2/1/77

RE: Check List for Proposal Submission [NSF-SOC75-08186]

Our current & pending support consists of:

1) Radiocarbon Laboratory - [EKR* - FTE - 8 months]

a) Physics - Radiocarbon Budget, Univ. of Penna.

#52,294 annual University budject;
July 1 - 1976 to June 30, 1977;
expected to be renewed.

5,000 - Special equipment appropriation, Univ. of Penna., to supplement NSF-Grant No. EAR 76-14258 for purchase of new Micromass Mass Spectrograph

b) Modernization of Mass Spectrograph

NSF-EAR-76-14258

#22,500 8/1/76 - 1/31/78

c) Graduate Student Support

#6,300 The William Penn Foundation, 3/1/76 - 2/28/77

6,729 " " " " , requested for 3/1/77 to 2/28/78

d) C-14 Measurements of Known Age Samples
12/1/74 - 5/31/77
#78,600 NSF - DES - 74 - 22233

e) ^{14}C and $^{13}C/^{12}C$ Measurements of Known Age Samples and Laser Enrichment of ^{14}C revised to ^{14}C and $^{13}C/^{12}C$ Measurements of Known Age Samples (1/12/77)
#90,018 requested 1/1/77 to 12/31/78 (#49,439 first year, #40,579 second year)
NSF Proposal No. EAR 7683376

2) Museum Applied Science Center for Archaeology (MASCA)
[FGR* - FTE - 2 months ; EKR - FTE - 4 months]

a) #175,000 3/15/75 - 8/31/77, NSF SOC-75-04203
(#100,000 first year, #75,000 second year)

b) #300,017 3/1/77 - 2/28/79, Proposal No. SOC-77-08186.
(#150,000 first year, #150,017 second year)
(This is the present application for renewal).

Notes: FGR = Froelich G. Rainey
EKR = Elizabeth K. Ralph
↳ PI = Principal Investigator

1) Radiocarbon Laboratory, EKR - PI, all grants
2) MASCA, FGR - PI, both grants

Museum Applied Science Center for Archaeology

Froelich Rainey, Director Elizabeth K. Ralph, Associate Director

THE UNIVERSITY MUSEUM • UNIVERSITY OF PENNSYLVANIA
33rd & SPRUCE STREETS • PHILADELPHIA, PENNSYLVANIA 19104
386-7400 (Area Code 215) Cable Address "Antique"

April 29, 1977

Dr. Murray Aborn
Program Director
Special Projects and Social Indicators
National Science Foundation
Washington, D.C.

Dear Murray,

Following our recent discussion, I am submitting herewith the revised budget for MASCA Grant Proposal No. Soc 77-08186 covering a one year grant in the reduced amount of $129,035.00.

If you have any questions or if there are any additional changes necessary, please let me know.

Yours sincerely,

Froelich Rainey
Director

c.c. Office of Research Administration

Budget - First Year

May 1, 1977 - April 30, 1978

1. Salaries and Wages	
a. Mark C. Han, Research Chemist (A-1) Full-time - 12 months	$ 17,030.
b. Three Research Fellows (A-2) 3 summer months - full time Academic year - 1/2 time FTE - 8 man-months each	3 \ $ 16,695. 5,565
c. Kathleen Ryan, Research Bibliographer (A-3) Full-time - 12 months	$ 9,965.
d. Technician I (A-4) Half-time - 6 months FTE - 6 months	$ 4,439.
TOTAL SALARIES	$ 48,129.
2. Employee Benefits	
A-1 - 17,030 x 18.0%	$ 3,065.
A-2 - 16,695 x 24.3%	$ 4,056.
A-3 - 9,965 x 23.0%	$ 2,292.
A-4 - 4,439 x 23.0%	$ 1,021.
TOTAL EMPLOYEE BENEFITS	$ 10,434.
3. Expendable Equipment and Supplies	
a. For Thermoluminescence Nitrogen and other chemical supplies Expendable electronic components, including replacement photomultiplier tubes	$ 1,000.
b. For Archaeological Prospecting Spare parts, tools, cables and replacement batteries	$ 1,500.
c. For aerial Photography Kites, filters, balloons, films, etc.	$ 1,500.
d. Information Center	$ 1,000.
Book purchases	$ 750.
Journal subscriptions	$ 700.
Supplies and Duplicating	$ 400.
Publication of MASCA Newsletter (2 volumes/year)	$ 3,000.
TOTAL EXPENDABLE EQUIPMENT AND SUPPLIES	$ 10,050.

4. Services

Machine Shop, for assembly of experimental TL components	$ 1,000.
Rental of experimental prospecting instruments for field trials	$ 2,000.
Aircraft rental (for aerial photography)	$ 500.
Film processing	$ 500.
TOTAL SERVICES	$ 4,000.

5. Travel

For mud-brick preservation, archaeological prospecting, aerial surveys, and collection of samples for ^{14}C and TL dating

Domestic	$ 2,000.
Foreign	$ 4,000.
TOTAL TRAVEL	$ 6,000.

6. Sub-Total for Calculation of Overhead	$ 78,613.
7. Overhead at 51%	$ 40,092.
8. Sub-Total Plus Overhead	$ 118,705.

9. Equipment

a. Thermo-Gravimetric Analysis (TGA) Accessory for DuPont 990 Thermal Analysis System (The Dupont 990 temperature programmer, controller, and recorder are currently available in LRSM (Laboratory for Research on the Structure of Matter, University of Pennsylvania).	$ 8,000.
b. X-Ray Generator - used dental apparatus or equivalent - to produce 1000 rads in 10 seconds for the precise irradiation of pottery.	$ 2,330.
TOTAL - FIRST YEAR	$ 129,035.

EXHIBIT II-3

PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION
Cover Page

FOR CONSIDERATION BY NSF ORGANIZATIONAL UNIT (please specify):
Division of Behavioral and Neural Sciences: Anthropology

PROGRAM ANNOUNCEMENT/SOLICITATION NO.:

CLOSING DATE (IF ANY):

NAME OF SUBMITTING ORGANIZATION TO WHOM AWARD SHOULD BE MADE (INCLUDE BRANCH/CAMPUS/OTHER COMPONENT):
Trustees of the University of Pennsylvania

ADDRESS OF ORGANIZATION (INCLUDE ZIP CODE):
Office of Research Administration 409 Franklin Bldg./-16
Philadelphia, 19104

TITLE OF PROPOSED PROJECT:
Museum Applied Science Center for Archaeology (MASCA)

REQUESTED AMOUNT	PROPOSED DURATION	DESIRED STARTING DATE
$ 258,282	Two years	July 1, 1978

PI/PD NAME AND SOCIAL SECURITY NO. (SSN)*	PI/PD PHONE NO.
Martin Biddle 241-80-1725	(215) 386-7400

PI/PD DEPARTMENT	PI/PD ORGANIZATION
Anthropology	University Museum

ADDITIONAL PI/PD AND SSN*	ADDITIONAL PI/PD AND SSN*

ADDITIONAL PI/PD AND SSN*	ADDITIONAL PI/PD AND SSN*

FOR RENEWAL OR CONTINUING AWARD REQUEST, LIST PREVIOUS AWARD NO.: Soc 75-04203-A02

REMARKS: *Submission of social security numbers is voluntary and will not affect the organization's eligibility for an award. However, they are an integral part of the NSF information system and assist in processing the proposal.

PRINCIPAL INVESTIGATOR/ PROJECT DIRECTOR	AUTHORIZED ORGANIZATIONAL REP.	OTHER ENDORSEMENT (optional)
NAME: Martin Biddle	NAME: Anthony Merritt	NAME:
SIGNATURE:	SIGNATURE: Anthony Merritt	SIGNATURE:
TITLE: Director of Univ. Museum	TITLE: Director of Office of Research Administration	TITLE:
DATE: November 29, 1977	DATE: November 29, 1977	DATE:

PROPOSAL

UNIVERSITY OF PENNSYLVANIA

PHILADELPHIA, PENNSYLVANIA 19104

PROPOSAL FOR CONTINUING RESEARCH SUPPORT

Museum Applied Science Center for Archaeology
(MASCA)

National Science Foundation
Division of Special Projects
Washington, D.C. 20550

Principal Investigator:	Froelich Rainey, Director, MASCA and Professor of Anthropology		
Social Security Number:	198-26-6211		
School:	University of Pennsylvania	Department:	University Museum
Starting Date:	May 1, 1977	Duration:	One year

FUNDS REQUESTED

One Year (5/1/77 - 4/30/78: $129,035

CORPORATE NAME OF UNIVERSITY: THE TRUSTEES OF THE UNIVERSITY OF PENNSYLVANIA
(a Pennsylvania non-profit corporation)

Contracting Office: OFFICE OF RESEARCH ADMINISTRATION, Franklin Bldg.; I6.
University of Pennsylvania, 3451 Walnut Street,
Philadelphia, Pa. 19104 (215-243-7293)

Name, Title and address of Official to whom checks should be mailed:
Trustees of the University of Pennsylvania
3451 Walnut Street, Franklin Building
Philadelphia, Pennsylvania 19104
Attention: Mr. Anthony Merritt

Approved: _____
Froelich Rainey, Principal Investigator
Director, MASCA

Approved: _____
Archer W. Kinney
Assistant Director, Research Administration

Date: _____

OUTLINE OF MASCA PROPOSAL

MUSEUM APPLIED SCIENCE CENTER FOR ARCHAEOLOGY

I. INTRODUCTION

The Museum Applied Science Center for Archaeology (abbreviated MASCA) was initiated in 1961 by Professor Froelich Rainey. Its aim has been to apply new principles and technologies developed in the physical sciences which are appropriate to archaeological and anthropological research.

After the application of carbon-14 dating became successful in our laboratory (established here in 1951) and others, it was considered that many more technological advances should be investigated for their possible applications to archaeology. As a beginning in this direction, work was started in the following fields:

1) Thermoluminescent dating of pottery

2) Development and use of instruments for archaeological prospecting

3) Information Center and the MASCA Newsletter.

Within the context of the complexity, scale and diversity of research now being carried out in many laboratories, the role of MASCA's staff and collaborators is to search out those new discoveries which can be adapted to archaeological purposes through experimentation and modification. Presently, examples of this are radiocarbon and thermoluminescent methods of dating archaeological materials, the use of magnetometers and other geophysical prospecting instruments, aerial photography for archaeological prospecting, and more recently, the preservation of mud-brick and friable stone structures.

Archaeology, in a way similar to so many other research disciplines, has taken a new direction as a result of these trends in science. MASCA is based upon the assumption that with new directions and future

changes, it will continue to draw upon the adaptation of the best of the techniques developed by physical scientists, biologists, archaeologists and anthropologists.

MASCA and Oxford's Research Laboratory for Archaeology (RLA) have been the only major organizations in the world with a similar function in archaeology. The RLA is manned by physical scientists only and tends toward basic research: hence its specific objectives and operations are somewhat different from those of MASCA. The latter is based in an institution which carries on anthropological and archaeological research in practically all fields. This has led to cross-fertilization between the physical sciences and anthropology-archaeology as well as to extensive experimentation in the field and in the laboratory. To a large extent MASCA exists because of the University Museum's support of so many expeditions - about 15 per year, on average. Because of this large number of expeditions abroad, some of the field trials of our new techniques have been done in collaboration with other institutions where investigators are working on similar developments or at sites which are ideal for trials. Moreover, while many countries do not now allow the export of artifacts, scientific samples, and especially those of environmental significance - ecofacts - can still often be exported for examination elsewhere.

MASCA has up to this point been primarily concerned with those developments in nuclear physics, chemistry, electronics, remote sensing and other fields which are now producing fundamental changes in scientific technology. But the physical and chemical sciences are by no means the only disciplines where scientific approaches are applicable to the expansion of archaeological knowledge; the life sciences are now recognized as fundamental to the recreation of the past environment of

mankind. Already in 1970 in the book Science and Archaeology, Brothwell and Higgs devoted three of the seven sections, comprising virtually half of all the chapters, to floral, faunal, and human remains. Any approach to the past must now view human populations and their activities as an essential part of the ecosystem and this is possible only by the development and application of what is coming to be termed 'environmental archaeology'. Moreover, it is archaeology alone which can provide the raw materials needed for research into past environments within the context of a firmly dated timescale. Thus archaeology may and probably will increasingly become a provider of dated materials for research objectives within other disciplines.

In consonance with these developments, MASCA will now begin to develop a broadly-based initiative within the life sciences. We wish as a first step to explore the establishment of palaeobotanical and palaeozoological programs, drawing on the facilities available within the University of Pennsylvania under the catalytic influence of funded positions within MASCA itself. The excavations of the University Museum across the world (on four continents in summer 1977 alone) will provide a rich source of research materials in these fields and in other fields such as human osteology. Here we would hope not only to advance current handling of osteological data, but also to develop advanced approaches to the study of ancient disease via parasitology and immunological techniques (Biddle 1967).

Support for these developments in MASCA's activity will be sought in due course in relation to specific programs. Meanwhile, the present application seeks support for specific aspects of MASCA's activity in relation to the physical sciences.

II. DATING OF POTTERY BY THERMOLUMINESCENCE (TL)

In 1959, Elizabeth Ralph started research directed toward the possibility of using thermoluminescence for dating pottery, a theory which had been suggested originally by Farrington Daniels in 1953. This work has been pursued actively at the MASCA research center by Mark Han since 1962.

During the past fifteen years, under the direction of Drs. E.K. Ralph (Associate Director) and W.E. Stephens (Associate Director for Research), improvements in the overall technique and a specific method of sample preparation have been developed independently here at MASCA.

Thermoluminescent dating is based upon the fact that particles emitted from traces of radioactive elements in the clays bombard the other constituents and raise electrons to metastable levels. When the clay is heated, enough extra energy is supplied to enable the electrons to return to normal states. In this transition, each one emits a photon of light. Thus, the firing or final heating of a ceramic is the starting point of the accumulation of metastable electrons.

The essential features of thermoluminescent dating of ceramics are the measurement of the inherent radioactivity, and the natural and artificial glow curves, from which, ideally, the age (or date of last firing) can be determined. (This apparatus is illustrated in Fig. 1.)

In principle, the method is straight-forward, but in practice, there are many problems and uncertainties. The primary causes of these problems are the lack of understanding of the behavior of various complex ceramic fabric systems and the effects of pottery-manufacturing technologies on that behavior. Our experiments have shown that the thermoluminescent responses of different types of clay, in addition to the responses of various crystalline inclusions,

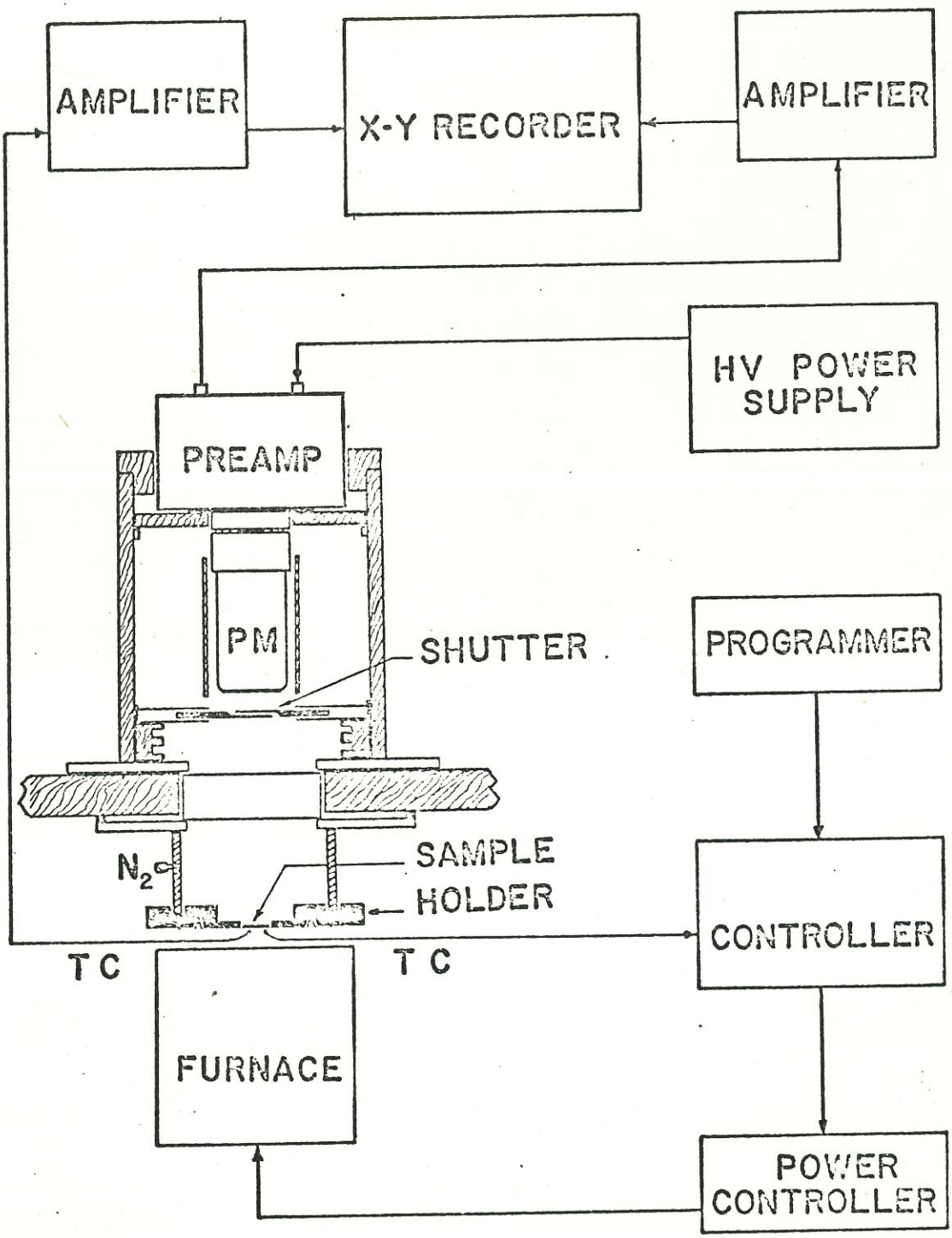

Figure 1. Block diagram of TL glow curve apparatus and programmer, which provides a linear rate of temperature increase for heating the sample.

are highly dependent upon the previous thermal history and chemical composition, and on the type of radiation applied.

It has been our intention to focus our experimentation upon these problems which are poorly understood, in order to obtain the knowledge needed to improve the reliability of the thermoluminescence method as a tool for dating fired earthen artifacts.

Our major breakthrough recently has been the detection of the total inherent radioactivity of sherds by means of gamma/ray spectrometry, with the use of a high sensitivity Lithium-drifted Germanium detector. This was made possible by the collaboration of Professor William Stephens, and the use of his Ge detector in the Tandem Accelerator Laboratory in the Department of Physics. With this method we have shown that it is possible to determine the absolute amounts of inherent U, Th -- and daughters, including radon (a volatile gas) -- and ^{40}K in pottery. By means of this new technique, the total amount of energy deposited dissipated may now be calculated.

Previously, estimates of inherent radiation had been based on the assumption by Oxford that Th and U were in secular equilibrium, and therefore were present in constant ratios. Our results from the analysis of 20 samples have indicated that the Th/U varies by as much as 4.1/0.5. The ^{40}K content determined by this method is in good agreement with that found by flame photometry, usually of the order of 0.1 to 4.3 percent.

With the encouragement of our results, the Research Laboratory for Archaeology at Oxford has recently obtained a grant to apply similar gamma/ray spectrometry to their samples. These measurements had been considered to be impossible, but we, at the University of Pennsylvania, have demonstrated that they are not only possible, but, that they will lead to reliable TL

dating of pottery. (TL dates for samples of known age and for those with associated ^{14}C dates are shown in Fig. 2)

During the past ten years, this laboratory has processed approximately 700 pottery samples, which represent 133 major sites from 35 countries. The major areas of interest are as follows:

Iran: Hasanlu; Fars; Susa; and other sites.

Turkey: Alaca Hüyük; Çatal Hüyük; Hacilar; Kadiköy; and other sites.

Egypt: Adydos; Beit Khallaf; Dendereh; Thebes; Deir-el-Bahri; Karnak; and other sites.

Thailand: Ban Chiang; Non Nok Tha; and other sites.

Japan: Sites with Jomon pottery.

Italy: Plain of Sybaris; Torre Mordillo; and other sites.

Samples have also been processed from 29 other countries.

Current experiments are directed toward the development of a new technique of sample preparation, namely, the deposition of only the fine clay grains by the evaporation of a volatile liquid such as acetone, in which they are suspended. The main purpose of this new approach is to eliminate any large crystalline inclusions that may have been present in coarse-grained sherds. Similar techniques have been employed at Oxford (Aitken et al., 1968; Zimmerman, 1968 and 1971). The cores of large crystalline inclusions are known to have been subjected to a lesser amount of alpha particle radiation, from uranium and thorium contained in the clay, than have the finer sized grains, because of the short range of alpha particles in clay. Previously, except for various experiments, we had ground whole sherds regardless of their particle size, and measured the

resultant powder.

Before the fine-grain technique can be accepted as the ideal method, many associated problems must be resolved. One of the most immediate is that after the fine grain particles are deposited on an aluminum foil sample holder by the evaporation of the acetone, the sample is left in a dry state. The adhesion between the grains is through solid-to-solid physical contact, which reduces the rate of heat transfer. An even more disturbing phenomenon is the apparent regeneration of thermoluminescence which we have observed after the sample had been heated in a pure nitrogen atmosphere and then exposed to the air for a short time. This regeneration is not always predictable and seems to vary as different types of fired clay are tested. With our previous standard technique, both of the above problems were eliminated by mixing samples with silicone oil, and then depositing them on aluminum foil by the silk-screen method. The presence of the silicone oil not only permitted a faster heat transfer between the particles, but also prevented the particles from coming into contact with the surrounding air and/or moisture, which are known to have a surface effect upon fine grain particles, and this generated a type of spurious thermoluminescence.

Among the other experiments currently under investigation which should prove valuable in elucidating some of the factors having direct effects upon the thermoluminescence method, are the following:

1. Identification of the type of clay by means of X-ray diffraction.
2. Determination of the orginal firing temperature of the sherd by techniques such as thermogravimetric analysis (TGA) and differential thermal analysis (DTA).

3. Continuation of experiments on the use of gamma/ray spectrometry to measure the inherent radioactivity of samples. Experiments conducted to date have been made possible through the cooperation of the Tandem Accelerator Laboratory. The time allocated to MASCA for the use of this equipment is necessarily limited, therefore we are seeking funds to purchase our own Germanium gamma/ray detector and associated components. We are applying to the Engineering Specialized Research Equipment Grants Division of the NSF for these funds.
4. Investigation of a direct method for the determination of the true effective radiation damage of alpha particles. To do this, we plan to mix a calibrated liquid ^{210}Po source with the sample, and measure the resultant thermoluminescence.
5. Use of a beta source (^{36}Cl) for the irradiation of samples, to compare the effects of alpha, beta and X-ray doses.

III. ARCHAEOLOGICAL PROSPECTING

Due to the destruction of many archaeological sites by the rapid encroachment of modern civilization, there is a great need for the acceleration of the finding of sites, and for the delineation of structures within sites already found. Also, because the cost of labor is increasing all over the world, it is becoming impractical to excavate unless there is a certainty that meaningful structures or levels of habitation will be found.

With this in mind, MASCA tested and used previously developed instruments that are suitable for archaeological exploration. These include the Elsec proton magnetometer, the Gossen Geohm (a resistivity instrument), and various metal detectors and seismographs. In the course of our search for the ancient Greek city of Sybaris, buried at depths of 4 to 6 meters, we learned that proton magnetometers were not sufficiently sensitive for the detection of structures or archaeological deposits at such depths. Therefore, Rainey and Ralph sought the collaboration of Varian Associates and as a result, they designed and developed for MASCA a more sensitive portable cesium magnetometer, with digital readout and differential mode of operation. We now have two complete units, that is, two readouts and four sensors.

With the differential mode of operation, we not only have the capability of a useful sensitivity 20-fold greater than that of proton magnetometers, but also the cesium magnetometers are much faster to use. We may take readings almost every second, instead of having to wait for a polarizing cycle of 5 to 6 seconds. In previous grant proposals and publications (Ralph et al., 1968), we have described our procedure for doing surveys and have listed the more than 50 sites, both abroad and in the U.S.A., where we have worked.

The basic financial support of MASCA by the NSF and the University of Pennsylvania (see Table I) has enabled us to pioneer in the development and use of new instruments, and to conduct worldwide surveys, whereas, in the past, we had been limited to excavations supported by private funds donated to the University Museum, or related in some way to it.

Because of this previous experience and support, we have just recently received a contract from the National Park Service (U.S. Dept. of the Interior) for Archaeological Survey and Research at Valley Forge (Pa.) National Historical Park. This is basically a one-year contract ($99,994) to conduct aerial, magnetometer, soil-penetrating radar, etc. surveys, and to perform test excavations for the interpretation of the anomalies found. All anomalies,historical features etc. located will be plotted on specific detailed maps of the park. In the meantime, under separate contract, five historians are studying whatever historical records are available. They will also assist us in the interpretation of what we find.

Because the Park Service contract covers repair and battery costs, we have not requested in the budget,funds in the first year for extensive magnetometer repairs, etc., nor much for aerial photography.

While our exploratory reconnaissance at Valley Forge for the National Park Service will apply our proven instruments which are known to be ideal in this situation, we also plan to test a number of other instruments on an experimental basis; because of this, we will include this effort under this NSF grant. On a 30-meter square test-area at Valley Forge, we have already used our magnetometers and rented gamma/ray spectrometers to make maps of geophysical anomalies. We will now apply at least three additional instruments to this same test area: the ground-penetrating radar, a soil electrical resistivity meter (at several electrode spacings), and a seismic refraction instrument. After these five surveys are completed, we will excavate the test area so that we can make a detailed comparison of the

effectiveness of the five instruments in this type of archaeological application. The tests with ground-penetrating radar have already indicated the existence of a pronounced linear anomaly, and since this was not detected with the cesium magnetometer, we are quite certain that it is not a modern pipe, power line, or such.

Upon completion of the field work at Valley Forge, Pa. in the late summer (1978), a site abroad that might be suitable for a cesium magnetometer survey is one in the Hashemite Kingdom of Jordan.

A sounding of a burial cave in the area of the Beqa'a Refugee Camp, approximately twenty kilometers north of Amman, Jordan, was carried out in the Summer of 1977 under the auspices of the American Schools of Oriental Research. This excavation produced a very extensive and representative repertoire of Late Bronze I pottery with some overlap into the Middle Bronze IIC and Late Bronze IIA periods, along with a rich collection of accompanying grave goods, including scarabs, cylinder seals, bone inlay, ostrich eggs, toggle-pins, bracelets, earrings, and a wide assortment of different types of beads. A preliminary survey of the region, which has never been adequately explored, brought to light at least three more caves dating to about the same time, while entrances to another three caves were found which may very well be Late Bronze I in date. All of these caves lie in a line along the lower western slopes of a valley, and it is presumed that the series could be added to with further systematic exploration. Since the Late Bronze I period on the East Bank of the Jordan is virtually unknown, a marvellous opportunity thus presents itself for filling in a gap in Jordan's cultural history, while possibly helping to clear up some of the many problems associated with Late Bronze I on both the East and West banks.

As a first step before actual excavation, one of the directors of the American Schools' cave sounding, presently a Research Fellow with MASCA, is

planning to carry out a cesium magnetometer survey in the Beqa'a area sometime during 1978. While ordinary archaeological survey techniques would probably miss many cave mouths which have been covered over by soil and vegetation, the magnetometer should detect an anomaly between the fill of the cave and the surrounding limestone into which it is cut. Samples of stone and soil from the cave sounding of this past summer are now being sent to MASCA, in order to test this assumption for the Beqa'a area. Should it not hold true, soil-penetrating radar or some other instrumentation being developed at MASCA will possibly be used. Additional financial backing from an American source, possibly NEH, to be matched by the Jordianian Department of Antiquities, will be sought to support the project.

NEAR AND REMOTE SENSING: GEOPHYSICAL SURVEYS.

A Fast and Accurate Traverse Marker.

With most of our geophysical surveys, we use measuring tapes and calibrated ropes to determine the location of the traverses and stations for readings to be followed by the surveying crew. While this allows accurate control of position within a survey grid, a faster method would be desirable for our large-area surveys. A new system which we plan to construct will allow us to define fast and accurate lines of traverse. A wheel with a 2/m circumference will serve to indicate positions along a traverse by its rotation as it is pushed along; this wheel will be made of nonmagnetic materials so that it can be rolled near the sensitive sensor of our cesium magnetometer. The line of the traverse will be marked with a sharply-collimated beam of light, possibly from a diffused laser. A person walking towards this narrow-angled beam can readily and precisely follow its straight line. In hilly terrain, a fan-shaped beam would be needed. A further variation would be to use a collimated retro-reflector at the end of a traverse line; a light carried by

the individual with the sensor would then be reflected only when he was on the traverse line. Other possibilities we may try would employ the parallax of a pair of vertical poles or the interference of a pair of simple radio transmitters; the latter would be valuable in wooded terrain.

A Profiling radiometer.

One of our aims is directed toward the development of electromagnetic geophysical survey instruments which will provide more detailed and faster underground information than a four-point resistivity probe, but which will also be less expensive than the ground-penetrating radar systems which are currently available. A profiling radiometer might be the desired instrument. Buried objects emit electromagnetic radiation which is dependent upon their temperature and emissivity; the propagation of this radiation to the surface is influenced by the electrical parameters of the intervening soil and rock. Both effects can give us valuable clues to subsurface materials which may lead to the location of archaeological artifacts and structures. By scanning the frequency of the radiometer through a band between 100 MHz and 1GHz, one may get an indication of the depth of an object, up to a maximum of about 5 m. We plan to investigate the design of a possible system and will test a prototype if it is feasible.

NEAR AND REMOTE SENSING: AERIAL PHOTOGRAPHY.

A New Detector of Color Anomalies.

Patterns of anomalous colors can be used to indicate the location of buried objects. Color contrasts in soil or vegetation can reveal architectural features such as refilled ditches or buried walls. While aerial photography has been successfully applied to this reconnaissance problem, certain difficulties have remained. If the color contrast is precisely known, the film and filter combination for the camera can be selected to

maximize the visibility of that specific contrast. However, in many cases, the exact color anomaly is not known; therefore incorrectly chosen films and filters can degrade the contrast of the aerial photograph.

We plan to test a possible way out of this dilemma. A color-dispersing prism will be placed in front of the camera's lens; then, with color film, a chromatic spectrum will be formed, marking the boundaries of the areas which have a color contrast. Even with black-and-white film in the camera, these color boundaries will be revealed by light or dark toned bands on the photograph. This has been demonstrated by Bruce Bevan (PhD. thesis, University of Pennsylvania 1977). With both approaches, (Color and black/white) chromatic dispersion by means of a prism provides a general technique for detecting any color contrast.

IV. INFORMATION CENTER

The MASCA Information Center maintains a catalogue of scientific techniques of value to archaeology and anthropology. Current publications are covered for new ideas and new applications of the physical sciences in archaeology, abstracts are made of relevant articles, and copies of the most useful articles are kept in the files of the Information Center. In recent years we have expanded our subjects covered to include some headings in the environmental sciences, e.g. climatology, ecological information and faunal analysis. The files contain about 10,000 abstracts collected over 16 years. In addition, we maintain a small library of books and monographs on techniques, subscribe to 20 journals directly and receive 11 journals on exchange.

Faculty and students or interested members of the public can use the files, books and journals in the Information Center library, or material can be signed out for short periods of time. The MASCA Information Center staff are on hand to assist users of the library in the selection of references. They will suggest avenues of investigation of specific problems and will conduct library searches in response to specific requests.

Many requests for assistance come from outside the Philadelphia area. To speed up our response to such requests, we have devised a system whereby we can send out Xerox copies of references and abstracts on each subject. Outside requests constitute over 50% of requests for information. Requests range from requests for information on a particular technique to general information on all techniques. Of two recent requests, one was for information on neutron activation analysis from a professor teaching a class of Classical archaeology students, the second was for background information on scientific techniques for a television program on the evolution of man.

A MASCA Newsletter is published periodically to exchange ideas, techniques and information on the applications of science to archaeology. The Newsletter contains material provided by members of the MASCA staff and by other scientists from around the world, in an approximate 50-50 ratio, and is sent out free of charge to interested subscribers. At the moment our subscription list stands at approximately 4,300 and includes subscribers from all over the world. An issue devoted to remote sensing by satellite in archaeology is in press.

V. PRESERVATION OF MUD-BRICK AND FRIABLE STONE STRUCTURES

In 1971, Darrel Butterbaugh retired from industry, and offered to be a volunteer in MASCA. With his PhD. in organic chemistry, he is eminently qualified to conduct our program of preservation of mud-brick walls, etc. at archaeological and other sites. This program and specific new activities are now described.

Adobe and Friable Stone Program

Acrylic and methacrylic polymer solutions in dilute concentrations have been used to consolidate and stabilize mud-brick and mud structures. Both wet and dry stabilization are achieved. Comparable treatments on soft and friable stone also impart very significant strengthening to the treated substrate. A controlled mini-sandblasting technique in the laboratory has made it possible to compare quantitatively the dry strengthening being achieved. This, coupled with simulated rainfall and wet freeze-thaw cycling has enabled us to carry laboratory testing quite far. However, field testing under local environments is the only true measure of effectiveness. Outdoor test stations have been established in Philadelphia, Florida, Guatemala and Iran. A new test on mud is planned for Casa Grande, Arizona, and a test on soft sandstone, for Petra, Jordan.

The polymer solution-technique is particularly effective for consolidating and preserving some of the very soft and highly carved stone and plaster at Tikal, Guatemala: we plan to perform a demonstration field test at this site. In addition, we will soon have two years' exposure on the limited tests on stone consolidation at Quirigua, Guatemala. A larger test should be initiated in the near future. Both sites have been excavated by the University Museum

The field tests on mud bricks and walls at Hasanlu in Iran (also excavated by the University Museum) have now been in place for 25 months. Periodic inspections and photographs have been made by visitors to Iran, but these have not been people with training in preservation. In 1978 a detailed inspection and evaluation of this large field test should be made by a specialist from MASCA.

There is strong evidence that polymer solution-treatment retards or eliminates salt incrustation of adobe or stone. A test wall with controlled water injection to the base is to be treated to evaluate the laboratory experiments. Laboratory work should also be extended to salt-growth-control on museum specimens.

A new, high-boiling, non-toxic monomer is becoming available for adobe and stone impregnation and in situ polymerization. Preliminary work indicates that the penetration is deep, polymerization control is easy, and consolidation strong. Too much discoloration occurs for some applications. Further work in the laboratory is needed to find ways of overcoming this difficulty and of adapting this new monomer to a practical use in adobe and stone preservation.

Chemically modified mud has been demonstrated to be quite resistant to extreme weather conditions. Outdoor tests in Philadelphia, Florida, Guatemala, New Mexico and Iran are showing the advantages and disadvantages of this method of restoration. Further work in the laboratory and the field are needed to improve adhesion to mud wall surfaces.

Marble and Limestone.

Current laboratory work indicates that soft marble statuary can be strengthened markedly by treatment with certain polymer solutions or by

impregnation with suitable monomers followed by in situ polymerization. Both conventional and the newly available monomeric material previously mentioned should be adapted to free-standing statuary and decorative stone mouldings.

A polymer coating applied to marble and limestone has shown marked resistance to water and acid attack. Treated samples can be immersed in strong acid for weeks without reaction. Coatings are on out-of-door test specimens at present. If they do not show serious soiling this winter, field tests should be set up in several severe city atmospheres. In many cities and particularly in Athens, atmospheric acid sulphur contamination is quite severe. The marked acid protection provided by this coating suggests that it may prove to be an excellent candidate for marble statuary preservation. A test on marble in a non-conspicuous spot in Athens will be most useful.

VI. COLLABORATION

A. Collaboration with Industries.

1) Varian and GeoMetrics

In regard to magnetometers and computer plots of results, we have had the active collaboration of GeoMetrics (Sunnyvale, California), and, especially, of the president of the company, Dr. Sheldon Breiner, who was formerly with Varian Associates.

2) Du Pont

Currently, we are fortunate in having the active participation of Hugh Sharpe (a member of the Board of Managers of the University Museum and active in E. I. Du Pont de Nemours and Co., Wilmington, Delaware). He owns and flies a private airplane, and has been generous in offering his services for aerial photography, especially in Mexico and the southwestern U.S.A.

3) Rohm and Haas

Dr. Otto Haas, Vice-Chairman of the Board of Rohm and Haas Company and a member of the Board of Managers of the University Museum, has volunteered his services to work with MASCA as Associate Director for Development. As a start he is acquainting himself with our activities and visiting other centers of research such as the U.S. Geological Survey and RLA at Oxford. Eventually, his travels will be more extensive in his search for new ideas and techniques that are or can be applied to archaeological-anthropological research.

Also from Rohm and Haas, Darrel Butterbaugh, a retired research chemist, has joined MASCA as a part-time volunteer to tackle the problem of the consolidation of mud-bricks by means of polymer chemistry.

4) General Electric Company

We have begun a series of conferences with the General Electric Company and its Space Division with headquarters at Valley Forge, Pennsylvania.

Their great expertise with remote sensing equipment and interpretation techniques should be a fine asset to our efforts to apply technology to the needs of archaeology. In discussions with Mr. Robert Jones and Dr. Kiyo Tomiyasu and others, we have exchanged ideas about our respective projects and goals. A specific project we have investigated is the Orbital Flight Test program for the space shuttle, and the possibility of an experiment in space photography for archaeology. We are also considering foliage-penetrating radar; this would be very helpful in the exploration of jungle areas in Central America and in Southeast Asia.

B. Collaboration with Other Laboratories and Research Centers

1) Laboratory of Tree-Ring Research

MASCA has collaborated with the Laboratory of Tree-Ring Research, University of Arizona, since 1959. The uniqueness of this laboratory in respect to its program of field research and collection of ancient trees as well as the subsequent dating of the wood, has made collaboration a prime objective. The precisely dated wood samples of the Tucson laboratory are the keystone of one of MASCA's important projects, that is, the comparison of the dendro-dated tree-ring samples with the radiocarbon dates derived from the samples. The observed consistent variations over a period of more than 7300 years formed the basis for MASCA's correction factors for radiocarbon dates (Ralph, et al., 1973).

Reciprocally, MASCA's radiocarbon dating of "floaters", that is, tree-ring samples which could not be readily dendro-dated, has helped resolve

some of the problems encountered by Arizona's Laboratory of Tree-Ring Research. Dr. C. W. Ferguson is MASCA's principal contact at the Tree-Ring Laboratory, and the person who has achieved this great series of tree-ring dates.

Not directly pertinent to this application for MASCA funds, nevertheless of significance to dating techniques generally, are the finds of ancient wood (bristlecone pine) made during the summer of 1977 by C. W. Ferguson and our H. N. Michael. On preliminary analysis, at least two pieces of the wood will reinforce the (hitherto unpublished) chronology between 5400 BC and 6000 BC, and may even reach into the 7th millennium BC. Of even greater significance is the find by Ferguson of wood which may span the approximately 1000 year gap between the years 6000/6100 BC-7000 BC, the latter having been in Ferguson's possession for several years.

If all of these correlations work out, we will be able to extend the dendrochronology -- and with it the correction factors for radiocarbon dates -- to about 8000 BC, that is, across a span of nearly 10,000 years.

2) The Stanford Research Institute

During the period 1974 to 1977 MASCA has actively collaborated with the Stanford Research Institute in connection with the use of soil-penetrating radar for the discovery of buried archaeological structures and buried woods in alluvial fans. The collaboration has been described in some detail in MASCA Newsletter volume 11, number 1. The collaboration continues, and we hope to continue to utilize soil-penetrating radar for the location of buried wood, as well as at archaeological and historical sites such as Valley Forge.

C. Collaboration with Other Departments at the University of Pennsylvania

1) Laboratory for Research on the Structure of Matter (LRSM)

Our collaboration with the Department of Metallurgy began in 1963 with a study of a corroded iron dagger by Mr. Reed Knox, who was directed by Professor Robert Maddin, Chairman, and encouraged by Professor Cyril Stanley Smith (Institute Professor, M.I.T.). Subsequently, with the financial support of NSF Grant GP-4766 (1964-1966) entitled "A Training Program in Metallurgy and Archaeology", several graduate students participated in combined archaeological-metallurgical studies. These studies were supervised by Professors Maddin and Smith and by various curators in the University Museum. The results of two of these were incorporated into PhD. theses, and one formed the basis of a Master's thesis.

The active participation of graduate students diminished at the termination of the grant. Now, however, we have resumed this collaboration. This permits members of MASCA, curators of the University Museum, graduate students and visiting scholars to work with the personnel of the LRSM laboratories in centers equipped with electron microscopes, microscopic scanners, non-dispersive X-ray detectors, X-ray diffraction equipment and, of course, metallographic and photographic equipment.

In addition to the above arrangements, Dr. Andrew McGhie, supervisor of the analytical chemistry section in LRSM, has been working with us in connection with our thermoluminescence project, as mentioned previously. We also plan to develop new techniques to measure TL without sample removal from objects. Also, his section is equipped for gas chromatography, and maintains associated components, such as those required for analyses of the possible contents of ancient pots.

However, the gas chromatograph is not available to MASCA for routine analysis.

2) Department of Chemistry

For many years we have had contacts with various members of the Department of Chemistry. Our closest and most continuous has been with Dr. John G. Miller, who is the professor in charge of the Mass Spectrograph which we have used for the measurement of $^{13}C/^{12}C$ ratios (a small correction factor for ^{14}C dates). We have recently acquired a new Micromass isotope ratio mass spectrometer (NSF Grant EAR 76-14258) which allows more accurate determination of correction factors in ^{14}C dating, as well as new tests of fractionation mechanisms.

In both LRSM and the Department of Chemistry we are collaborating with Professor Hochstrasser to test the feasibility of extending the effective range of radiocarbon dating by enrichment of the naturally occurring ^{14}C with lasers. We are using lasers and spectrometers which are part of the facilities of LRSM. Much of the synthetic chemistry for this project has been done by Andrew McGhie of LRSM. We have also arranged through Professor Alan Smith of the Chemistry Department of Drexel University for the use of a N_2-pumped dye laser.

3) Department of Physics

With the Radiocarbon Laboratory located in the David Rittenhouse Laboratory, which houses the Departments of Physics, Mathematics and Astronomy, there are naturally frequent contacts with members of the Department of Physics, and a variety of workshops and services to which we have access, including the Li-Ge detector associated with components of the Tandem Accelerator. Dr. William E. Stephens, Professor of Physics and Associate Director of Research for MASCA, is readily available to aid us with any problems and to advise us in our research. Both Drs.

Stephens and Roy Middleton are designing experiments for the direct measurement of ^{14}C, which has been demonstrated by Nelson et al. at Rochester to be feasible (Nelson et al., 1977; Bennett et al., 1977).

4) Department of Geology

From the beginning, Dr. Henry Faul, Prfessor of Geology, has been keenly interested in the Radiocarbon laboratory and in our dating programs and other activites. (Dr. Faul is well known for his construction and operation of Potassium-Argon dating equipment.) Dr. Faul and several students are investigating fission-track analysis and its application to palaeothermometry as well as to dating.

We have also collaborated with Dr. Robert H. Giegengack of the Geology Department in a detailed study of carbon isotope geochemistry of Havasu Creek in the Grand Canyon, Colorado. This study has enabled him to assess quantitatively the validity of radiocarbon ages on calcareous tufa (a common form of inorganically precipitated $CaCO_3$), that has been widely used as a climatic-stratigraphic indicator. The negative results of this program have indicated that ages determined from calcareous tufas are not at all reliable (Giegengack et al., 1977).

5) Department of Electrical Engineering

Members of the University's Electrical Engineering department are now collaborating with MASCA on the development of new archaeological exploration techniques. In addition to optical imaging systems, the possible advantages of radar and passive microwave imagery are being investigated. Electromagnetic sensors can provide additional spectra both for anomaly imaging and underground penetration, and for detection which is impossible at optical wavelengths. Dr. H.N. Kritikos, an expert in the application of electromagnetic theory, is collaborating

with us in the design of new geophysical instruments.

6) University Museum

MASCA, as such, is housed in the University Museum, where the Departments of Anthropology (including American Archeology) and Classical Archaeology are located, as well as all the curators of the various sections and collections. Naturally, our contacts with many members of the staff are both frequent and fruitful.

VII. FACILITIES

A. MASCA LABORATORIES, UNIVERSITY MUSEUM

1) Space

MASCA has adequate laboratory and office space. This includes seven rooms for the regular staff plus a large well-equipped laboratory for visiting scientists, volunteers, and for conferences. With funds from NSF Grant GS 36308X, all of the rooms are now air-conditioned by means of a central water-cooled system.

2) Equipment

a. Thermoluminescence

Equipment purchased with NSF grants GS-566, 1028, 1568, 2716 and 36308X is available in MASCA. This includes two sets of glow-curve apparatus with linearly controlled heating programmers, nine functional alpha counters, and a photon counting system. X-ray apparatus is available in the Department of Physics. Beta and gamma sources are available through the cooperation of Dr. Suntharalingam at Jefferson Medical College. However, for convenience we are purchasing a ^{36}Cl beta source, and two more ^{210}Po sources per year to continue the alpha experiments. Grinding equipment, dosimeters, and other minor components have also been purchased.

b. Dendrochronology

A dendrochronograph and low-power microscope, for measuring the widths of tree-rings, were purchased several years ago. H.N. Michael has collected and tree-ring-dated an adequate number of sequoia and bristlecone pine samples for MASCA's studies, for exchange and for exhibit. The collection also includes other woods that were at one time or another processed in the laboratory, such as Lebanon cedar, black pine

from Anatolia, and zapote from Central America.

c. Equipment for Archaeological Prospecting

As described previously, we possess two cesium magnetometers; one proton and one flux-gate magnetometer; four Geohms; metal detectors; and seismic-sonic components. We also have tools and test equipment including a battery-powered oscilloscope.

d. Aerial Photographs

As a result of the flights of the US Air Force at 3500 meters and the Italian Air Force at 600 meters over Southern Italy, we have two different sets (2000 each) of photographs of the Plain of Sybaris and surrounding hills. From more recent experiments, we have 1000 prints taken over various archaeological sites in England, and 8 rolls of transparencies of the Snaketown, Arizona region, as well as photos of Valley Forge and other sites.

e. Information Center

This contains a small library of books and articles from periodicals, extensive card files of abstracts indexed both by author and by subject, and also the central MASCA files.

It is now located in a larger room (no. 185). One end is reserved for work space, and the center portion of it is now equipped with a sizeable table and chairs for those using the files.

B. RADIOCARBON LABORATORY, DAVID RITTENHOUSE LABORATORY, DEPT. OF PHYSICS

1) Space

The ^{14}C laboratory was formerly located in only the two connecting rooms (BW4 and BW6), each 6 x 6 meters. With funds from NSF GS 36308X, a large adjacent room (BW8) measuring 6 x 15 meters which had been a storeroom, was equipped, air-conditioned, and added as a laboratory room. There is now adequate space for the radiocarbon laboratory.

2) Equipment

After the establishment of the radiocarbon laboratory in 1951, it was moved to the "new" Department of Physics in 1956. At that time equipment was purchased to convert from solid carbon to carbon dioxide gas proportional counting. We now have the following components for routine and experimental ^{14}C dating:

Two fume hoods for the pretreatment of samples with HCl and NaOH, nitrogen pyrolysis, and other projects.

One CO_2 combustion and purification train, as shown diagrammatically in Figs. 3 and 4.

Two counter-filling trains and vacuum systems. (One of these is used routinely for our standard ^{14}C counting; the other is available for experimental purposes.)

Three CO_2 gas proportional counters (two 8-liters and one 1-liter capacity), with surrounding shielding and associated electronic components, as shown diagrammatically in Fig. 5.

Oscilloscopes, voltohmmeters, thermocouples, potentiometers, and many other auxiliary components that are required to maintain the operation of the laboratory and to conduct new experiments.

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IX. PERSONNEL

A. The organization of MASCA and our basic financial support are shown in the attached block diagrams (Tables I and II).

B. Curricula vitae of the members of MASCA staff are attached.

X. SUMMARY

The activities of MASCA which in final analysis correlate with each other, may be summarized as follows:

1) Radiocarbon and thermoluminescent dating of samples in the laboratories.

2) Dendrochronology -- continued search for and dating of older bristle-cone pines.

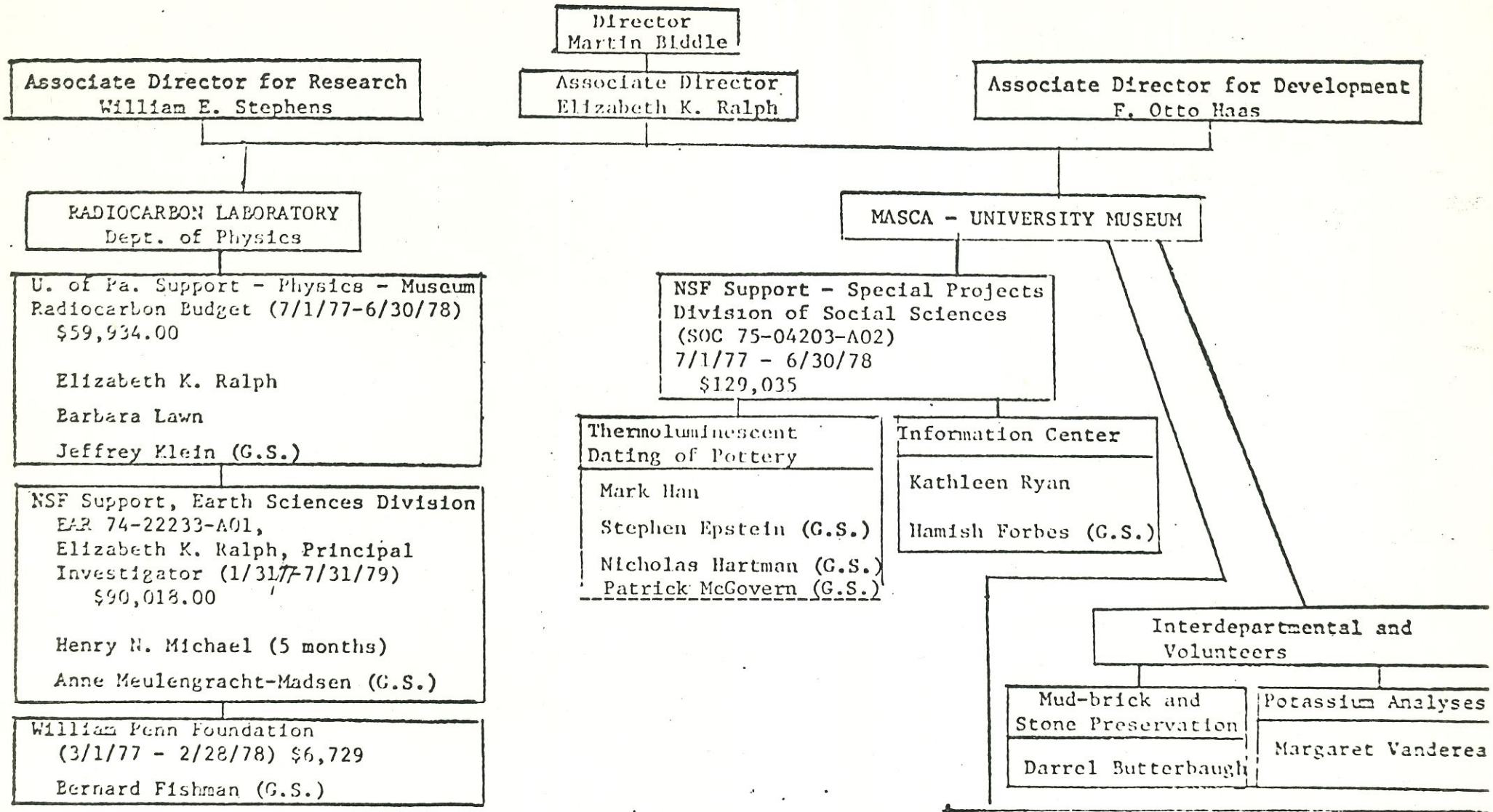
3) Near sensing -- ground surveys with geophysical prospecting instruments, including magnetometers and soil-penetrating radar.
Remote sensing -- both aerial photography and interpretation of satellite imagery.

4) Information Center -- the collation and dissemination of data gathered from pertinent literature, field surveys, excavations and laboratory dating, as well as of data related to other new techniques.

5) Chemical stabilization of archaeological structures.

TABLE I

MASCA PERSONNEL INCLUDING RADIOCARBON LABORATORY



NOTES: 1) G.S. = Graduate Student

2) The U. of Pa. and NSF grants include funds for supplies, equipment, services, etc. as well as for salaries.

TABLE II

CURRENT SUPPORT AND PENDING APPLICATIONS

Current Support

Radiocarbon Laboratory

University of Pennsylvania-Physics — $59,934.00
Radiocarbon Budget (7/1/77-6/30/78)

Elizabeth K. Ralph, Principal Investigator
6 man-months

NSF Support, Earth Sciences Division — 90,018.00
EAR 74-22233-A01 (1/31/77-7/31/79)

Elizabeth K. Ralph, Principal Investigator
2 man-months

MASCA Laboratories

NSF Support, Special Projects — 129,035.00
SOC 75-04203-A02 (7/1/77-6/30/78)

Martin Biddle, Principal Investigator
1.2 man-months

National Park Service, Valley Forge Project — 99,994.00
(1/10/77-12/31/78)

Elizabeth K. Ralph, Principal Investigator
2 man-months

Pending Support

MASCA grant proposal (7/1/78-6/30/80)

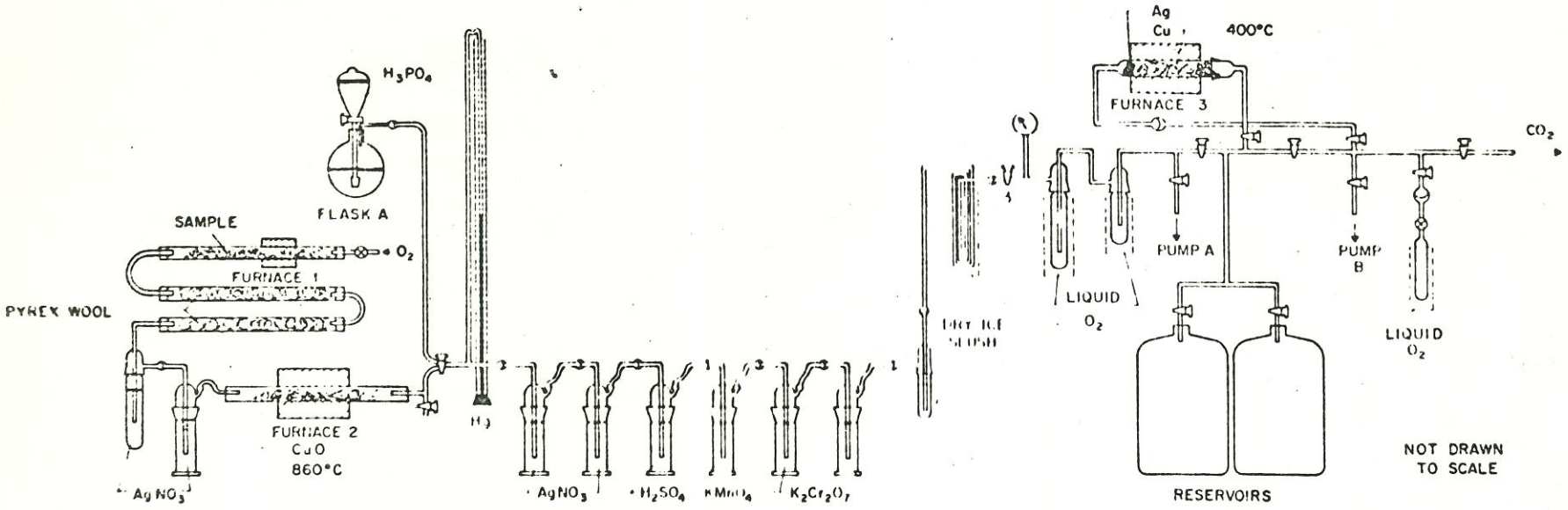


Fig. 3 Block diagram of U. of Pa. carbon dioxide combustion and purification train, Part I

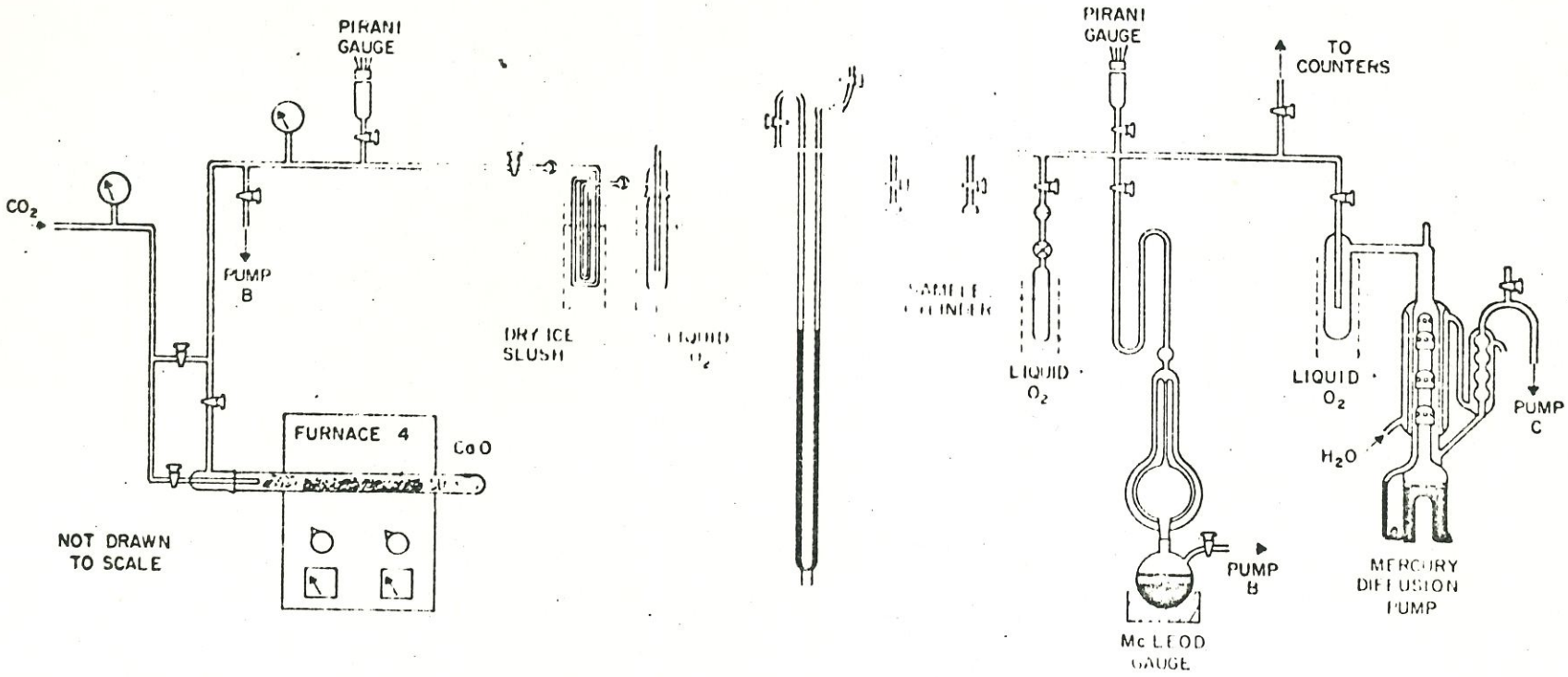


Fig. 4 Block diagram of U. of Pa. carbon dioxide combustion and purification train, Part II

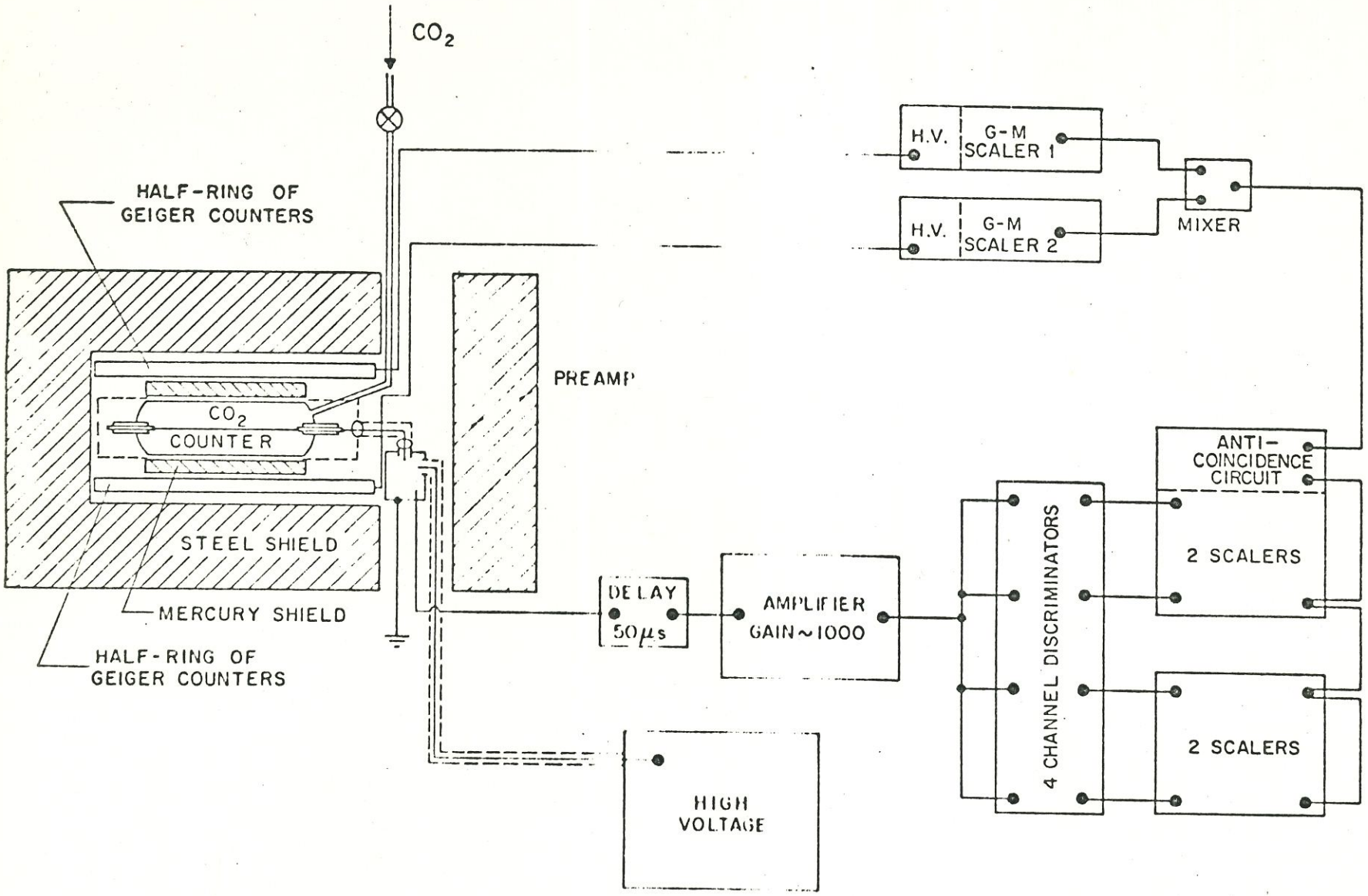


Fig. 5 Block diagram of U. of Pa. electronic counting system for radiocarbon dating

MASCA BUDGET - REQUESTED FROM NSF

	First year ending 6/30/79	Second year ending 6/30/80
A. THERMOLUMINESCENT (TL) DATING & NEW ASSOCIATED EXPERIMENTS		
1. Salaries & Wages		
a. Research Associate in the Basic Physical Sciences (A-2) Full-time - 12 months FTE - 12 man-months	17,000	18,020
b. Two Research Fellows (A-2)* 3 summer months - full-time; academic year - 1/2 time FTE - 8 man-months each	10,800	11,450
TOTAL SALARIES	$27,800	$29,470
2. Employee Benefits		
A-2 (27,800 X 24.8%)	6,894	(29,470 X 25.8%) 7,603
TOTAL EMPLOYEE BENEFITS	6,894	7,603
TOTAL SALARIES PLUS BENEFITS	$34,694	$37,073

*The two Research Fellows will be primarily associated with TL dating and new experiments. However, they will assist occasionally with field work, the Information Center and other projects in the laboratories; both in order for them to gain a broader experience and to help with the miscellaneous emergency needs of MASCA.

MASCA BUDGET (page 2)	First year ending 6/30/79		Second year ending 6/30/80
3. Expendable Equipment and Supplies	750		800
Nitrogen and other chemicals, sample containers, and minor laboratory supplies			
Minor electronic components including photomultiplier tubes	1,000		1,000
TOTAL EXPENDABLE EQUIPMENT AND SUPPLIES	$1,750		$1,800
4. Services			
Machine shop for assembly of experimental TL components	700		700
Service contract for central air-conditioning (This unit services all MASCA labs, but is most essential for the stability of the TL equipment)	250		300
TOTAL SERVICES	$950		$1,000
5. Travel			
For attending conferences at Brookhaven and nearby research centers	200		250
TOTAL - DOMESTIC	$200		$250
Archaeometry Conference (This was held at U. of P. in 1977 at no cost to NSF, and will probably be held abroad for several years)			900
TOTAL - FOREIGN			900
TOTAL - TRAVEL	$200		$1,150
6. SUB-TOTAL FOR CALCULATION OF OVERHEAD	$37,594		$41,023
7. OVERHEAD AT 52.5%	$19,737	(@ 54.0%)	$22,152
8. SUB-TOTAL PLUS OVERHEAD	$57,331		$63,175
9. Equipment			
Tektronix Oscilloscope with storage CRT (to replace obsolete, non-functioning CRO)	2,100		
Keithley (or equivalent) Linear Picoammeter (10^{-13} to 3 X 10^{-5} amps)	2,000		
New experimental, not readily available, such as Gas Chromatograph and associated components			5,000
TOTAL EQUIPMENT	$4,100		$ 5,000
10. OVERALL TOTAL	$61,431		$68,175

MASCA BUDGET (page 3)

		First year ending 6/30/79		Second year ending 6/30/80
B. ARCHAEOLOGICAL PROSPECTING WITH GEOPHYSICAL INSTRUMENTS, AERIAL, & REMOTE SENSING (Since Prospecting and Sensing are complimentary and are usually performed by the same personnel, these must necessarily be grouped together)				
1. Salaries and Wages				
a. Geophysicist, Research Specialist II (A-1) Full-time - 12 months (Bruce Bevan) FTE - 12 man-months		13,500		
b. Junior Research Specialist (A-1) Full-time - 12 months FTE - 12 man-months				13,000
TOTAL SALARIES		$13,500		$13,000
2. Employee Benefits A-1	(@ 18.5%)	2,498	(@ 19.5%)	2,535
TOTAL EMPLOYEE BENEFITS		$ 2,498		$2,535
TOTAL SALARIES PLUS BENEFITS		$15,998		$15,535
3. Expendable Equipment and Supplies				
a. For Archaeological Prospecting Spare parts, cables and minor components		500		1,000
b. For Aerial Photography and Remote Sensing Kites, filters, films, copies of satellite photos, etc.		635		1,000
TOTAL EXPENDABLE SUPPLIES AND EQUIPMENT		1,135		2,000

MASCA BUDGET (page 4)

	First year ending 6/30/79	Second year ending 6/30/80
4. Services		
a. Aircraft rental for aerial photography	300	500
b. Film processing	200	300
c. Machine shop for adaptation of items listed under equipment	300	300
TOTAL SERVICES	$800	$1,100
5. Travel		
For archaeological prospecting and aerial surveys at Lixus, Morocco and/or other sites (second year possibly Jordan) FOREIGN	1,200	1,500
Sites in U.S.A. such as controlled tests at Chaco Canyon, New Mexico DOMESTIC	500	700
TOTAL TRAVEL	$1,700	$2,200
6. SUB-TOTAL FOR CALCULATION OF OVERHEAD	$19,633	$20,835
7. OVERHEAD AT 52.5%	10,307	(@ 54%) 11,251
8. SUB-TOTAL PLUS OVERHEAD	$29,940	$32,086
9. Equipment		
For color anomaly detector	430	
For traverse marker	350	
For profiling radiometer	350	
TOTAL EQUIPMENT	$1,130	
10. OVERALL TOTAL	$31,070	$32,086

MASCA BUDGET (page 5)

	First year ending 6/30/79		Second year ending 6/30/80
C. INFORMATION CENTER			
1. Salaries and Wages			
Research Bibliographer (Kathleen Ryan)	10,560	(A-3)	11,190 (A-1)
Full-time - 12 months			
FTE - 12 man-months			
TOTAL SALARIES	$10,560		$11,190
2. Employee Benefits			
A-1 X 19.5%			2,182
A-3 X 29.5%	3,115		
TOTAL EMPLOYEE BENEFITS	$3,115		$2,182
TOTAL SALARIES PLUS BENEFITS	$13,675		$13,372
3. Materials and Supplies			
a. Book purchases	750		800
b. Journal subscriptions	700		750
c. Office supplies and duplicating (including xerox copying)	400		500
TOTAL MATERIALS AND SUPPLIES	$1,850		$2,050
4. Publication of MASCA Newsletter			
Two issues per year @ 4¢ /page	3,000		
@ 5¢ /page			3,500
TOTAL PUBLICATION COSTS	$3,000		$3,500
5. SUB-TOTAL FOR CALCULATION OF OVERHEAD	18,525		18,922
6. OVERHEAD AT 52.5%	9,725	(54.0%)	10,218
7. OVERALL TOTAL	$28,251		$29,140

FINAL

MASCA BUDGET (page 6)

		First year ending 6/30/79		Second year ending 6/30/80
D. MUD-BRICK AND FRIABLE STONE PRESERVATION				
1. Salaries - NONE This work is performed by Darrel Butterbaugh, a volunteer Research Chemist. In the field, he is frequently assisted by students and workmen at excavations conducted by the University Museum and other Institutions		- 0 -		- 0 -
2. Chemical supplies and minor components for testing new methods of preservation		1,000		1,000
3. Travel				
a. Foreign Mud-brick preservation at Lixus, Morocco		1,200		
Preservation and inspection at Petra, Greece and Hasanlu, Iran				1,700
b. Domestic - Inspection at Chaco Canyon, N.M., etc.				400
4. Sub-total for calculation of overhead		$2,200		$3,100
5. Overhead	(@ 52.5%)	1,155	(@ 54%)	1,674
6. Equipment - NONE				
7. OVERALL TOTAL		$3,355		$4,774

MASCA BUDGET - SUMMARY (page 7)

ACTIVITIES	First Year	Second Year	Total
A. Thermoluminescence	61,431	68,175	129,606
B. Prospecting & Aerial Photography	31,070	32,086	63,156
C. Information Center	28,251	29,140	57,391
D. Preservation	3,355	4,774	8,129
TOTALS	$124,107	$134,175	$258,282

Final

SUMMARY PROPOSAL BUDGET

EXHIBIT II-4

ORGANIZATION AND ADDRESS
MASCA, University Museum, 33rd and Spruce Streets,
Philadelphia, Pa. 19104

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR
Martin Biddle

FOR NSF USE ONLY
PROPOSAL NO.
DURATION (MONTHS) PROPOSED | REVISED

NSF USE	A. SENIOR PERSONNEL (LIST BY NAME; SHOW NUMBERS OF PEOPLE IN BRACKETS; SALARY AMOUNTS MAY BE LISTED ON SEPARATE SCHEDULE) GPM 205.1b	NSF FUNDED MAN MONTHS CAL.	ACAD	SUMR	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
	1. P.I./P.D. Martin Biddle, Director	1.2			$ 0	$
	2. CO P.I./P.D.				$	$
	3. CO P.I./P.D.				$	$
	4. CO P.I./P.D.				$	$
	5. CO P.I./P.D.				$	$
11115	6. ( ) SUBTOTALS A1 - A5				$	$
	FACULTY AND OTHER SENIOR ASSOCIATES (ATTACH EXTRA SHEET IF NECESSARY)					
	7. Elizabeth K. Ralph, Assoc. Director	4			$ 0	$
	8. William E. Stephens, Assoc. Dir. for Res.		1		$ 0	$
	9. F. Otto Haas, Assoc. Dir. Development	1			$ 0	$
	10.				$	$
	11.				$	$
11117	12. ( ) SUBTOTALS A7 - A11	6.2	1		$ 0	$
	B. OTHER PERSONNEL (LIST NUMBERS IN BRACKETS)					
11141	1. (2) POSTDOCTORAL ASSOCIATES	12			$ 30,500	$
11149	2. ( ) OTHER PROFESSIONALS				$	$
11150	3. (2) GRADUATE STUDENTS				$ 10,800	$
11152	4. ( ) UNDERGRADUATE STUDENTS				$	$
11182	5. (1) SECRETARIAL - CLERICAL				$ 10,560	$
11183	6. ( ) TECHNICAL, SHOP, OTHER				$	$
	TOTAL SALARIES AND WAGES (A+B)				$ 51,860	$
11200	C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$ 12,507	$
	TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$ 64,367	$

D. EQUIPMENT (LIST ITEMS AND DOLLAR AMOUNTS FOR EACH ITEM)

Color anomaly detector	430
Traverse marker	350
Profiling radiometer	350
Tektronix Oscilloscope with storage CRT	2,100
Keithley (or other) Linear Picoammeter with range of 10^{-13} to 3×10^{-5} amps.	2,000

23181 TOTAL EQUIPMENT $ 5,230 | $

E. MATERIALS AND SUPPLIES

32630 Chemical, minor electronic components, magnetometer batteries, films and other minor items for aerial photography $ 3,885 | $

F. DOMESTIC TRAVEL

42111 Field research and conferences at nearby centers $ 700 | $

G. FOREIGN TRAVEL (LIST DESTINATION AND AMOUNT FOR EACH TRIP; GPM 731)

42112 Archaelological prospecting and mud-brick preservation at Lixus, Morocco (2 persons) $ 2,400 | $

SUMMARY PROPOSAL BUDGET

PROPOSAL NO.

52999	H. PUBLICATION COSTS/PAGE CHARGES MASCA Newsletter @ 4¢/page	$ 3,000	$
62315	I. COMPUTER (ADPE) SERVICES	$	$
	J. CONSULTANT SERVICES (IDENTIFY CONSULTANTS BY NAME AND AMOUNT; GPM 516)		
	K. PARTICIPANT SUPPORT COSTS, IF ALLOWED BY PROGRAM GUIDE (ITEMIZE) GPM 518	$	$
	1. STIPENDS $		
	2. TRAVEL $		
	3. SUBSISTENCE $		
	4. OTHER - SPECIFY $		
	5. TOTAL PARTICIPANT COSTS (K1 + K2 + K3 + K4) $		
	L. ALL OTHER DIRECT COSTS (List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.)	$	$
	Book purchases and journal subscription $ 1,450		
	Services - Xerox and duplication $ 400		
	" machine shop, aircraft rental, film $ 1,500		
	Contract: air conditioning $ 250		
5991	TOTAL OTHER DIRECT COSTS		
	M. TOTAL DIRECT COSTS (A THROUGH L)	$ 3,600	$
	N. INDIRECT COSTS (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs included in on/off campus bases in remarks.)	$ 83,182	$
	University of Pennsylvania overhead		
	@ 52.5% for all items except equipment		
2100	TOTAL INDIRECT COSTS		
	O. TOTAL DIRECT AND INDIRECT COSTS (M + N)	$ 40,925	$
5500	P. LESS RESIDUAL FUNDS (If for further support of current project; GPM 252 and 253)	$ 124,107	$
5555	Q. AMOUNT OF THIS REQUEST (O MINUS P)	$	$
		$ 124,107	$

REMARKS

NOTE: SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233). THIS IS REVISION NO.

SIGNATURE OF PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	DATE OF SIGNATURE	TYPED OR PRINTED NAME AND TITLE
SIGNATURE OF AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	DATE OF SIGNATURE	TYPED OR PRINTED NAME AND TITLE

FOR NSF USE ONLY

INDIRECT COST RATE VERIFICATION			PROGRAM OFFICER APPROVAL
Date Checked	Date of Rate Sheet	Signature	

Grant Number	Amend No.	Institution	Organization	Fund Acct.	Program	Object

Proposal Number	Dur.	Chr.	Award Date	Proposed Amount	Prgm Ele.

Final

SUMMARY PROPOSAL BUDGET

EXHIBIT H 4

ORGANIZATION AND ADDRESS

MASCA, University Museum, 33rd and Spruce Streets, Philadelphia, Pa. 19104

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR

FOR NSF USE ONLY
PROPOSAL NO.
DURATION (MONTHS) PROPOSED | REVISED

NSF USE	A. SENIOR PERSONNEL (LIST BY NAME; SHOW NUMBERS OF PEOPLE IN BRACKETS; SALARY AMOUNTS MAY BE LISTED ON SEPARATE SCHEDULE) GPM 205.16	NSF FUNDED MAN MONTHS CAL.	ACAD.	SUMR.	FUNDS REQUESTED BY PROPOSER	FUNDS GRANTED BY NSF (IF DIFFERENT)
	1. P.I./P.D. Martin Biddle, Director	1.2			$ 0	$
	2. CO P.I./P.D.				$	$
	3. CO P.I./P.D.				$	$
	4. CO P.I./P.D.				$	$
	5. CO P.I./P.D.				$	$
11115	6. ( ) SUBTOTALS A1 - A5				$	$
	FACULTY AND OTHER SENIOR ASSOCIATES (ATTACH EXTRA SHEET IF NECESSARY)					
	7. Elizabeth K. Ralph, Associate Director	5			$ 0	$
	8. William E. Stephens, Assoc. Director Research		1		$ 0	$
	9. F. Otto Haas, Assoc. Dir. Development	1			$ 0	$
	10.				$	$
	11.				$	$
11117	12. ( ) SUBTOTALS A7 - A11	7.2	1		$	$
	B. OTHER PERSONNEL (LIST NUMBERS IN BRACKETS)					
11141	1. ( ) POSTDOCTORAL ASSOCIATES				$	$
11149	2. (1) OTHER PROFESSIONALS	12			$ 18,020	$
11150	3. (2) GRADUATE STUDENTS				$ 11,450	$
11152	4. ( ) UNDERGRADUATE STUDENTS				$	$
11182	5. (1) SECRETARIAL - CLERICAL				$ 11,190	$
11183	6. (1) ~~XXXXXXXXXXXX~~ OTHER Jr. Research Specialist				$ 13,000	$
	TOTAL SALARIES AND WAGES (A+B)				$ 53,660	$
11200	C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$ 12,320	$
	TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$ 65,980	$
	D. EQUIPMENT (LIST ITEMS AND DOLLAR AMOUNTS FOR EACH ITEM)					
	New equipment - Gas Chromatograph and associated components for experiments directed toward organic chemistry, analyses of gases, etc.					
11183	TOTAL EQUIPMENT				$ 5,000	$
	E. MATERIALS AND SUPPLIES					
	Chemical, minor electronic components, batteries, films, and other minor items, for aerial photography					
12630					$ 4,800	$
	F. DOMESTIC TRAVEL					
12111	Field work Chaco Canyon, N. Mexico & local conferences				$ 1,350	$
	G. FOREIGN TRAVEL (LIST DESTINATION AND AMOUNT FOR EACH TRIP; GPM 731)					
	Mud-brick preservation in Petra, Greece and Hasanlu, Iran;				1,700	
	Annual Archaeometry & Geophysical Prospecting Conference in Europe				900	
	Geophysical Prospecting, Lixus and Jordan				1,500	
12117					$ 4,100	$

FINAL

MASCA -- Second Year (continued)

XHIBIT H-4 con.

AGE 2 OF 2 PAGES

SUMMARY PROPOSAL BUDGET

PROPOSAL NO.

2225	H. PUBLICATION COSTS/PAGE CHARGES MASCA Newsletter @ 5¢/page	$ 3500	$
2315	I. COMPUTER (ADPE) SERVICES	$	$
	J. CONSULTANT SERVICES (IDENTIFY CONSULTANTS BY NAME AND AMOUNT; GPM 516)		
		$	$
	K. PARTICIPANT SUPPORT COSTS, IF ALLOWED BY PROGRAM GUIDE (ITEMIZE) GPM 518		
	1. STIPENDS $		
	2. TRAVEL $		
	3. SUBSISTENCE $		
	4. OTHER - SPECIFY $		
	5. TOTAL PARTICIPANT COSTS (K1 + K2 + K3 + K4)	$	$
	L. ALL OTHER DIRECT COSTS (List items and dollar amounts. Details of subcontracts, including work statements and budget, should be explained in full in proposal.)		
	Book purchases and journal subscriptions $ 1,550		
	Services - Xerox & duplicating $ 500		
	Services - machine shop, aircraft rental, film processing. Air conditioning contract & other repairs $ 300		
5001	TOTAL OTHER DIRECT COSTS	$ 4,150	$
	M. TOTAL DIRECT COSTS (A THROUGH L)	$ 88,880	$
	N. INDIRECT COSTS (Specify rate(s) and base(s) for on/off campus activity. Where both are involved, identify itemized costs included in on/off campus bases in remarks.)		
	University of Pennsylvania overhead @ 54.0% for all items except equipment		
4100	TOTAL INDIRECT COSTS	$ 45,295	$
	O. TOTAL DIRECT AND INDIRECT COSTS (M + N)	$134,175	$
5500	P. LESS RESIDUAL FUNDS (If for further support of current project; GPM 252 and 253)	$	$
5000	Q. AMOUNT OF THIS REQUEST (O MINUS P)	$134,175	$

REMARKS

NOTE: SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPM 233). THIS IS REVISION NO.

SIGNATURE OF PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR	DATE OF SIGNATURE	TYPED OR PRINTED NAME AND TITLE
SIGNATURE OF AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	DATE OF SIGNATURE	TYPED OR PRINTED NAME AND TITLE

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INDIRECT COST RATE VERIFICATION			PROGRAM OFFICER APPROVAL
Date Checked	Date of Rate Sheet	Signature	

Grant Number	Amend No.	Institution	Organization	Fund Assy	Program	Object	

Proposal Number	Dur.	Cog.	Award Date	Proposed Amount	Period Cov.	

DATE	CODE	CLASS	DEPT. NO.	ACCOUNT	JOB NO.	REQ. NO.
11-11-76	27	5	27708 XB	213		77-5

ORDER NO. 20691

1. INVOICE IN DUPLICATE TO
UNIVERSITY OF PENNSYLVANIA
PURCHASING DEPARTMENT
PHILADELPHIA, PA. 19174
Telephone 243-7216
2. Refer to this number on all invoices, packages, and correspondence.
3. No changes to this order unless authorized by the Purchasing Dept.
4. See terms and conditions on reverse side.

L
875. TO HERBACH & RADEMAN INC
401 E ERIE AVE
PHILA PA 19134
ATT NICK RAONE

Deliver to 209 S 33RD ST PHILA PA 19174
E K RALPH X 8168

DEPARTMENT PHYSICS DES 22233

SHIPPING INSTRUCTIONS

		EST. COST
25	GC10B DECATRON TUBES @ 35.00	875.00
	SHIP PREPAID- CONFIRMING- DO NOT DUPLICATE	

In response to the question of our awareness of TL developments going on elsewhere, as well as our apparent failure to incorporate these "advances" into our TL methodology, we would like to point out the following:

(1) The Information Center here at MASCA provides a ready source of current research developments and applications in all of our fields of research including TL.

(2) We are in constant communication with other laboratories working in the field of TL dating.

(3) We assist other institutions who are desirous of setting up their own TL laboratories, despite the acknowledged difficulties and uncertainties of the method as a dating technique.

The approach of the TL laboratory at MASCA is different from that of some institutions, notably Oxford. At Oxford, work has proceeded as thesis projects of graduate students under the direction of Dr. M.J. Aitken. For a thesis in physics, it is essential to investigate a fundamental aspect of a physical process. At MASCA, work is directed toward continued development of a single technique, in an effort to improve its reliability and usefulness. As a result, the character of the research is different. It is not always desirable to immediately adopt new techniques with their unsolved problems in preference to refining existing ones which have benefited from constant development. Through the years, since our initial report in 1966, we have carried out our dating by the same general procedure, in order to accumulate sifficient data to show the workability of TL for archaeological purposes. At the same time we have continued research into the associated problems in an effort to improve reliability of TL as a means of dating.

In response to the specific criticisms of the reviewer, we would like to make the following comments:

(1) Although we would agree with the reviewer that the currently employed measurement of induced TL susceptibility should provide an adequate correction for the variations in natural TL sensitivity, we have reason to suspect that this correction may not be adequate in all cases. In 1974, when we first presented our findings on quartz susceptibility as a function of annealing temperature, we

thought there was a direct relationship implying increasing sensitivity with increasing annealing temperature. Subsequently our work with clays has added to our appreciation of the complexities of the relationship (see p. 11). No one has yet shown that the sensitivity/temperature relationship is the same for all types of radiation, and it is this which we feel must be investigated in order to eliminate any doubt concerning sensitivity assessments made by measuring X-ray induced TL. The work published by Fleming (Archaeometry 15(1973)3-30) is not relevant to this question, since it is concerned with the pre-dose methods of annealing samples at 500° C to change the 320° C peak.

(2) Most of the factors found by other laboratories which affect TL determined ages have in fact been discovered by Oxford, and are influential to the extent that TL is considered an absolute and not a relative dating technique. In particular, though grain size is undoubtably important to dating methods using the inclusion method (S.J. Fleming, Archaeometry 12,2(1970)133-146), in tests conducted here at MASCA using the relative dating technique, whole sherds are used. Similarly, variations in alpha efficiency, effects of ground water, supralinearity and anomalous fading (A.G. Wintle, Archaeometry Conference, Philadelphia 1977) are factors affecting the TL-determinations using the fine grain method (D.W. Zimmerman, Archaeometry 13,1(1971)29-52) and do not seem to be of great importance to TL dating as done at MASCA. The general applicability of these three recent methods has not been demonstrated; most of the pioneering work was done on carefully selected sherds. Furthermore, the principal investigators have expressed doubts (M. Aitken to E.K. Ralph at the 1977 Archaeometry Conference). The only factor mentioned which we have found to be important is the assumption of equilibrium in the thorium decay series. In cooperation with the nuclear physics department, we are currently using a solid state (lithium drifted germanium crystal) γ -detector and a multi-channel analyzer to test this equilibrium. The results of these experiments indicate that

the ratio of thorium to uranium is not a constant, but ranges from 0.5 to 4.0. Additionally, using the γ-detector, we are able to test for radon leakage and can calculate the total energy deposited as a result of the internal radioactivity. In preliminary results obtained thus far, it appears that the total energies deposited as calculated from the γ-detector are in good agreement with estimates from α-counting.

(3) As already mentioned, we do feel that it is important to examine the temperature dependence of the TL-phenomenon. Matrix and firing temperature have been shown to be two of the more important factors affecting TL. TGA and DTA are subject to serious limitations imposed by reabsorption of water and other factors, but may well be effective techniques, when coupled with TL measurements, for determining firing temperatures, as detailed on pages 25-26 of the proposal.

(4) The method of sample preparation developed by Mr. J.R. Watson (former graduate student assistant of MASCA) was different from that reported by Goken and co-workers (thin-section method). For further clarification on this point, see MASCA Newsletter 12,2(December 1976).

(5) Eight articles were published between 1966 and 1976 dealing with TL development and specific problems associated with work at MASCA. These are listed in the Curricula Vitae of the staff, p. 51.

PRESERVATION OF MUD-BRICK AND STONE STRUCTURES

We did not mean to imply that preservation research was unique to MASCA. On the contrary, we are very well aware of work that is being done at other institutions, especially work done in Italy, Iraq, and in our own National Park Service. Dr. Butterbaugh, our volunteer research chemist, is a member of the Association for Preservation Technology and attends meetings concerning preservation problems. Mr. Vincent Pigott, Dr. Butterbaugh's volunteer associate, attended the Second International Symposium on the Conservation of Buildings in Mud Brick at Yazd in March 1976 giving him an opportunity to discuss common problems with experts from all over the world. As a result of our own bibliographic research at MASCA, contact with other researchers in this field, and personal observations of eroding mud and stone structures in many parts of the world, we feel that we do indeed recognize the "serious difficulties" involved.

Dr. Butterbaugh has worked for many years with materials which are used as cement additives and improvers and with other polymers and resins. He is able to draw on the large background knowledge acquired from his former business association with a large chemical company. E-330, for instance, has been thoroughly tested and is used as a cement additive and improver. This is the first significant testing of E-330 as a soil stabilizer. The material has been tested in the Southwest U.S. for three years. Best results have been achieved by applying a water/mud/E-330 plaster over existing walls so the problem here is to get good adhesion rather than deep penetration of the material into the wall. With A-21 the penetration is 2-4 cm. Others have used these same or similar solutions at much higher concentrations and penetration has been poor. We are using very dilute solutions and so we are achieving deeper penetration.
If and when failure occurs, whether due to greatly accelerated lab weathering by simulated rain, and freezing and thawing, or by natural erosion due to outdoor exposure, only the top surface grains or particles of soil erode, not the entire depth of treatment. Therefore less damage occurs than would occur from normal weathering of untreated surfaces. To the best of our knowledge no effective method of solidifying mud brick walls has been developed which will withstand hundreds of wet/freeze/thaw cycles.
These treatments do.

We measured the samples not by fundamental measurements but by subjecting them to wet/freeze/thaw tests in the lab. We as well as others have made physical measurements for hardness, stiffness, water repellancy, abrasion, etc. but the real test is for durability in the field. This is precisely the purpose of our tests in Iran, Florida, Chaco Canyon and Guatamala. We know that it will be many years before we can expect conclusive results. It is also essential that more than one test be established in various parts of the world. Climatic conditions, modes of construction, types of clay, etc. vary widely between different parts of the world where mud structures are constructed. In the case of stone weathering, conditions vary even more widely. We therefore must make allowance for special problems in different areas. To avoid damage to archaeological structures only very limited surfaces have been treated. In most cases we have constructed our own mud brick walls in the test areas.

One of our experiments in Guatamala which was geared towards the problem of constructing safer structures in an area likely to be damanged by earthquakes was in collaboration with a team from CARE and was only one of many experiments which included experimental constructions of quake proof structures using various materials - from treated adobe, to wood, to ferro cement. It was suggested that the lower courses of houses might be constructed of treated adobe to prevent the serious problem of the adobe buildings collapsing due to the seepage of rain or groundwater.