron oxides, particularly magnetite. From X-ray diffraction and fluorescence analyses, additional iron compounds as well as aragonite, calcite, and α-silicon dioxide were identified. This study contributed information which was helpful to the archaeological studies of the identification and significance of the iron objects.

NSF GRANT GP-4776

METALLURGY OF ARCHAEOLOGICAL SPECIMENS

FINAL REPORT

July 26, 1968

This project was initiated partly as a result of a successful pilot study made on the detection of iron carbide structures in the oxide remains of an ancient steel blade from Hasanlu, Iran. This study illustrated the potentialities of what could be learned about ancient metallurgical technologies by closer collaboration between metallurgists and archaeologists.

The grant enabled this joint pursuit to be explored further. Since it was a new concept of collaboration between departments, there were a few "growing pains". At first, it was hoped that specific studies would provide thesis material for both students in metallurgy and in archaeology. It soon became evident, however, that new metallurgical techniques were not required nor appropriate to obtain the answers to questions that the archaeologists are seeking. Therefore, the research was conducted mostly by graduate students in archaeology and anthropology, each one under the direction of a faculty member in the University Museum. Needless to say, the whole program was supervised by Prof. Maddin who guided both archaeologists and metallurgical students and technicians into meaningful pursuits.

The general procedure was that each student selected a particular region of the world and a particular time or range of times for which metallurgical studies were vitally needed. He then studied the pertinent publications and texts. Next, he selected a series of objects from the collections of the University Museum which were appropriate and which could be sampled for his project. These were then mounted and polished for metallurgical examination.

To help with the interpretation of the microscopic studies, and to obtain additional information, chemical analyses were also performed. It was hoped that X-ray fluorescence analyses would be sufficient, because these required less material and less cost. However, in most cases the surfaces of the mounted samples were either too irregular and in some cases too small to obtain reliable quantitative results. Therefore, 38 of the objects were resampled and analyzed by emission spectroscopy, and for seven of these the major and minor elements were checked and confirmed by wet analysis. Hardness tests were made also on all of the objects studied.

The particular studies which were undertaken are summarized under the following captions:

Egypt

Biblical Archaeology

Near East

Cuneiform Documents

Underwater Archaeology

Some of these were reported in our progress report of April 17, 1967, but are included here for completeness of the final report.

EGYPT

Fifty copper/bronze artifacts in the Egyptian Collection of the University Museum were selected for metallographic and spectrographic analysis. In addition, eight objects were selected for spectrographic analysis only. The dates for this material ranged from the First Dynasty (ca. 3200-2900 B.C.) to the end of the New Kingdom (ca. 1085 B.C.). Included within this material were a variety of metal types: mirrors, axe-heads, wire, pins, needles, adzes, and chisels.

The metallographic analyses were made by Mr. Dan Tomalin, a graduate student in the Department of Metallurgical Engineering, University of Pennsylvania. The spectrographic analyses were carried out by Mrs. Ann Millet, Laboratory for Archaeology and the History of Art, Oxford University. The information obtained from these technical studies was correlated with the archaeological and lexicographical evidence on Egyptian copper metallurgy by Mr. James Weinstein; the results will shortly be submitted to the Department of Oriental Studies at the University of Pennsylvania as a Master's Thesis. This program was supervised by Mr. David O'Connor, Department of Egyptology.

The most significant conclusion to be drawn from the metallographic analyses is that there is no noticeable improvement in the complexity or sophistication of the metallurgical techniques practiced in Egypt in the two thousand year period covered by this project. The same mistakes made by

the Egyptian coppersmith in 3000 B.C. were being made in 1200 B.C.: e.g., annealing an object for an insufficient length of time, or excessive hammering (as evidenced by internal cracking). Most Egyptian artifacts, whether made of copper, arsenical-bronze or tin-bronze, were made by the same technique of casting, hammering, annealing, and final re-hammering; there was no correlation between the type of artifact and the method of production, or between the chemical composition and the method of production.

The spectrographic analyses have shown that the use of arsenical copper preceded that of tin-bronze in Egypt. Although not all of the analyses are available at the time of this report, it seems likely on the basis of the present material that arsenical copper came into use in Egypt towards the end of the Old Kingdom (ca. 2400-2300 B.C.), while tin-bronze cannot be indisputably attested until the beginning of the Middle Kingdom (ca. 2000 B.C.). This situation parallels the precedence of arsenical-bronze over tin-bronze elsewhere in the ancient world; it also shows that developments in Egyptian metal-working may be related in some cases to developments in metallurgy in other areas.

A considerable amount of archaeological, geological, and lexicographical evidence has been collected to supplement the evidence obtained from the analyses themselves. Among the most important conclusions drawn from this research are:

(1) The Egyptian word for tin-bronze (and arsenical-bronze?), ḥsmn, was not introduced until the Fifth Dynasty; this is about the same time as the first documented use of arsenical-bronze. There may possibly be some connection between the two events, but no firm conclusions can yet be drawn.

(2) The Egyptian language contains relatively few terms relating to metal-working techniques. In a number of cases the words which were applied to metal-working were simply derived from already existing words. For example, the word which means "to melt (copper)", nbi, has a much earlier history in the Egyptian language as the word nbi, "to swim."

(3) There is no definite evidence for the importation of copper from foreign lands in the third millennium B.C. The sources which the Egyptians exploited at this time were on the Sinai peninsula, in the Eastern Desert, and in the northern Sudan.

(4) Analysis of geological reports reveals that both Egypt and the northern Sudan contain tin deposits; hence, the commonly accepted theory that Egypt has no tin resources, and that, therefore, the Egyptians must have imported all of their tin in order to make tin-bronze, is no longer valid.

(5) The source of arsenic minerals -- such as realgar or orpiment -- needed to produce arsenical-bronze is a complete mystery. The Egyptian words for realgar and orpiment do not appear until almost 800 years after the introduction of arsenical-bronze, and the few times that these minerals are referred to in later times give no hint of their provenience. There are no known deposits of realgar or orpiment in Egypt. Another possible source of arsenic, the sulf-arsenate ores, are not known to occur in Egypt. The meager evidence now available suggests that the sulf-arsenate ores or non-cupriferous arsenic minerals were obtained by the Egyptians through trade.

Biblical Archaeology

Miss Ralph

SUMMARY OF WORK ON PALESTINIAN BRONZES

From the Palestinian collection of the University Museum 46 bronze objects were selected with dates ranging from the 20th to the fourth centuries B.C. The criterion of choice was that the objects must be from loci which are securely datable on archaeological grounds. These objects were redescribed, measured and drawn in order to have a good record of things which might be partially or totally destroyed.

Of the 46 objects selected on archaeological grounds, 27 were chosen as suitable for metallurgical study. These were mounted, polished and etched. The sections were examined microscopically and interpreted by Prof. Madden. The metallurgical interpretations provide an interesting commentary on the development of techniques through the time period covered, and also on the development of specific techniques for special purposes. Considerable difference was noted between the various time periods, but it should be remembered that the number of samples studied was limited. Observations and conclusions must stand as tentative until more work can be done.

Samples of 25 of these specimens were sent to Oxford for spectrographic analysis of the metal content. (In a few cases, there was insufficient unoxidized metal remaining after the metallurgical analysis.) All but three are bronze with 2 to 10 percent tin content. Later specimens also contain a high percentage of lead. The earliest sample is almost pure copper. Two samples which still contained much good metal were sent for both spectrographic and wet chemical analysis. The identification of major minor and trace elements

was similar, but the percentages indicated by the two tests differed by up to 2 percent. This margin of error gives fair warning not to make too many interpretations based on small percentage variations.

In addition to these laboratory projects, I have been preparing a catalogue of bronze objects dating to the second millennium B.C. from Palestinian sites which have been excavated and published. This will provide a typological classification for bronze objects where previously even the basic nomenclature has been far from consistent.

The detailed results of the analyses, the catalogue and typology, and whatever chronological and geographical conclusions can be drawn from these, will be included and discussed in my dissertation for the Department of Oriental Studies of the University of Pennsylvania. This project, under the direction of Prof. Pritchard, will also include a study of references to bronze and metallurgy in the Old Testament.

Ruth C. Matson

Near East

The purpose of this part of the project was to learn more about the history of manufacture of metal objects from the Near East, especially from Iran and southeastern Turkey. Miss Carol Kramer, under the direction of Dr. Robert Dyson, selected 37 objects to be studied, and made a summary of relevant archaeological and bibliographical data for each artifact.

Fragments of 12 artifacts have been sent for experimentation to Dr. Robert Brill (Corning Museum of Glass). Included in the experiments are more precise quantitative spectrographic analyses.

This project has not been concluded at the time of writing this report.

Cuneiform Documents

The ancient cuneiform documents run into the thousands and not a few of them are relevant to the history and technology of metals and metallurgy. But, very little has been done to collect and evaluate this widely diffused source material. There is a need, therefore, to collect all of the cuneiform contexts in which metals and metalworkers are mentioned in the translated cuneiform texts in order to lay the groundwork for a better understanding of ancient metallurgy.

Under the direction of Dr. Samuel Kramer, Mrs. Judith Kingston Bjorkman started with diversified reading on the practical, archaeological, and philological aspects of metallurgy. She made file cards of all references to metals found in the 9 volumes of the Chicago Assyrian Dictionary, and some from Limet's Le travail du metal au pays de Sumer, and C. Hillen's 1955 doctoral dissertation, The Early Development of Metal-Working in the Ancient Near East (Univ. of Chicago Press). She read and made notes on at least 11 books, 3 theses, and 60 articles or parts of books.

Mrs. Bjorkman is now writing a Master's thesis. The tentative structure of the body of the thesis is as follows:

Ch. I. The beginnings of metalworking - archaeological evidence.

Ch. II. Smiths and metalworkers in Sumerian and Akkadian "belles-lettres"

Ch. III. Smiths and metalworkers in the earliest texts

(down to Ur III)

- the gods of the smiths

- conclusions

UNDERWATER ARCHAEOLOGY

A study of concretions surrounding decomposed iron objects found in a sunken Byzantine ship, and reconstruction of the original forms of the objects by means of molds was made by members and students in the Department of Classical Archaeology under the supervision of Dr. George Bass, Associate Professor. This work is described by M. L. Katzev and F. H. van Doorninck, Jr. in an article entitled "Replicas of Iron Tools from a Byzantine Shipwreck" (Studies in Conservation, v. 2, 1966). (Four reprints were enclosed with the yearly progress report).

As one of the projects in this grant, Mr. Katzev made a detailed study of a concreted iron nail from the wreck. Metallurgical examination revealed that the original nail had decomposed into iron oxides, particularly magnetite. From X-ray diffraction and fluorescence analyses, additional iron compounds as well as aragonite, calcite, and α-silicon dioxide were identified. This study contributed information which was helpful to the archaeological studies of the identification and significance of the iron objects.

NATIVE METALLURGY OF NORTHERN NORTH AMERICA

PRELIMINARY REPORT

American Indian tools of native copper from Alaska and western Canada were submitted to metallographic and chemical analysis to relate the metal to its geological sources and to reconstruct the metal technology of various American Indian cultures. This study is being continued to include larger series from other museum collections, more analyses, and additional techniques.

The coppers are exceedingly pure, and trace elements were at the limits of detection by X-ray fluroescence. Emission spectroscopy sorted the coppers into three groups: those of the Central Eskimo which originate in the basalts of the lower Coppermine Basin; those of the interior Dene peoples, which originate in the basin of the Copper, Chitna, and White Rivers of Alaska; those of the Tlingit and Haida Indians of the Northwest Coast, the source of which has not yet been identified. Wet-bench chemistry of samples from the same specimens was conducted by chromatographic column and atomic adsorbtion techniques. This revealed the same branches of trace elements, but showed that their abundance was less than 10% of that measured by spectroscopic methods. Samples are now being submitted to the neutron activation technique.

Metallographic studies of grain structure, hardness, and

other details within sections of specimens sorted the tools into three technological groups. The Tlingit and Haida tools had been made by stone-sawing slabs from a large piece of copper and by grinding the slabs to shape. The workment seem to have been concerned with conserving gross crystal patterns within the metal, and with their development as visible structure through chelation of copper surfaces with fish-oil. The Central Eskimo tools were formed in the same way, but cutting edges were then highly cold-forged to stress harden them, a refinement missing on the Northwest Coast tools. The Dene tools show shaping by forging with extensive annealing, with cutting edges stress hardened.

It is thus possible to define three different stone age technologies in native copper, each associated with a different copper source. Eskimo and Northwest Coast peoples worked copper by the same sawing and grinding techniques which they applied to jade and slate, their metal working being a simple extension of stone working. The Dene smithing is of a different character, having much in common with the technologies of metal age cultures.

John Witthoft

Frances Eyman

September 17, 1968