Conservation

Analytical

Laboratory

Annual Report

1995
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Foreword

Lambertus van Zelst, Director

Fiscal year 1995 posed a multitude of challenges to the Conservation Analytical Laboratory, and I am proud to state that the staff truly rose to the occasions. The year started with the full implementation of the revised organizational structure, which required staff to adapt to new reporting lines and, as the year progressed, new or revised policies and procedures. Short term programmatic priorities were developed that resulted in reallocations of staff and other resources, including work spaces, and the phasing out of some programs and projects. In Research and Development, the highest priorities were assigned to the various conservation research programs, with work on the preservation of natural history collections especially earmarked for increased allocations and activity. The biogeochemistry program also received high priority, as it is closely interrelated to the science collection preservation work. In the characterization of archaeological and historical materials, trace element source characterization of ceramics remains a high priority, and it is anticipated that in the near future new analytical technologies will be introduced in this work. In Education and Training, shifts were made in the types of internships provided, and the production of reference texts was identified as an area for increased emphasis. Production and aggressive marketing of a series of revised CAL "Guidelines," in an attractive and consistent format, was recognized as a high priority for the immediate future. More in general, an emphasis on educational outreach to related professions and sectors of the general public, especially students at various educational levels, was identified as imperative. In Support and Collaboration, the continued provision of high-quality analytical, technical, and information support services to CAL programs and other Smithsonian units was recognized as a high priority. A mechanism for collaborative projects with other units in which CAL staff devote more substantial time and other resources to such a project, was created, and indeed two such projects are now in place with the Arthur M. Sackler Gallery as partner. Continued strengthening of the in-house technical production of publications and the automatization of the filing and retrieval of technical information were identified as areas for special attention.

Absorbing and adapting to these changes would in themselves already have represented a substantial burden on the staff, but the problems were complicated even further. In December 1994 a change in the plans for the highly needed replacement of the Museum Support Center's ventilation system confronted CAL with an imminent shutdown of about half the laboratory for a period of three to four months, followed by a similar shutdown for the other half. Generous assistance in the form of temporary laboratory spaces elsewhere in the Museum Support Center was offered by the National Museum of Natural History. These spaces allowed various research programs to continue during the seven month construction period, although substantial time and effort went into moving back and forth. Some of the larger instruments could not be moved, however, such as the scanning electron microscope and x-ray equipment, and as a result the Analytical Support group in particular was severely handicapped. Education programs were also affected by these shutdowns as no laboratories were available for courses and fellows and interns had to work in temporary spaces or even outside CAL. The space reallocations mentioned above were implemented as staff moved back into refurbished laboratories and office areas, and by the end of the fiscal year all programs were fully up and running in their new work spaces. The CAL staff, while
occasionally laboring under great stress, overcame many obstacles and made fine progress in a wide range of programs and projects. The following pages of this annual report document these accomplishments, but it is important to note the often-difficult conditions under which they were achieved.

Another major event for CAL took place in September 1995, just before the end of the fiscal year. It had been quite a few years since CAL had received an external review, and in consultation with the Smithsonian Institution's Provost and the Assistant Provost for Science a decision was reached to convene a meeting of a newly established CAL Advisory Committee. Invited to this committee were seven international experts in conservation science and education, museum research, anthropology, and archaeology. Having been provided with ample documentation in advance, the committee met at CAL for a critical review of programs, organization, priorities, and resource allocations. During a two-day period, the members of the committee received briefings by Smithsonian and CAL management, heard presentations by project leaders, met with individual staff, and inspected the facilities. We all are very grateful for the considerable amount of time and effort that all these committee members have devoted to this review. While the committee's report could of course not be completed before the end of the year, preliminary reactions from the members were very positive and appear to confirm the quality of CAL programs and the validity of its goals. I hope that this annual report for the fiscal year 1995 will elicit similar reactions in its readers.

I want to thank all CAL staff for their contributions for this report and especially the three program coordinators, Ronald L. Bishop, Donald C. Williams, and Melanie E. Feather, who introduced, organized, and edited the material, and Gail L. Goriesky, who took care of design and production. I hope that our readers will enjoy this report, and I welcome all comments and questions.
Research and Development

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Research at the Conservation Analytical Laboratory is, by its very nature, interdisciplinary. The research staff represent a wide range of disciplines, and the interaction among them achieves a fuller understanding of complex objects, conditions, and contexts. Specialists from different fields, such as chemistry, engineering, conservation, and archaeology share specialized equipment and may collaborate to solve specific problems. Projects examine the preservation-related properties of materials and the processes and parameters of their deterioration, extract historical information from the technical record of artifacts, and develop and improve conservation treatment technology.

Preservation research in CAL strives to enlarge understanding of how materials and composite objects deteriorate. This research generates both data and models used to formulate conditions for storage, display, and other uses that will minimize deterioration. CAL projects also develop and test treatment technologies for stabilizing deteriorating collection materials. All these studies require analyses and characterizations of object materials and deterioration products and examination of
the way external and internal factors, such as environmental conditions or chemical composition and physical structure, affect the nature and rate of these alteration mechanisms.

Collections-based research draws on the vast reservoir of the scientific information contained in the natural and cultural materials curated in the Smithsonian and other institutions. Research using these collections develops, adapts, and applies methods of analysis for the characterization of materials to expand understanding of the biological, technical, economic, social, or political aspects of past lifeways. Depending upon the specific questions asked, the scale of the investigations varies widely. Collaborations with non-CAL scholars are a critical component for many projects, permitting not only the increased benefit of greater intellectual diversity but also wider access to collections and highly specialized instrumentation.

Although their objectives differ, CAL's research programs all involve the analysis and characterization of cultural and natural collections materials and the environments in which they are curated. Specific projects are initiated by CAL staff and by Smithsonian bureaus and research units. Projects may also be undertaken in response to suggestions made from the national and international professional community. CAL staff prepare formal proposals that describe the specific problem to be investigated, the methodology that will be employed, and the expected significance of the research. These proposals may be subjected to both internal and external review. Scholarly quality, importance and relevance to the appropriate professional audience, nationally and internationally, and concurrence with formulated priorities are the principal criteria in program development. Timely peer-reviewed publication of the research is required.

Significant accomplishments of CAL research projects during fiscal year 1995 are described below.
Preservation Technology

Damage to cultural and artistic objects results from both chemical reactions and mechanical responses to changes in temperature, relative humidity, and impact and vibration. Collaborative research among CAL scientists has progressed beyond the point of determining the sources and mechanisms of most of environmentally induced deterioration; the effects of potentially hazardous environmental and transit conditions for most objects can now be predicted. Research direction benefits from the use of a general theoretical model that mathematically relates externally applied forces to environmentally induced stresses in materials. This model allows the use of standard engineering test procedures to characterize the physical and mechanical properties of the cultural materials typically found among the objects in the Smithsonian Institution's collections.

Mechanics Research and the Effects of Environments

Studies of the response of materials and composite objects to changes in environmental conditions and the formulation of safe and cost-efficient environmental condition ranges for collections have now reached the stage where safe ranges have been formulated for the exhibit and general storage of collections. This work by CAL staff has generated great interest in the museum field. Research findings were originally presented in a news release from the Smithsonian Institution's Public Affairs Office for August 21, 1994. The November 1994 AIC Newsletter and the December 12 issue of the Smithsonian Torch also picked up on the Smithsonian press release.

An invited explanation of CAL's environmental work was published in the Western Association for Art Conservation's WAAC Newsletter. The WAAC article was reviewed in the December 1994 Abbey Newsletter. Further publicity continued in the March/April 1995 issue of Museum News, which featured a short description of the environmental research. The summer 1995 issue of the Smithsonian's Research Reports reported on the impact of the press release on how museums address environmental issues. The AIC Newsletter for September 1995 reviewed the research on environment for the past year and the effects of the earlier press release on how the museum environment is maintained. It also summarized the presentations of CAL staff at a June symposium concerning the appropriate standards for the indoor environment.

Within the Smithsonian, past environmental specifications have been set aside in light of the CAL research, and new testing techniques are being invoked to obtain a more efficient-energy management. Recognizing the relevance of these results for Smithsonian Institution guidelines for climate control standards in its facilities, CAL has detailed the two principal researchers to the Office of Design and Construction to assist in the formulation of these guidelines.
Photographic Materials

Research is undertaken on the physical and chemical properties affecting the preservation of photographic materials. By far the major portion of the photographic materials in collections can be characterized as "modern," that is, gelatin based. However, within this group a wide variety of substrates and color rendition technologies present a series of preservation problems. While most of these are of a chemical nature and could be negated by storage at low temperature, mechanical consequences of such storage environments have to be evaluated to complete the picture of long-term preservation.

Low-Cost Storage Systems

Many chemically-related deleterious effects are slowed at cold temperatures, therefore prolonging the life of the images by several orders of magnitude. Research led to the use of an equation that correctly predicts the time required for a specific moisture-content rise in photographic materials when they are packaged in moisture-barrier polymers such as low-density polyethylene and stored in conventional freezers. A project to develop a low-cost packaging method was completed, resulting in an easy and inexpensive packaging system that is designed to control and monitor relative humidity and to function satisfactorily in relatively inexpensive commercial freezers. This generic packaging method, originally developed in FY 1994, allows a wide variety of photographic materials (motion picture films, sheet and roll still films, fiber-based and resin-coated prints, etc.) to be safely stored at subzero temperatures. The method employs two recloseable polyethylene bags - a simple moisture trap comprised of a small volume of hygroscopic materials, such as paper, mat board, or silica gel, and a cobaltous chloride moisture content indicator to show that the package is functioning safely. The packaging was refined to the point of implementation during 1995.

More than 100 copies of a paper describing the findings of the cold storage research, prepared for publication in the Journal of Society of Archivists, have been requested in advance of publication. Within the Smithsonian, the packaging method will be used to store the nitrate and color slide photographic materials of the Freer Gallery of Art Library. Also at the Freer Gallery of Art Library, a new cold storage vault will be converted to conform to the guidelines established by the research.
Chemical Degradation Processes

Paint Cleaning Study

The cleaning of paintings has been investigated from a number of aspects, including the effects of solvents and aqueous cleaning agents. The purpose of the research is to improve approaches to the cleaning of paintings, making it as safe as possible by defining the possible effects and determining the ways various cleaning agents and processes act on paint films. The results of the study of the effects of resin soaps on paints have been published, and the study of the effects of solvents cleaning on paint films is under way. This current phase uses paint films cast from paints specially formulated for this project using traditional materials. Results from this work will be used to determine criteria and procedures to minimize the effects of cleaning on paint films.

This research, in combination with CAL's environmental research, has resulted in collaboration with the Norwegian Institute for Cultural Heritage Research in the analysis of paint from, and environmental recommendations for, the medieval wooden stave churches in Norway.
Modern Materials

Polymeric Materials

Research concerning this class of materials seeks to develop a resource center for modern polymeric materials that will serve the Smithsonian Institution and other museums by compiling historical information on the technology of modern plastics and elastomers and information on chemical aging and degradation processes and developing recommendations for the treatment of objects. The initial focus is on the understudied class of elastomers.

Comparisons of relatively new rubber materials from spacesuits and aircraft tires with older rubber artifacts (up to 400 years old) yielded information that will help preserve the thermal history information held by both. New rubber displays only small amounts of crystallinity, which forms at a very slow rate at room temperature. Previous studies had demonstrated that this crystallization rate increases at lower temperatures, while the heat necessary to remove the crystals decreases. This finding had indicated that optimal storage temperatures for rubber were below 5 degrees C, since the crystallinity could be removed easily by allowing the objects to sit at room temperature before handling. The purpose of including old rubber in the studies was to expand on previous artificial aging studies, which had demonstrated that the above phenomena held true in oxidized rubber; oxidized rubber crystallized more slowly but still held the same temperature relationships.

The results of thermal analysis on naturally aged rubber from the Southwest United States and Mexico, however, were surprisingly rich in information, indicating multiple crystal formation temperatures as well as a previously unknown degree of crystallization. The environmental information preserved in these artifacts is complex and can easily be lost if the artifacts are exposed to solvents or heat, indicating the need for caution when handling, cleaning, and storing the artifacts.

Future work in this project may include increasing the number of old rubber samples studied, drawing on the collections of the National Museum of the American Indian. For the present, the data gathered have supplied the basis for a new guideline on the storage of rubber artifacts.
Magnetic Media

The Fourier transform infrared spectroscopic (FTIR) technique that was developed previously to study the binder on videotape was further modified so that no samples needed to be taken for analysis. The tapes can now be analyzed by spooling a small amount of slack out from the tape cassette and placing it under the attenuated total reflectance attachment for the FTIR microscope. The attachment is brought into light contact with the tape, with the pressure of contact monitored by transducers to ensure that the tapes are not damaged. After collection of the spectra, the tapes are spooled back into their cassettes for storage.

This spectroscopic method was used on a collection of tapes from the Smithsonian Institution Archives. This collections was chosen because it was well documented and had been kept in a relatively controlled environment since recording. Most tapes were about 10 years old; one is only about 5 years old. All the tapes were still playable.

The tapes, when grouped by manufacturer, showed some spectral similarities within their groups, thus indicating that the slight changes in manufacturing materials can be detected by this method. In addition, when the differences in manufacturer were taken into account, a relationship appeared between the age of the tape and the strength of certain absorbances attributed to aging reactions in the binder. However, since even the oldest tape had not failed, it is impossible to tell if these aging reactions are the ones responsible for reported failure in aging tapes.

This project will continue to survey naturally aged tapes, including other collections from the Smithsonian Institution Archives, and the results will be compared with varieties of artificially aged tapes. Particular attention will be paid toward obtaining "failed" tapes for comparison. With these results, development of the FTIR method to be a lifetime prediction method for archival tapes will be possible.
Technical Studies and Treatment Development

CAL conservators conducted a number of artifact-based technical studies. Research as part of these studies relate to CAL's mission of characterizing and preserving collections and contribute significantly to developments for conservation treatments of individual artifacts and groups of similar artifacts.

General Technical Studies

Technical studies during FY 1995 included the continued characterization of coating materials through microscopy; investigations into contemporary synthetic picture varnishes; the formal research project to develop assessment techniques for evaluating stone-cleaning methods; continued inquiries into the desalination of archaeological pottery; a continuation of Chinese paper studies; evaluating optical brighteners for photographs; investigations into the technology and treatment of Chinese wood block prints; duplication and digital imaging; and identification of media on paper.

In addition to these studies, research and development projects in support of ongoing conservation treatment projects were conducted. These are listed elsewhere in this report, under Support and Collaboration.

Surface Coatings

Work has continued on CAL-sponsored development of commercially viable surface coatings for museum professionals and the general public. A patent application is being prepared. It is the intention to have these products produced and distributed under a Smithsonian license.
Natural History Specimen Preservation

Research is being conducted on the chemical deterioration of natural history specimen components to determine whether this deterioration is the result of internal-to-the-specimen chemical reactions or the reactivity of the specimen with its environment (fluids or air). An understanding of this fundamental chemistry will allow a better description of deterioration processes and, as a consequence, provide a basis for the development of more chemically rational preparation and storage methods.

Effect of Storage Materials on Mollusks

In collaboration with the National Museum of Natural History, experiments were carried out concerning the effect of storage materials on mollusk specimens. These included artificial aging studies using three types of mollusk shell: oyster, cowrie, and freshwater clam. The shells were incubated for varying times at 82 degrees C in the presence of pure formic acid, pure acetic acid, and diluted mixtures of the acids. In addition, portions of each shell were incubated in the presence of samples of oak, poplar, pine, masonite, cork, paperboard from specimen trays, and cotton, both in the presence and in the absence of water. Samples of cowrie also were incubated with butyric acid at different strengths. Head-space gas samples were withdrawn daily from all samples at intervals and analyzed by mass spectrometry. At the end of the experiments, each shell sample was analyzed by scanning electron microscopy and x-ray diffraction.

Analytical results indicate that formic acid is produced in much greater quantities than acetic acid by the storage materials, in contrast to the more abundant production of acetic acid that is reported in the literature. Formate, acetate, and mixed salts are produced on the shells, including a new, as yet uncharacterized, mineral.

Enzyme Cleaning of Skeletons

Because of rapid faunal depletion, maximum utilization of museum skeletal material is gaining in importance. Use of the enzyme trypsin to prepare skeletons is a successful new technique developed to improve the quality of the preparation and also save effort, time, and money. Future research will seek to develop a quantitative method to determine the changes in the degree of cleaning that takes place over time and to extend this work to include the enzymatic removal of lipids from skeletal material.
Protein Chemistry

CAL began an investigation into the deterioration of fluid-preserved specimens in existing collections by analyzing the fluids in which specimens are stored to determine why and how they are deteriorating. Current studies indicate that specimens are slowly dissolving in these solutions and that better preservation conditions need to be found for the future.

Lipids and proteins, including structural proteins, are being hydrolyzed and removed from fluid-stored mammal specimens; the proteins are identified in the storage medium. Similar results were found for many other taxa preserved in fluids, and proteins were found in the storage medium. The research conducted thus far reveals that specimens of all taxa preserved in 70 percent ethanol are slowly dissolving.

This coming year a more complete and quantitative study of this "dissolving" phenomenon is being planned. The basic chemical reactions of the materials composing fluid-preserved specimens will be studied using accelerated aging tests to simulate long-term storage under various conditions.
Biogeochemistry research at CAL expands understanding of molecular preservation in the fossil record and seeks new methods of using collections as informational reservoirs of preserved ancient biomolecules to address questions of paleoclimate, paleodiet, and paleopathology.

Molecules on the Edge

The addition of biochemical and molecular biology approaches to the study of archaeological materials has opened up a new level of analysis and new types of information. Small amounts of partially degraded protein or DNA may be useful for interpreting behavior in the past. In recent years two of the most common archaeological artifacts, stone tools and pottery, have been subjected to molecular-level analysis and found to contain evidence of past use in the residues still adhering to these materials.

In 1995, with funding from the National Center for Preservation Technology and Training of the National Park Service, examination was carried out of an assemblage of stone tools excavated from several sites, collectively called Barney Circle, along the Anacostia River in Washington, DC. Parallel experimentation was performed on a set of experimental tools in order to examine the effects that excavation, conservation, and storage may have on stone tools and pottery artifacts as these materials make their journey from the archaeological site to the museum drawer. Two of the most common interventions, human handling and washing, severely and disadvantageously affected both protein identification by immunological techniques and DNA amplification using the polymerase chain reaction.

For residue analysis to provide maximal information to archaeologists, alterations in excavation techniques, post-excavation processing and storage, and long-term curation will have to change dramatically. While it is unrealistic to propose that all excavations and museum collections accommodate the special needs of molecular-level research, select sites and collections will benefit from the consideration given to the friable nature of ancient biomolecules. A shift in perception that considers the inorganic remnants of past life as divorced from the ancient biosphere and unaffected by present biota to a more inclusive and organic view will add to the interpretation of the archaeological record.

At the Barney Circle site, multiple tools were identified with macroscopic residues adhering to the surface, and several different proteins were identified on the basis of molecular weight and immunological reactivity. In cases where protein was preserved on stone tool edges, the use of the tool on animal products can be assigned through the identification of the albumin molecule from blood. The amount of protein remaining after some 1,5000 years is vanishingly small. Further surveys of tool assemblages from excavations where human handling was not permitted will form the basis of comparative work ongoing in the laboratory.
Cross-Linking of Ancient Molecules

That macromolecules outlast their expected lifetime in the fossil record has been a theme in geochemistry for the past 50 years. New life has been breathed into the notion of extremely ancient molecular preservation with the amplification of DNA by the polymerase chain reaction from extracts of museum and recently collected fossils. Although these results remain equivocal, interest has been renewed in mechanisms that might account for exceptional preservation of macromolecules in the fossil record.

In 1995, two disparate groups of samples were examined for protein and DNA content and molecular state. DNA was extracted from a group of naturally aged bones collected in Kenya by Anna K. Behrensmeyer of the National Museum of Natural History. DNA content as a function of time postmortem and extraction protocol was not static during the 15 years of collection. Rather, preliminary evidence suggests an influx of exogenous DNA in the most gentle and denaturing extracts, a decline in the DNA bound to the mineral phase of the bone, and an increase in the DNA tightly bound to the major protein in vertebrate bones and teeth - collagen. In an ongoing study of the Paleolithic Kents Cavern fauna remains from southern England, evidence for DNA cross linkage to collagen was obtained. These data form a part of a larger project on Kents Cavern that has reexamined the radiocarbon dates from the site and applied light isotope ratio mass spectroscopy to a study of paleodiet and paleoenvironment. The cave was excavated in the 1860s by William Pengelly, and faunal remains are stored in many museums around the world including the Smithsonian's National Museum of Natural History and the Torquay Museum in England.

Paleodiet and Individual Amino Acids

In collaboration with Marilyn Fogel of the Carnegie Institution of Washington, investigations into the utility of carbon isotopic values obtained from individual amino acids have been perused. As initially observed at the Carnegie Institution, the range of carbon isotopic values (13C) within one molecule of collagen can often exceed the entire range of 13C found in whole tissues or molecules from and entire ecosystem. By utilizing the collagen from the Kents Cavern fossils, radiocarbon dated to approximately 40,000 years before present, CAL staff were able to demonstrate that many of the 13C values from individual amino acids have been altered by post-mortem diagenetic changes. The most likely candidate for the preservation of an in vivo signature of isotopic values were found in the amino acid glycine and glutamic acid. As research moves back in time with paleodietary and paleoenvironmental reconstructions, the need for more highly resolved information at the molecular level is apparent.
Inorganic Collections Research

Neutron Activation Analysis Program

CAL maintains a research facility located at the National Institute of Standards and Technology (NIST), Gaithersburg, Maryland, which provides high-precision multi-element chemical data for use in a wide range of chemical characterization research projects conducted by CAL staff, fellows, and research collaborators. The chemical analysis of artifacts and raw materials using instrumental neutron activation analysis (INAA) is a powerful tool for unique characterizations of a variety of artifact materials. It can allow the tracking of artifact movement on the inter- and intra-regional level or reveal patterns reflecting specialized production. Major CAL ongoing research projects include studies of Classic Maya pottery, Pre-Columbian and historical Hopi pottery, Pre-Columbian Peruvian ceramics, Bronze and Iron Age ceramics from Gordion in Turkey, medieval Islamic ceramics and stone paste ware, ceramics from the Indus Valley in Pakistan and the Oman Peninsula, and Middle Eastern obsidian. Analytical data and accompanying descriptive information are curated in the Smithsonian Archaeometric Research Collections and Research (SARCAR) facility maintained at CAL. Drawing upon data produced as part of CAL’s programs as well as from other laboratories, SARCAR curates the data and makes it available worldwide to interested scholars.

Renovations to the NIST nuclear reactor prevented the irradiation of samples at NIST during FY 1995. This downtime was used to summarize several projects for which analytical data had previously been collected. A few of these are briefly described below.

Mississippian Pottery

In collaboration with staff of the University of Missouri Research Reactor, neutron activation analysis of Mississippian-period ceramics obtained from 21 locations across the southeastern United States revealed the existence of distinctive chemical groups that are associated with four large geographical subregions. One group is associated with sites along the Mississippi River and its western tributaries, a second with sites on the Appalachian Rim in Tennessee, a third with sites on the Piedmont and associated drainages, and a fourth with sites in Alabama. The pattern reflects the existence of several large clay-mineral provinces in the Southeast that can now be recognized as sources in future studies of long-distance exchange.
Classic Maya Painted Pottery

Classic Maya elite painted polychrome pottery is one of the great ceramic traditions of the world. The vessels carry images of the Maya worlds of the living and the dead, often with hieroglyphic texts that record historical narratives or encode information about whom the pottery was made for or by. In collaboration with Dr. Dorie Reents-Budet, curator of Pre-Columbian Art at the Duke University Museum of Art, more than 1,700 non-provenienced whole vessels drawn from national and international collections were chemically attributed to production loci within the Maya region, permitting the styles, themes, and hieroglyphic texts to be interpreted within a geographic context.

The need to correlate aspects of theme, style, or glyphic content with chemical analysis required the development of an efficient means of image and description data retrieval. Responding to this need, the 35mm images of whole vessels and samples ceramic fragments scanned and linked with descriptive attributes were entered into an image database system. This work, carried out largely by Erin L. Sears, a contractor who was previously a CAL intern, is almost complete for the whole vessels, and the digitizing of the photographs of the ceramic fragments will be undertaken during FY 1996. Upon completion of this project, the original 35mm slides will be preserved in cold storage for the use of future scholars.

The Fine Paste Traditions of the Western Maya Lowlands

Research is directed toward the synthesis of analytical data, generated over many years, on the archaeological ceramics of the site of Palenque, in Chiapas, Mexico. The project uses a combination of approaches that focus on compositional analysis as an indication of production sources and exchange. A principal objective is to determine the ceramic relationships of the large Classic Maya site of Palenque, often considered to be one of four regional capitals of the Southern Maya Lowlands, to the surrounding minor sites, which are commonly regarded as economic and political dependencies of Palenque.

Data synthesis and monograph preparation during FY 1995 focused on the fine paste ceramic tradition in which Palenque, ca. A.D. 500-800, was an innovator. This tradition flourished while the Southern Lowland sites were declining and a new Postclassic order was emerging in the Northern Maya Lowlands. Compositional data synthesis of the fine paste component of the Palenque research attempts to identify production zones and exchange in the pottery and to place its production within broader concerns of Maya archaeology. This research addresses, among others, problems of changing socioeconomic patterns that mark the transition from Classic to Postclassic.

Almost half of the monograph summarizing research findings was written in FY 1995. Completion is planned during FY 1996, with publication to follow by the Middle American Research Institute, Tulane University.
Greater Nicoya’s Ceramic Links to the North

Lower Central America - today Honduras, El Salvador, Nicaragua, and Costa Rica - once lay between the Maya culture to the north and cultures of the Andean area to the south. People, goods, and ideas clearly moved through the area, and what was retained was reworked into a vigorous local cultural setting. Several closely related projects have been designed to define and document the strength of local cultural traditions and to seek an enhanced understanding of the nature of the changes that occurred from approximately 800 B.C. up to the time of Spanish contact. Program emphasis is on the documentation of regional ceramic production, inter- and intra-regional contacts (as these are revealed by ceramic distributions), and the exchange of stylistic information.

During FY 1995, archaeologist Wilson Valerio Lobo of the Museo Nacional de Costa Rica was funded by the Organization of American States to assist in writing a monograph that summarizes what is known to date from the multiyear Greater Nicoya research program. Completion of the summary is expected in FY 1996. The monograph will be published in Spanish, thus making the research findings more readily available to Latin American archaeologists.

Large-Scale Production of Pottery at Gordion

Analysis of forming and finishing methods has suggested large-scale production of pottery in the Late Bronze Age (1400-1200 B.C.) and Early Phrygian periods (ca. 950-700 B.C.) at Gordion, Turkey. Chemical characterization of both pottery and local clay samples has defined markedly different patterns of resource use in the two periods, suggesting a change in the geographic scale of the economy.
Control of the flow of materials moving in long-distance exchange networks is a factor in the emergence of social stratification because it enables the concentration of wealth in an elite class. Changes in procurement and redistribution patterns are indicative of shifts in social organization. INAA characterization of geological obsidian source samples and archaeological artifacts, obtained by international collaboration, are used to examine the mechanisms of intra- and inter-regional procurement and exchange systems and their evolution through time in the ancient Near East, the Caucasus region, and the Mediterranean.

Research as part of the Trans-Caucasian Obsidian Project establishes the primary data base for obsidian sources in this area and examines the obsidian procurement strategies employed during the Neolithic through the Bronze Age for several regions in the present republics of Armenia, Azerbaijan, Georgia, and Russia. Statistical analysis of data for obsidian sources from the Trans and Cis Caucasus Region and from the adjacent Kars Region of northeastern Turkey is continuing.

As a small segment of research regarding Old World obsidian exchange, the source of obsidian used by the aceramic Neolithic occupants of Kalavasos-Tenta, Cyprus, was summarized during FY 1995. As there is no obsidian source on Cyprus itself, all obsidian discovered in archaeological sites was imported. Its chemical composition, determined by neutron activation analysis in collaboration with the University of Missouri Research Reactor facility, indicates that it was derived from a central Anatolian source. On the basis of the chemical composition, obsidian from five Cypriot Aceramic Neolithic sites has been determined to have the same provenance. The data suggest that analyzed fragments were not derived from a single core source, and, because the obsidian occurs throughout the Aceramic period of occupation of Kalavasos-Tenta, it appears unlikely that the artifacts recovered from the side represent a onetime transfer of material. Thus the inhabitants of Kalavasos-Tenta probably had an enduring supply of obsidian, suggesting that they were never completely isolated from the mainland.


**Lead Isotope Program**

In many areas of the world metals take second place only to pottery in the study of contacts between social groups or cultures. Data derived from lead isotope analyses have been shown to be highly effective for identifying the source of ores used in bronze and copper artifacts. Research projects carried out by the lead isotope program use isotope ratios determined on a National Institute of Standards and Technology's thermal ionization mass spectrometer designed for high-precision measurements. Access to the NIST facility is provided through the collaboration of Robert D. Vocke, CAL research collaborator and analytical chemist, with NIST.

**Spanish and Spanish Colonial Glazed Ceramics Artifacts**

Research in FY 1995 was conducted in a final phase of a multiyear project to determine the origins of the lead used in Spanish majolica glazes. Historical documentation exists regarding the sources of lead used by potters in Spain during the 15th and 16th centuries. Two of these sources, the mining regions near Berlanga in the province of Badajoz and near Linares in the province of Jaén, have been confirmed by lead isotope analysis as probable sources of the lead in artifacts excavated from Spain and Spanish colonial sites in the New World. Lead isotope data for the mines in southern Spain have also been obtained from the geological literature. However, the isotopic composition of lead from other ore sources in southern Spain does not match the lead composition of these 15th-16th century Spanish artifacts.

Ore specimens from Berlanga and Linares include 24 samples analyzed at CAL and three determinations from the geological literature. Although Linares is known as a historical source of lead, only 14 of the analyzed artifacts match it as a source. Thirty-four of the Spanish artifacts match the lead from Berlanga. The Berlanga region, which is not presently and economically important source of lead, was sampled specifically for this project. In addition to those artifacts that match the lead from Spanish sources, 32 of the artifacts reported earlier match lead from ore sources in Belgium and Germany, a finding that also confirms the historical documentation.

The ore samples from the mining region of Berlanga, submitted by Mark Hunt, University of Seville, are zinc-lead ores. Additional geological ore data provided by the Isotrace Laboratory at Oxford University on ore sources in the Murcia, Almeria, Andalusia, and Huelva regions and the Aznalcóllar area near Seville in southern Spain were included into the CAL European geological data base this year. A statistical reassessment of all the geological ore data shows distinct correlations among the documented evidence, the lead data analyzed at CAL, and published sources and provides an important confirmation of the value of lead isotope analysis in determining the sources of lead in archaeological artifacts.
Lead Isotope Analysis and the Great Orme Mine

In 1990, Bronze Age copper mines were discovered on the Great Orme mine, Llandudno, northern Wales. The extensive network of Bronze Age tunnels includes the largest and deepest prehistoric copper in all of Europe. The depth of extraction (70 meters) was limited only by a perched water table, which effectively prevented any lower extraction of ores until the mine was drained in the mid-19th century.

One CAL component of research concerning the Great Orme mine is the investigation of the scope of the process from ore genesis to production of the final bronze object. Lead isotope analysis, as a technique applicable equally to ores and artifacts, was used to characterize the copper- and lead-bearing ores believed to have been mined from the mine in the Bronze Age and to establish a relationship between the ore exploitation and the metal production. The results reveal a tight correspondence between copper ores and excavated metal fragments from within the mine. Both sample sets fell within the established lead isotope fields generated by multivariate statistical analyses of the published lead data on Welsh ore mineralization. However, the analyses of galena from a stringer deposit within the mine show it to be an anomalous lead, having an isotopic composition different from that observed thus far on ores from northern Wales.

The lead isotope data for specific copper and galena ores from the Great Orme mine reveal that only the simplest copper ores - malachite and azurite - were exploited during the Bronze Age. Statistical analyses of the lead isotope data obtained from these ores, in combination with previously published lead data, show the distribution of the copper ores from the Great Orme conform well to the isotopic ore fields generated for galena deposits in Mendip, in southern and northeastern Wales. The artifact samples group equally well with the copper ores. However, the characterization of ores from various mineral deposits at the Great Orme, conducted at the Isotrace Laboratory at Oxford University, suggest that significant variability exists. Differences in the research approach to the study or the ores from the Great Orme have led to different interpretations of the isotope data derived from their characterization. The next and final phase of this project will combine the data from both laboratories to study the ages of the various mineralizations and their geological implications.
Studies of Nigerian Bronzes and Comparative Samples

This project seeks to identify the sources of copper alloys used in West Africa from the middle of the first millennium A.D., based on the evidence offered by lead isotope analysis. Work to date has concentrated on samples from the earlier part of the tradition, including those from Marandet, Igbo Ukwu, and Benin. There are some distinct and well-separated groupings among the lead isotope ratios in objects from these various sites, indicating that various ore sources were used in their production. Data for samples from Igbo Ukwu, Ife, and Marandet reveal exploitation of two main sources. Benin, which according to historical documents traded with several different parts of Europe, shows a single, very compact source.

Dr. Frank Willett, CAL research collaborator and research fellow at the Hunterian Museum, Glasgow, Scotland, assisted in sampling objects at the National Museum of Natural History and the National Museum of African Art. During a short-term visitor tenure at CAL, arrangements were made to obtain samples of objects from the ancient city of Jenne in Mali, that are in the collections of the Virginia Museum of Fine Arts, in Richmond. Samples of objects from Lower Nigeria, including the areas of the Forcados River and Andoni Creeks and from the Apapa Hoard were also obtained this year from the British Museum.

A Smithsonian Research Opportunity Fund (ROF) grant facilitated visiting, consulting and establishing collaboration with curators at several foreign museums, including the Liverpool Museum, the Hunterian Museum in Glasgow, and the Royal Museum of Scotland in Edinburgh, as well as the Leadhills in Scotland and the Great Orme mine in northern Wales.
Ancient Technology

Ceramics (broadly defined as plasters, pigments, glasses, glazes, metallurgical slags, and clay-based products) and metals are complex inorganic materials that retain in their structure a record of their manufacturing history and subsequent use. This technological history and its cultural significance are a focal point of CAL research. Subjects of investigation concern the identification of the physical bases of appearance, the constraints and variability of raw materials, the methods and sequences of manufacture, the processing parameters, and the use of artifact properties to interpret cultural function. Critical aspects of the ancient technologies may be replicated and compared with analogous modern practices. Resource survey and contextual field studies are a significant component of investigating and reconstructing ancient technologies.

The structure, composition, and properties of artifacts are intrinsically measurable, independent from the human behavior that produced them. Processing, use, and function are, however, explicitly part of the human realm and reflect both individual and group behavior. They can be reconstructed with less certainty than structure and properties. For culturally significant interpretations, these areas must be considered together. CAL's focus is centered on times and regions where cultural and technological change coincide, interact and evolve together. The aim to establish the nature of the patterns of manufacture and use as well as reconstruct what knowledge would have been required of the practioners of the various crafts. Such technological complexes or behaviors as can be determined by studying artifacts, their raw materials, and their contexts are then used to group or distinguish technologies from one another. CAL researchers are finding that the organization of craft technologies commonly found in contemporary village and urban cultures does not correspond to that in the past, when many of these technologies were in an incipient stage.
Hydrogen reduction as a strategy for firing of ancient Chinese ceramics

Hydrogen reduction is commonly thought to be a process developed for European steelmaking practice in the industrial revolution. However, this firing strategy was used for ceramics in China dating to the 16th century and probably to the Han dynasty (206 B.C.-A.D. 220) and earlier. A two- to three-fold increase in hydrogen concentration occurs on the surface of modern and ancient brick and roof tiles, evidence that they were bathed in a hydrogen-rich atmosphere. This increase was measured using forward recoil energy spectrometry (FRES), a new technique for semiconductor research developed at Los Alamos National Laboratory.

The production of gray brick and roof tile has been significant in China for two millennia and was used as a way of identifying Chinese installations in Siberia and on the northern and western frontiers of China, as opposed to the red brick made by peoples to the west. The first clear literary evidence of this special firing procedure is contained in a 17th century A.D. text that shows water being introduced into a kiln. Study in collaboration with the Shanghai Institute of Ceramics of similar modern kilns making gray tile and brick in both urban and village contexts has shown a special three-regime firing schedule. To achieve the gray color, the kiln is charged with extra fuel, then closed at the firebox and flue openings, and water is introduced from a pool on the roof without subsequent introduction of air. The water dissociates, as has been described for water gas firing or water smoking in steel production.

The results of this firing produce bricks that are distinctive not only for their color but for their microstructure, which indicates that further sintering has occurred, strengthening the bricks. In future studies in collaboration with the Freer and Sackler Galleries of Art, CAL researchers hope to investigate the possible presence of this specialized technology in the Neolithic period in China.
Technological Variability of East Asian Green Glazes

Green-glazed ceramics, or celadons, have long been prized as luxury goods and have been sought after as nearly indestructible symbols of prosperity, status, and high quality. The literary evidence of connoisseurship in green-glazed Chinese ceramics has a history of about 800 years. It is understandable that several regions within China as well as several other countries have tried to produce similar wares. When they were close in appearance to the Chinese originals, they have often been confused in museum collections. Sufficient regional archaeological excavations of production kiln sites have now been carried out to make a study of the materials science of each type of green glaze technology and its range of production parameters, beneficial in isolating the differences among the different green-glazed wares. This study of how one culture chooses to imitate another aims to isolate the materials, processing and production choices on one group and differentiate them from others. Researchers are finding that the development of green glazes in several instances influenced the way later ceramic technology was conducted.

The range of compositions, microstructures, firing temperatures and raw materials from several 8th-16th century A.D. kilns is being studied both in the laboratory and at the archaeological excavations on the production sites. In collaboration with the Tokyo National Research Institute of Cultural Properties, the evolution of green glazes from naturally deposited ash was studied based on excavated materials from the Sanage kilns in the Mino-Seto region of Japan. This region was the earliest producer of green glazes in Japan. A project in collaboration with the Ho-am Museum in Korea is studying the diversity of green to white glazes produced at the 8th-11th century kiln complex of Sori. By using similar materials, a variety of visual effects ranging from green to gray to white were produced; then later in the sequence the range of materials narrowed to produce two separate types of visual effects - white and gray-green. A further project, in collaboration with Sophia University in Tokyo is studying a variety of kiln sites in Vietnam with a wide range of visual effects.

CAL researchers have investigated the possibility of examining microstructure nondestructively using micro-CT, or cat scan, with a 20 micron resolution in order to examine green-glazed whole vessels from excavations and treasure houses, many of which are significant national cultural properties. Collaboration with Exxon Research and Development has enabled successful completion of this study. The technique at low magnifications of up to 500x replaces scanning electron microscopy (SEM), and above 500x it complements but does not replace scanning electron microscopy in the backscattered mode.

In collaboration with a modern artist-potter, Jack Troy, materials from various kilns sites were fired and tested in a wood-fired anagama or hill-climbing kiln in order to differentiate between accidentally accumulated and intentionally applied ash glazes. This study led to insights into modern practices as well as ancient ones.
Paleolithic Pigment Processing in Eurasia

Following characterization of pigmented artifacts, so-called mortars and a pigment palette, from La Madeleine and Tarte in France, now in collections of the National Museum of Natural History, researchers concluded that many of the materials and marks identified were not applied by Paleolithic peoples but were the result of museum storage and handling. Differentiation between red marks made by firing and those from pigment application was empirically established. Attributions such as mortar or palette may not be functionally indicated by the materials analysis.

Pigments from the newly discovered underwater French cave of Cosquer were analyzed in a collaborative study with the French Ministry of Culture. The cave has two episodes of pigment application, one at 27,000 and the other at 17,000 B.P., but the pigment materials remained the same. On-site resource survey and collaboration with the French Geological Institute have concluded that no manganese blacks were available in the local region. Study of the morphology of the large flakes of charred wood remaining in the pigment on the wall suggests that red pine was the sources of the blacks. The size of the flakes indicate that no grinding was involved. Charred wood sticks of the same type of wood found at the base of one of the images may have been the means of black pigment application.

The red pigments are an alumina-rich red clay, similar to that used in the outstanding thermal shock-resistant cookware for which the region has been known since the 16th century A.D. The site of Baux, for which the mineral bauxite was named, is nearby. This rock art find and CAL's analysis add considerably to understanding of the ceramic technology of this region.

Projects in Historical and Archaeological Metallurgy

Research in historical and archaeological metallurgy explores metals from their earliest beginnings in the Bronze Age to their developments in the 20th century. The studies address questions in collaboration with curators, archaeologists, historians, and conservators both at the Smithsonian and at other scholarly institutions. Typically curators present CAL staff with problems of authenticity, where knowledge of the appropriate alloy and fabrication method can be crucial. The aluminum crankcase original to the 1903 Wright Flyer was a recent example of such authentication. Conservators are interested not only in identification of the metals but in their likely points of weakness as well. Historians are more interested in the general development of the technology, while archaeologists need reliable identification of the alloys and the techniques used in specific objects regardless of their sometimes highly fragmentary condition.
Fortepiano Kapsels

Conservators are occasionally faced with the problem of restoring not only the appearance of a historic object but also its function: some objects are meaningful for what can be done with them rather than for their form and color. Among these "functional objects" are musical instruments. Some historical instruments are robust enough that restoration to playing condition is feasible, allowing their characteristic voices to be heard. For those that are too fragile, close reproduction offers an alternative. The reproduction of the fortepiano - the small, wood-framed predecessor of today's cast iron-framed pianoforte - requires a small brass assembly called a "kapsel" (capsule) as part of its delicate action. When conservators used brass whose composition had been specified by industrial metallurgists for fabrication of kapsels in the simple, traditional way, these kapsels routinely failed. No amount of heat treatment, as recommended by one academic department of metallurgy, provided a cure. The problem vexed conservators in Europe as well as North America.

The problem was solved at CAL, using compositional analysis and metallographic examination of the failed kapsels in comparison with authentic kapsels made available by the Metropolitan Museum of Art in New York and makers Rod Regier of Freeport, Maine, and Thomas Wolf and Barbara Wolf of The Plains, Virginia. Failure was caused by the presence of lead in the modern brass parts. Substitution of an unleaded yellow brass similar to that used in late 18th- and early 19th-century practice has proved entirely successful, making it possible to replace missing kapsels with new ones that are so like the originals that the performer senses no difference in the action of the instrument.
Mail Links

Earlier work in CAL on 17th- and 18th-century music wire showed that the ferrous wire was not steel but a particularly well-refined iron that, by a special process of selection, contained as much as 0.2 percent phosphorus. A change in the proportions of wire-strung instruments about 1600 convinces some scholars that a stronger wire was introduced then, but there is no artifactual proof to indicate the date when high-phosphorus low-carbon iron wire went into production.

Mail armor ("chain mail" is considered tautological usage) is an obvious source of early wire, though it was also fabricated from sheet and from strands. Many suits of mail have survived in collections, but it has been long-standing practice to replace links as they broke in order to keep the armor intact. Thus the date of a particular link studied for comparison may not correspond with the date of the armor it was taken from and, in fact, the chosen link may have been inserted in the armor centuries after its initial construction. Mail armor provides a vary peculiar instance of collections being an unreliable source of dated material. Unexpectedly, the opportunity came to CAL to study links from the controlled excavation of a well-dated site.

The long-sought 1539-40 winter encampment of Hernando de Soto was discovered in Tallahassee, Florida, in 1987. This site is pivotal in the history of armor because it was here that captured Apalachee warriors demonstrated it uselessness against their arrows, which easily pierced it. The excavator, Charles W. Ewen, made available 20 mail links or fragments of them, all heavily corroded, for examination in CAL. These links were not subject to the problem of dating described above but posed new difficulties in examining heavily corroded iron. Any evidence of phosphorus from the rusty surface accretions was meaningless because phosphorus contamination of the soil is expected at settlement sites. A method had to be developed to locate remnant areas of sound metal within the rust. By an approach that combined initial mechanical cleaning of the thick surface concretions with a dissecting needle and impregnation with plastic followed by highly controlled grinding and polishing rates, it was possible to locate a few remnant areas of sound iron and so to examine these for evidence of phosphorus.

Microscopic examination found evidence that the links had been made of drawn wire, but the evidence for phosphorus in the iron itself was inconsistent. Since phosphorus can occur in preindustrial iron, from some kinds of ore or even from the kind of charcoal used as fuel to smelt it, the intentional selection of iron for its high phosphorus content could not be demonstrated in these links. Nevertheless the method used did locate one sound area of metal that included a tiny rivet, a telling example of the exquisite workmanship of mail armor before 1540.
Metals of the Third Millennium B.C.

The site of Tell es-Sweyhat in Syria dates back to at least the end of the third millennium B.C. The excavator, Dr. Thomas Holland of the Oriental Institute, University of Chicago, recovered a few pieces of metal and provisionally identified some of them as silver. Because metal as early as this is scarce, it was of general interest to identify the metals authoritatively. There were some examples of copper alloys, which, as expected for the place and period, were either tin bronze or arsenical copper. The white metal was another matter. Analysis showed all the white metal to be lead. Even objects such as a ring and an earring that from their form and color appeared to be silver were found to be lead. This unexpected result raises troubling questions regarding the reliability of published identifications of white metal, especially those that have been based solely on visual identification, unconfirmed by laboratory analysis.

Traditional Abrasives

A subject that has been addressed by neither archaeologists nor archaeometallurgists, except for the occasional mineralogical identification of hone stones, is abrasives. In the workshops of an ecclesiastical silversmith in the Jewellery Quarter of Birmingham, England, a loose abrasive of peculiar gray-green color was until recently routinely being used to buff silver. Microscopic examination of the powder revealed a highly heterogeneous composition, supporting a workman’s description of this abrasive as river sand. With the collaboration of Michael Constable of the Birmingham Museum of Science and Industry, its source was traced to the Trent River.

Mineralogical characterization using x-ray diffraction identified the chief component of this abrasive as chalcopyrite, which has the formula CuFeS$_2$. This mineral is, and has been from ancient times, an important ore of copper but this is the first time that chalcopyrite has been identified as the material of an abrasive. This discovery suggests the possibility of confusing ores with abrasives in interpreting sites where ore minerals occur in particulate form. Finding ground chalcopyrite at a site might well mislead one to conclude that ore was being prepared there for smelting, rather than that objects were being ground and polished there.

Very few abrasives are documented. There is, however, in a Japanese document of ca. A.D. 700 translated by Anne Yonemura of the Freer Gallery of Art, mention of an abrasive described as iron powder that results from smithing. This is fire scale, the mineral magnetite, Fe$_3$O$_4$. If not considered as a possible abrasive, it could easily be mistaken as a byproduct of smithing at a particular site rather than being interpreted as evidence of polishing.
Education and Training

Education Coordinator/Senior Furniture Conservator
Donald C. Williams

Senior Conservators
Mary W. Ballard
Carol A. Grissom
Dianne van der Reyden
Melvin J. Wachowiak, Jr.

Conservators
Harriet (Rae) F. Beaubien
Jia-sun Tsang

Change and disruption were the key words for the Conservation Analytical Laboratory this past year, and Education and Training programs were certainly not insulated from them. FY 1995 saw the implementation of new administrative structures and programmatic schemes, reallocation of space within the Conservation Analytical Laboratory, and a major reconstruction of the physical plant of the Museum Support Center.

The Museum Support Center ventilation retrofit caused the closing of every CAL laboratory for varying periods of time and numerous temporary relocations of staff and programs. As part of the CAL administrative restructuring, Textiles Conservation was discontinued as a laboratory-based program, and the Paintings and Furniture Conservation Laboratories and staffs were merged into the newly named Coatings Laboratory. In addition, the new Coatings Group was relocated to a space 50 percent smaller than that previously occupied by the Paintings and Furniture Conservation Laboratories; the Paper Conservation Laboratory was relocated into a space 30 percent smaller than it previously occupied; and the former Textiles Conservation Laboratory was redesigned as the CAL Education Laboratory. For the new Paper Conservation Laboratory, a complete redesign of the room was accompanied by new furniture, purchased or donated. The final layout included a new collections maintenance section and preservation resource center available to Smithsonian staff who would like to be trained by CAL paper conservation staff.

These disruptions absorbed substantial time. Dealing with closing and moving laboratories and redesigning new spaces for the new occupants were, in fact, the largest elements of this year's activities. These changes had a profound impact on the activities and morale of CAL staff. Every single aspect of CAL Education and Training was affected: internships, courses and workshops, public outreach, and publications.

Internships and fellowships at CAL span a wide variety of educational levels and academic disciplines. Whether the visitor is a postdoctoral fellow, a graduate student, or a preprogram or summer intern in conservation or conservation science, there is a common emphasis on enhancing understanding of artifact characterization or preservation. This year saw the interruption of scheduled plans for many internships, as many CAL staff were occupied fully with other, more pressing, projects or were so completely disrupted by the construction that hosting an intern was impossible. For those who did still host interns, alternative intern work sites and
projects needed to be arranged at the last minute due to the closing of most CAL laboratories for the ventilation retrofit.

Courses and workshops are often a focal point for the professional communities related to the work at CAL. Through both long-term and short-term or one-time events, courses provide concrete applications of research implications and the principles of professional practices. Some of CAL’s curricula are focused on the established professional; others are tailored for specific audiences; and some are available to anyone interested in the topic. Since much of CAL was unavailable during FY 1995 as a training site, quite naturally the course offerings this year were severely limited. While most years there are 15-20 courses at CAL, this year there were only 6 CAL courses, with 2 additional CAL-hosted courses sponsored by outside entities.

CAL staff are extremely active in outreach and in presenting their work outside CAL to both professional and other organizations. This program area has now completed the first two of a series of instructional collections-care videos and has begun a course series in material technology for artists’ materials for a local arts-emphasis high school.

Despite the disruptions to CAL Education and Training activities, some very positive steps were taken toward cementing the successful educational programs of the past and the initiation of new ones for the future. Perhaps nothing was more important in this regard than the convening of several CAL-wide planning sessions to review past CAL Education and Training activities and to formulate agendas for new activities and emphases. Much of the discussion from these meetings is still undergoing review and synthesis, but the results will influence CAL Education and Training activities for some time to come.
Internships and Fellowships

The Conservation Analytical Laboratory offers internship and fellowship opportunities involving several academic levels and variety of artifact, preservation, and conservation treatment specialties. CAL’s commitment is to enhance the experience of the intern, whether the internship is an introduction to conservation or an advanced fellowship providing specialized technical training. This year CAL hosted 18 interns or fellows from wide-ranging locales.

Within a broader commitment to internship training, CAL offered four dedicated appointments in response to the special needs of emerging conservation and preservation disciplines. Under the auspices of the Objects Conservation Laboratory, CAL offers two archaeological conservation appointments, one for a graduate student intern, the other for a postgraduate fellow. These students, along with the CAL conservators, form the core of CAL’s archaeological conservation program, which includes both on-site conservation and research and related projects in the CAL laboratories. The Paper Conservation Laboratory has interns in archives conservation at similar levels. Typically the graduate intern and postgraduate fellow engage in a number of projects in conjunction with archival and special collections within the Smithsonian and in research and treatment projects within the laboratories.

This past year was a special challenge for internships, particularly as the Paper Conservation Laboratory was closed for much of the year during the reconstruction, then permanently relocated to a much smaller space afterward. Still, creative and beneficial activities were coordinated with off-site spaces to provide a full experience for the interns in six different locations: the National Portrait Gallery, the National Museum of American History, the Smithsonian Institution Libraries, the Office of the Smithsonian Institution Archives, the National Archives, and the Library of Congress.
Fellows, Interns, and Furniture Conservation Training Program Students with Appointments at CAL during FY 1995

Patrick Albert (University of Toronto) completed his third year of the Furniture Conservation Training Program. He is now interning in Paris and Quebec City.

Holly Anderson (Art Conservation Program, State University of New York - Buffalo) completed her term as a third-year graduate archives conservation intern with the Paper Conservation Laboratory. Her internship projects included surveys, collection care, treatment, and research.

Aniko Bezur (University of Arizona) was a ten-week summer research intern, studying polymeric and modern materials.

Tania Collas (Art Conservation Program, State University College of New York - Buffalo) was a graduate intern in archaeological conservation in the Objects Conservation Laboratory. She conducted research projects in the laboratory and fieldwork in Pakistan and Honduras.

John Courtney (East Carolina University) completed his third year of the Furniture Conservation Training Program. He is now interning in London and Winterthur, Delaware.

Evin Erder (Historic Preservation, University of Pennsylvania) performed laboratory testing in the Objects Conservation Laboratory for the U.S. National Park Service contract for development of an evaluation methodology for stone-cleaning damage assessment.

Emily Kaplan (Art Conservation Programme, Queen's University) completed her postgraduate archaeological conservation fellowship in the Objects Conservation Laboratory. She conducted research and treatment projects in the laboratory and fieldwork in Pakistan and El Salvador.

Paul Koenig (Purdue University) completed his third year of the Furniture Conservation Training Program. He is now interning in Winterthur, Delaware.

Mark Kutney (Pennsylvania State University) completed his third year of the Furniture Conservation Training Program. He is now interning in Williamsburg, Virginia.

Catherine Magee (Winterthur Art Conservation Program, University of Delaware) began her term as a postgraduate fellow in archaeological conservation in the Objects Conservation Laboratory.

Charles Jeffers (Jeff) Moore (Roger Williams College) completed his third year of the Furniture Conservation Training Program. He is now interning in Waltham, Massachusetts.

Andrea Morris (University of Delaware) was a ten-week summer conservation intern in the Coatings Laboratory. Her activities emphasized an introduction to conservation and treatment projects on painted furniture.
Alison Payne (University of Texas) was a full-year preprogram conservation intern in the Coatings Conservation Laboratory, working on a variety of treatments with an emphasis on easel paintings. She was accepted into the graduate program of the Courtauld Institute.

Andrew Robb (Winterthur Art Conservation Program, University of Delaware) continued his term as the postgraduate fellow in the Paper Conservation Laboratory, specializing in photographic materials. His fellowship projects included surveys, treatment, research, and outreach.

Marie Svoboda (Art Conservation Program, State University College of New York - Buffalo) was a postgraduate archaeological conservation fellow in the Objects Conservation Laboratory. She conducted research projects in the laboratory and fieldwork in Pakistan and Honduras.

Heather Tennison (University of Illinois) has begun her term as a preprogram intern in the Paper Conservation Laboratory. Her projects include surveys, collection care, research, and outreach.

Fei Wen Tsai (Libraries and Archives Conservation Program, Columbia University) completed her term as a postgraduate archives conservation fellow in the Paper Conservation Laboratory. Her projects included preservation planning, surveys, collection care, treatments, research, and outreach.

Andrew Wilson (Institute of Archaeology, University of London) began a term appointment as a research intern in the Biogeochemistry Laboratory.
**Courses**

The disruptions caused by the CAL reorganization and the Museum Support Center ventilation retrofit caused a sharp decline in the CAL course offerings for FY 1995, reducing the number of events by 60 percent from the previous year. Regular teaching spaces were undergoing construction or being used as temporary offices during the reconstruction. Moreover, CAL staff time was consumed by the reorganization and moving necessitated by the retrofit. Nevertheless, some very useful strides were made in CAL course offering through off-site events and activities occurring around the construction or in the CAL Theater.

CAL Education and Training events have a variety of emphases. In addition to two long-term curricula - the Furniture Conservation Training Program (FCTP) and the Research, Libraries, and Archives Conservation Task Force Program (RELACT) - there is a growing commitment on the part of CAL to develop outreach programming that will disseminate information about the material technology of historic artifacts far beyond the offices of CAL and its traditional conservator-oriented constituency. Many of the activities in this regard remain in the planning stages, but one initiative in particular, the "Material Technology of Traditional Artists' Materials" workshop series, will continue into FY 1996. Six half-day sessions were planned and begun with selected students from the Prince Georges County Suitland Center for the Visual and Performing Arts. In addition, in yet another new venture, CAL acted as host site for two sessions of the course "Microscopy for Conservators," sponsored by the Washington Conservation Guild and taught by the staff of the McCrone Research Institute.

RELACT, CAL's ongoing program for training specialists in preserving and conserving archival collections, is formulating a comprehensive approach to training archives collections care-takers and thus developing comprehensive strategies for preserving these vital collections. To facilitate greater access to the RELACT Lecture Series, CAL for the first time held lectures in the Ripley Center Auditorium on the Mall. This year's series focused on preservation and access of photographs, a topic of high priority at the Smithsonian Institution. Speakers representing not only the CAL Paper Conservation Laboratory but also the Library of Congress and the National Archives covered issues of negative preservation, cost-benefit analysis of duplication versus storage, colorimetry measurements for photographs on exhibition, and "scanning on demand" in cold storage. Each lecture was attended by 30-50 Smithsonian staff members from dozens of Smithsonian museums and divisions as well as from other federal agencies.

RELACT is the foundation for developing further curricula and training opportunities for archives specialists, especially as the Paper Conservation Laboratory increases its emphasis on hands-on laboratory instruction to archives preservation specialists.

The FCTP is a unique graduate-level program designed to allow practicing woodworkers and restorers to pursue advanced mid-career development and reorient their professional activities. Responding to a clear need for a larger professional community of furniture conservators, the FCTP was established in 1986. Program students come to CAL for four two-week graduate seminar courses per year over a three-year period; each course is worth four academic credits. The complete program concludes with a one-year full-time internship in a recognized furniture conservation laboratory or studio. FCTP students are individually enrolled in the
Independent Master of Arts degree program of Antioch University and receive an M.A. in furniture conservation at the completion of their studies. This year FCTP held the final three courses in its curriculum, then began the one-year hiatus coincident with the internship period for the students. Five FCTP students were joined by many conservation professionals and other visiting student attendees for the course sessions. Instruction by CAL and other Smithsonian staff, along with numerous expert faculty from industry and conservation disciplines, provided valuable insight and support.

The FCTP class of 1996 finished its academic course work in May 1995, and its members are now serving a one-year internship in conservation laboratories for the Society for the Preservation of New England Antiquities, the H.F. duPont Winterthur Museum, the Colonial Williamsburg Foundation, The Centre de conservation du Québec, and the Victoria and Albert Museum. The students' master's degree theses will be presented in the summer of 1996.

**CAL Courses Offered during Fiscal Year 1995**


   This course focused on the history and technology of metal powder and leaf surface decoration. Lecture topics included the history and craft of gilding, concepts and case studies in conservation treatment, and novel loss compensation techniques.

2. "Exhibition, Storage, and Handling of Furniture Collections," February 6-17, 1995 (9 attendees)

   This course covered the concepts of chemical and physical deterioration, the conservator's role in the exhibition process, storage and movement of objects, survey of collections, disaster preparation and mitigation, and special considerations given to historic objects housed in historic structures.


   This presentation by Donna Collins of the Library of Congress focused on the problems and proposed solutions for managing photographic collections.


   This final course of the FCTP program cycle summarized the scope of the conservator's professional activities, including private conservation practice and museum employment. Conservators and administrators lectured on the business of conservation, from large federal institutions and their hierarchies to the running of a solely owned private business.
5. "Case Studies in Preservation and Access to Photographs at the National Archives: Preservation Priorities for Photographic Materials, and Cost-Benefit Analysis for Storage and Access," July 13, 1995, a RELACT event at the Ripley Center Auditorium (45 Smithsonian staff attendees from a variety of bureaus and many from other federal agencies)

The presentation by Steve Puglia of the National Archives and Records Administration discussed the relative benefits of varying preservation and storage strategies.

6. "Case Studies in Preservation and Access to Photographs at the Smithsonian Institution: Preservation Projects with the Office of Photo Services, National Museum of American History, and Other Bureaus," September 7, 1995, a RELACT event at the Ripley Center Auditorium (25 Smithsonian staff attendees from a variety of bureaus and many from other federal agencies)

The presentation by Andrew Robb, a CAL postgraduate fellow in photographic archives, emphasized measuring deterioration of photographic images in storage and on exhibition.

**CAL and Visiting Faculty during Fiscal Year 1995**

The number or numbers in brackets at the end of each entry indicates the course or courses taught.

William Adair, owner and conservator, Gold Leaf Studios, Washington, DC [1]


Meg Craft, conservator, Art Conservation and Technical Services, Baltimore, Maryland [2]

David Erhardt, research organic chemist, CAL [2]

Ross Merrill, director, Conservation Department, National Gallery of Art, Washington, DC [4]

Stefan Michalski, senior conservation scientist, Canadian Conservation Institute, Ottawa, Canada [2]

Karen Motylewski, preservation programs officer, Northeast Documents Conservation Center, Boston, Massachusetts [2]

Rick Parker, principal and conservator, American Conservation Consortium, Gentry, Arkansas [4]

Edward Patterson, director, Conservation Division, Parks Canada Atlantic Region, Halifax, Nova Scotia [4]


Michael Pierce, exhibitions conservator, National Gallery of Art, Washington, DC [1]

Michael Podmaniczky, furniture conservator, Winterthur Museum, Winterthur, Delaware [1, 4]

Steve Puglia, photographic preservation specialist, Special Media Preservation Branch, Preservation Division, National Archives and Records Administration, Washington, DC [5]

Toby Raphael, ethnographic objects conservator, Conservation Center, National Park Service, Harpers Ferry, West Virginia [2]


Mervin Richard, deputy director, Conservation Department, National Gallery of Art, Washington, DC [2]

Andrew Robb, photographic conservator and graduate conservation fellow, Paper Conservation Laboratory, CAL [6]

James Swope, principal and conservator, Fine Arts Conservation, West Palm Beach, Florida [4]

Christine Thomson, senior conservator, Society for the Preservation of New England Antiquities, Waltham, Massachusetts [1]

Jonathan Thornton, associate professor of conservation, State University College at Buffalo, Buffalo, New York [1]

Charles Tumosa, senior research scientist, CAL [2]

Alan Ullberg, attorney, Office of General Counsel, Smithsonian Institution, Washington, DC [4]


Richard Wolbers, associate professor of conservation, University of Delaware [1]
Outreach and Special Projects

Perhaps no area is more important for CAL Education and Training activities than outreach, or the dissemination of information beyond CAL's traditional borders. Rather than speaking solely to specialist colleagues, CAL is determined to reach further, to influence as broad a community of collections caretakers as possible, and to make them aware of the nature of artifacts and the cause and prevention of deterioration. CAL has begun taking major steps in this area, working diligently to put knowledge in the hands of audiences thus far ignored or de-emphasized by the conservation profession.

No project at CAL typified this approach better than the "Angels" project for the Society of American Archivists (SAA) annual conference. In partnership with SAA, this project, entitled "Angels Help Save the Dinosaurs' Records," demonstrated to archivists the integration of activities required for the preservation of core holdings, including various types of surveys, prototypical housing materials and techniques for storage and display, and duplicating procedures to facilitate access to the images. A dozen participants from the SAA conference attended, getting advice from CAL and other Smithsonian staff and CAL interns on wide-ranging topics relative to archives preservation.

CAL staff also began a precollegiate education program with Suitland Center for the Visual and Performing Arts (SCVPA). The goals of this workshop and series are to increase and diffuse knowledge through lectures and demonstrations on the nature of artifacts and on the materials and techniques for creating, evaluating, and restoring works of art. The SCVPA's goals for the project are to broaden and deepen the students' view of the world of art through work with specialized Smithsonian professional staff, to give students the opportunity to interact with adult professionals, to help them learn about traditional and modern artists' materials and techniques, to provide lectures and hands-on demonstrations in art techniques and art preservation, and to add new and repeatable programs to the SCVPA curriculum that can be adopted by or for other academic programs at about the same level. The structure of the course included six lectures and studio sessions at CAL from 3:00 p.m. to 5:30 p.m. every other Tuesday. These units covered painting media, painting in wood (marquetry), egg tempera, "compo," paper, and gold leaf. The first of these units was held the final Tuesday of FY 1995, with the remainder to occur in FY 1996.

In addition, CAL staff designed and taught a two-week course "Conservation Treatment of Archival Material," for the International Centre for the Study of the Preservation and Restoration of Cultural Material (ICCROM) in Santiago, Chile, attended by 16 conservators representing most Latin American countries. The course included a discussion of theory, ethics, and practice of preservation and conservation of archival collections as well as practical exercises and demonstrations. The emphasis was on batched treatments required for large collections. Practice treatments were carried out on examples of clay-coated papers, tracing papers, and manuscript and printed materials prevalent in archives. The course resulted in the development of a Spanish-language curriculum and Spanish translations of CAL Paper Conservation Laboratory publications.
Finally, the second of CAL's instructional videos, Rescuing Records: Recognizing the Problems of Preserving Documents in Research Collections, was completed. The video defines some aspects of the value, use, and risks associated with documents found in research, library, archives, or private collections and explains what is needed to rescue documents from loss of informational, evidential, or intrinsic value. It outlines the responsibilities of a comprehensive preservation program, including assessment, treatment, collections maintenance, research, environmental control, training, and duplication. The various types of document substrates, media, and formats are identified, as are their inherent problems. The video is accompanied by handling guidelines and a select bibliography on preservation of documents. Both Furniture Care and Maintenance and Rescuing Records: Recognizing the Problems of Preserving Documents in Research Collections are now being distributed. Fiscal restrictions have suspended the development of any further offerings in this series.
Support and Collaboration

Scientific Support Coordinator/Conservation Scientist
Melanie E. Feather

Analytical Chemist
Camie S. Campbell

Senior Conservator, Paintings
Roland H. Cunningham

Publications Specialist
Gail L. Goriesky

Conservation Information Specialist
Ann B. N'Gadi

Organic Chemist
Walter R. Hopwood

Research Chemist
Emile C. Joel

Computer Network Administrator
Cheryl D. Sultzer

The Support and Collaboration Group is comprised of specialists from a wide variety of disciplines including the physical and natural sciences, conservation, and library science. Group members provide analytical and technical support to all CAL Research and Development programs and Education and Training programs, to conservation and curation programs in other Smithsonian bureaus to assist with the care and understanding of their collections, and, on occasion, to other museums and government agencies. This group is also responsible for the maintenance, update, and replacement program of all general-use scientific instrumentation and computer equipment at CAL. In coordination with the CAL research and education programs, larger collaborative projects with other Smithsonian bureaus are undertaken. Group members assist all CAL programs, other Smithsonian bureaus, other museums and government agencies, outside conservation professionals (both national and international), and the public in finding technical and professional conservation-related materials and assistance. Technical information services, including bibliographic assistance, data-base searches, and maintenance of a reprint file, are also provided. The production and distribution of CAL publications are a function of this group.

The Support and Collaboration Group is organized in two programs: Analytical Services and Technical Information. Collaborations involving CAL's conservation professionals also falls within the Support and Collaboration Group. A summary of new and upgraded scientific equipment follows the section descriptions.
Analytical Services

The Analytical Services staff operate and maintain a large number of analytical instruments and perform or assist with analytical chemistry techniques to support CAL research and education programs and to provide assistance to other Smithsonian bureaus and, occasionally, other museums and government agencies. Instrumental support offerings include Fourier transform infrared spectroscopy (FTIR), gas chromatograph-mass spectrometry (GC-MS), optical microscopy with image analysis (OM-IA), scanning electron microscopy with energy dispersive spectroscopy and wavelength dispersive spectroscopy (SEM-EDS-WDS), ultraviolet-visible spectrophotometry (UV-VIS), xero-radiography, x-ray diffraction (XRD), x-ray fluorescence (XRF), and x-ray radiography.

During FY 1995, the analytical staff performed about 1,200 analyses. About 32 percent of them were done to assist other Smithsonian bureaus and government agencies. The accompanying chart illustrates the distribution of these analytical services. The numbers are low this year because of the laboratory shutdown during the Museum Support Center ventilation retrofit. This shutdown affected the Analytical Services section for more than six months.

Analyses Performed for Units Other than CAL

<table>
<thead>
<tr>
<th>Unit</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freer/Sackler Galleries</td>
<td>117</td>
</tr>
<tr>
<td>Hirshhorn Museum &amp; Sculpture Garden</td>
<td>20</td>
</tr>
<tr>
<td>Museum Support Center</td>
<td>2</td>
</tr>
<tr>
<td>NMAfA</td>
<td>17</td>
</tr>
<tr>
<td>NMAA</td>
<td>16</td>
</tr>
<tr>
<td>NMAH</td>
<td>180</td>
</tr>
<tr>
<td>NMAI</td>
<td>9</td>
</tr>
<tr>
<td>NMNH</td>
<td>29</td>
</tr>
<tr>
<td>Holocaust Museum</td>
<td>21</td>
</tr>
<tr>
<td>US Army</td>
<td>16</td>
</tr>
<tr>
<td>George Washington University</td>
<td>10</td>
</tr>
<tr>
<td>Suitland High School</td>
<td>8</td>
</tr>
</tbody>
</table>

Within the Conservation Analytical Laboratory

Within CAL, analytical support has been provided for conservators, scientists, fellows, interns, and visiting scholars. Assistance for the Objects Conservation Laboratory included work on fibers, pigments, and salts found on Harappan ceramics, a Maya mosaic mask, a green surface accretion on Turkish ceramic sherds, and the development of an evaluation method for assessing stone-cleaning damage. For the Coatings Conservation Laboratory and the former Paintings Conservation Laboratory, several painting cross sections were examined, including those from a self-portrait by Andy Warhol, Thomas Wilmer Dewing's Portrait of Frances Houston (1880), Henry
Ossawa Tanner’s Portrait of Mr. and Mrs. Atherton Curtiss (ca. 1911), and a 19th-century folk painting Portrait of Woman and Child, which was also radiographed. Assistance for the Paper Conservation Laboratory included identifying a white coating from an Elgin watches advertisement of Father Time (ca. 1910), various photographs, and Chinese paper. Furniture conservation projects involved gilding samples and wood and resin. Materials science research studies using expertise from the Analytical Services staff included samples from videotape, paint chips from a Norwegian church, organic residues found in pottery from the Philippines, metallurgical cross sections and an ax from the Great Orme mine, colorations found on bone, stone tools and the residues found on them, Neolithic plasters, soda-lime silicate and Sardis glass, Islamic ceramics, Paleolithic ceramics and shale, and clays.

Within the Smithsonian Institution

Analytical Services staff also contributed to many Smithsonian projects outside CAL, primarily to assist the conservation efforts of staff conservators and curators. Assistance to the Freer and Sackler Galleries included analysis of paint cross sections. Hirshhorn Museum and Sculpture Garden work included varnish from Anish Kapoor’s At the Hub of Things (1987), a waxy sample from the sculpture Plastic Construction of Noise and Speed (1915) by Giacomo Balla, brown film found on some sculptures, samples from the water system, and paint from Vaclav Vytlacil’s Construction (1939). Assistance to the National Museum of African Art (NMAfA) included analysis of some Tuareg knife handles, a lacquer coating from a Sudanese box and key, the coating from a Fon copper alloy figure, and fumigation of a Tuareg mat screen. Analyses for the National Museum of American Art (NMAA) included two glass columns from the Gellatly Collection. National Museum of American History (NMAH) staff members requested assistance with a large variety of items, reflecting their wide-ranging collections. These included fasteners, hull sheathing, corrosion, and wood from the wreck of the yacht Cleopatra, painting cross sections from a set of 19th-century factory gates from Philadelphia in preparation for an upcoming exhibition, and wood from a painted chest dated 1680. Corrosion from some copper axes was examined for the National Museum of the American Indian (NMAI). The National Museum of Natural History presented CAL with a wide variety of objects to be examined. These included archaeological wood, cross sections and samples from a Native American painted tent cover, a possible exhibit mounting material, an Asian silk tapestry, and accretions found on an East Indian girdle.

Outside the Smithsonian Institution

CAL also assists other government agencies as needed, and on occasion, other museums, universities, and research institutions. Such organizations often lack the analytical facilities and staff expertise to perform certain examinations and analyses. Some unidentified red pigment found on bone was analyzed for an archaeologist at George Washington University. A McCrone Research Institute scientist requested assistance in the identification of the varnish on an 18th- or 19th-century wooden chest. Crystals and corrosion growing on and around several toothbrushes were analyzed for the United States Holocaust Memorial Museum.

As part of CAL’s public outreach mission, art students from Suitland High School in Suitland, Maryland, visited CAL. They attended lectures and demonstrations and participated in hands-on sessions looking at painting cross sections with some of the analytical equipment.
Technical Information

The Information Office is the center of CAL's public outreach programs. The staff assist conservators, scientists, and students within CAL, at the Smithsonian Institution, and from national and international organizations in finding technical and professional conservation-related materials and assistance. The Information Office also serves as the public inquiry center for conservation and general scientific information in the Smithsonian. Staff members conduct data-base searches, maintain an up-to-date reprint file, answer questions on conservation-related issues or refer the inquiries to someone who can, and distribute CAL publicaton, including *Approaches to Pest Management in Museums* and *A Primer on Disaster Preparedness, Management, and Response: Paper-Based Materials*. The staff is responsible for the production and distribution of all CAL publications. Staff members also conduct official tours of CAL laboratories for visiting scholars, professionals, and dignitaries.

Information Assistance

The staff of the Information Office answered 681 inquiries from conservation professionals and the public in FY 1995. They also referred 328 inquiries to CAL conservators and scientists. Such work involves discussing the inquiry with the person initiating it to determine where to route the question, assigning the request, preparing an informational packet to send out, and checking with the person initiating the inquiry to make sure his or her needs were met. Referrals for radiocarbon dating services were also made.

Data bases used in the searches include the Conservation Information Network (CIN), Internet, Smithsonian Institution Research Information System (SIRIS), and CAL Archives. Searches during FY 1995 included the following topics: images on synthetic supports, leather lubricants and softeners, Pliacre epoxy putty, European tapestry restoration, mold on silk and on paintings, mordants, philatelic conservation, binders for paint and ink, removal of murals on canvas, mechanical properties of parchment, technical authentication techniques for medieval manuscripts, harpsichords, costume and textile dry-cleaning, Islamic glass and enamel, glass transition temperature, resistance of coatings to abrasion, vapor permeability of coatings, metal paint on architectural elements, museum environments and collections, a 1903 Winton carburetor, photocopying, effects of lighting during photography on objects, shellac on paper, laser pointers and safety of use with oil paintings, lasers in art conservation, measurement of fading photographic materials, photographs and computer scanners, cold storage for photographs, exhibition and display of photographs, spectrophotometers, Liquitex paint for inpainting and problems with fading, alabaster, condensation on roofing, mounting and framing of documents and coins, paint analysis of architectural elements, mortar analysis, image permanence on Mylar, lining paintings with beeswax, consolidation of flaking gelatin glass plate negatives, accelerated aging of paper, conservation of trunks, green accretions on ceramics, "latrine green," Anish Kapoor and his use of Prussian blue, white chalk on paper and parchment, ethics of cleaning silver objects, most recent standards for lighting collections, and bibliographies on Bernard M. Feilden, James M. Fitch, and Marino Maggetti.
Requests on availability and location of reprints come to CAL from throughout the United States and around the world. The CAL Information Office is one of the few places where copies of many conservation and conservation-related publications can be found. If the item is not in the CAL reprint file, the Information Office tries to locate a copy.

The accompanying United States and world maps show where technical and public inquiries, data-base search requests, and reprint requests originated. Nationally, there was a total 818 inquiries and requests from 47 states, the District of Columbia, and Puerto Rico. Internationally, 191 such inquiries and requests were received from 48 countries.
**Document Imaging-Retrieval System**

The Information Office is the home of CAL's new document imaging-retrieval system, which was installed and placed into operation during FY 1995. The system is used for storing the in-house analysis, research, and conservation treatment reports generated by CAL activities and some of CAL's administrative files. The end result is full-text retrievable reports.

CAL hired a consultant to conduct a needs assessment, then get the image-retrieval system up and running and provide staff training and support service. The hardware system consists of a Pentium computer with a 3.5 inch disk drive and a cassette drive, a Cornerstone 21 inch color monitor, a Hewlett-Packard 1300T optical disk drive and laser printer, a Fujitsu scanner, and a Smart-Ups American Power Conversion unit. The software includes Microsoft Windows, FileMagic Plus database, and Colorado Backup. The capabilities now include full-text searching, keyword searching, basic halftone images of photographic material, inputting items from a disk and the scanner, and printing information. Future possibilities include having the information available on CAL's local area network, importing and exporting information by fax, network, or disk, scanning in slides, photographs, other photographic materials, and large or odd-shaped papers (graphs, charts, etc.).

At the end of FY 1995 there were 270 CAL reports and 146 administrative files in the system.
**Desktop Publishing**

CAL has implemented a desktop publishing program that enables its publications to be produced in a standardized format, in-house. This new program required staff retraining and equipment purchases. A Dell 590/XM Pentium PC and ViewSonic 21 inch monitor were purchased and installed with appropriate software for desktop publishing. A Microtec ScanMaker IIIs scanner and an Epson ESE P2 color inkjet printer were later added.

CAL's annual report for FY 1994 was compiled using QuarkXpress, Excel, Freelance, and Photoshop software, enabling, for the first time, images and photographs to be used to illustrate CAL's activities in a document of this type. This annual report, for FY1995, is being produced in the same way.

The Information Office's records were searched to determine the most-asked public inquiries, thus permitting priorities to be set regarding "Guideline" brochures, now being produced, updated, or redesigned using the new desktop publishing equipment. Several existing "Guidelines" were put into a more attractive and concise format. The "Time Capsule Guideline," for example, was condensed from about 30 pages of information, previously photocopied and mailed to interested parties, into an illustrated one-page brochure highlighting pertinent information and addresses. Several CAL scientists and conservators reviewed the portions of the brochure related to their area of expertise for technical accuracy. In addition, information on time capsules was gathered and shared internationally on the Internet in response to an overseas request for information on a conservation discussion list. New information was added to CAL's "Time Capsule Guideline" from this source; likewise, information gathered for CAL's "Time Capsule Guideline" was added to a trans-Atlantic project via the Internet.

Other brochures were also completed and were printed in-house on a Hewlett-Packard LaserJet 4si printer on an as-needed basis. Appropriate additions or changes can be made as research progresses or additional information on the various topics of the brochures becomes available and is pertinent. In this way, the expense of printing large quantities of brochures that quickly become outdated can be avoided and the information sent out from CAL will always be as current as possible.

Work began on compiling CAL’s publications over the past 20 years for a book that will not only provide a year-by-year listing of CAL’s publications but a pictorial history of the laboratory as well as a short historical narrative. The document is being prepared in a manner allowing yearly updates.
Conservation Collaborations

Conservation Treatments

Conservation treatment of artifacts allows CAL staff to develop new techniques or adapt old approaches to the problems of preservation and restoration. It also provides an excellent opportunity to teach the conservation profession to interns and visiting students, whether advanced or beginner. In most cases the treatment procedures developed at CAL are published in the conservation literature and presented at professional conferences.

Coatings Conservation Laboratory

The staff and interns of the Coatings Conservation Laboratory focused on a small group of conservation treatments through the year. A severely crackled 19th-century folk painting, *Portrait of Woman and Child*, was treated by a painting preprogram intern under the supervision of CAL staff. The discolored varnish was reduced, and the structure of the painting was strengthened by adding lining support.

*The Portrait of Mrs. J. Cropper* (1793) and *The Portrait of General John Cropper* (1792) by Charles Willson Peale (from the National Museum of American History), were treated and problematic cross-linked surface coatings were removed. The cross-linked surface coatings were analyzed along with other known aged samples of cross-linked coatings such as N-butyl methacrylate (F-10), Lucite 2044, and M varnish. Other thermal and solvent-induced swelling behaviors were characterized to further the understanding of these cross-linked coatings, which are not easily removable with standard solvent-based techniques.

Work continued on the long-term project to conserve the English japanned clock from the National Museum of American History's Division of Engineering and Industry collection. This extensive treatment is being executed by a contract conservator, whose serious injury in an accident during the year caused the project to be delayed.

A pair of 19th-century painted chairs from the Cooper-Hewitt collection was treated by CAL staff and interns, who replaced missing structural and decorative elements.

Objects Conservation Laboratory

Conservation of archaeological objects remains the focus of treatment and study activities for staff and interns of this laboratory. The principal treatment project for the year was the continued assembly and documentation of the 'Ain Ghazal plaster statuary cache, whose completion is required in FY 1996 for an exhibition at the Arthur M. Sackler Gallery.

An objects conservator and the archaeological conservation interns engaged in on-site conservation at two archaeological sites with long-standing association with CAL: Harappa, Pakistan, and Copán, Honduras, projects supported by a grant from the Samuel H. Kress Foundation. Hundreds of objects were examined and treated, and laboratories were set up by CAL conservators at the sites. Additional treatment and technical studies on selected artifacts from the sites were conducted at CAL.
**Paper Conservation Laboratory**

Staff and interns of the Paper Conservation Laboratory treated 10 pictorialist photographs for the National Museum of American History's Department of Photographic History, 30 panoramas for the National Archives (as part of an internship assignment), 10 exhibition pieces for the National Museum of American History, and 3 books for the Smithsonian Institution Libraries. Several other treatments were proposed and approved but have not yet been executed.

**Textiles Conservation Laboratory**

The CAL textiles conservator resumed her long-term collaboration of examination and treatment of a rare Chinese archaeological silk artifact from the Arthur M. Sackler Gallery collection and completed treatments and examination of a number of artifacts prior to the closing of the laboratory for the Museum Support Center ventilation construction.

**General Collections Care**

In addition to treatment, CAL conservators were involved in a variety of Smithsonian collections care venues, from informal consultations, to formal collections surveys and collaborations, to technical analyses. In FY 1995 CAL conservators made important contributions to the care and examination of Smithsonian Institution collections, including those described below.
Archives Preservation Priority Surveys

The staff and interns of the CAL Paper Conservation Laboratory are frequent collaborators with archives and research paper-based collections within the Smithsonian. In that context, a wide-ranging number of collections were surveyed to establish the priorities for preservation activities related to those collections.

For the Smithsonian Institution Archives, CAL surveyed the James Smithson Collection (1,000 objects of various media), the Vail Telegraph Collection (35 bound volumes and 1,000 objects of various media), the William N. Dall Collection (45 scrapbooks and 5,000 objects of various media), and the George Suckley Collection (100 objects of various media).

For the National Museum of Natural History, preservation priority surveys included the Department of Botany's M.L. Evans Tropical Botanical Illustration Collection (36 watercolors), the Margaret Mee Illustration Collection (10 watercolors), the Hughes Illustration Collection (20 watercolors), and the Framed Botanical Illustrations (13 watercolors and engravings); the National Anthropological Archives' Acee Blue Eagle Collection (300 drawings and paintings utilizing various media), Archaeological Map Collection, Numbered Manuscripts, River Basin Surveys, and Bureau of American Ethnology Map Collection; the Department of Paleobiology's O.C. Marsh Drawings (1,600 drawings, sketches, and tracings), and the Gilmore Archives (450 pencil and ink drawings, photographs, and tracings).

National Museum of American History collections prioritized included the Department of Photographic History's Daguerreotype Collection, Ambrotype Collection, Lantern Slide Collection, Stereocard Collection, Kromogram Collection, Carte de Visites Collection, and Print Collection.

Item-Level Surveys

In addition to broad, priority-establishing surveys, examinations of individual artifacts were conducted for a number of collections as well, including the National Museum of Natural History's Anthropology Archives Chinese Collection (50 original illustrations and archival materials), the Department of Botany's M.L. Evans Tropical Botanical Illustration Collection (36 watercolors), and the National Portrait Gallery collection of original cover illustrations for Time and Life magazines (300 mixed media).
New or Upgraded Scientific Equipment

CAL added or upgraded several pieces of research and computer equipment during FY 1995 with funds provided by the Smithsonian Institution Research Equipment Pool and the Smithsonian Institution Computer Pool. CAL also purchased some microscopy equipment through a cost-saving arrangement with the U.S. National Park Service. The Park Service bought some of CAL’s older, little-used microscopes, which its staff needed, and CAL used the funds to buy equipment its microscopy program needed. These equipment purchases substantially added to CAL’s microscopy, analytical, environmental monitoring, and computing capabilities.

Microscopy

The microscopy equipment at CAL continues to be expanded and updated.

Image Processing and Storage-Retrieval System for Optical Scientific Records

A new Leica computer-based image processing and analysis system will enable image information to be quickly and accurately processed and stored. The image information can also be quickly and accurately reproduced. While the system is ideal for color quantitative optical microscopy, SEM images and those from photographs, negatives, slides, radiographs, and actual objects can be directly processed. Images can be acquired and stored for future analysis or simply viewed in the image database and archive system. The hardware and software are integrated in an industry standard personal computer that is Windows-based for ease and compatibility with database and word-processing programs. The system builds upon equipment currently available, including the research microscope and color camera at CAL.

A variety of modes of image processing are possible, including addition, subtraction, and increasing contrast. Thresholds for detection can be customized. Field measurements, such as area, perimeter, and length, and individual features, such as particle counting, can be conducted with customized parameters. Calibrated gray-level measurements convert the video image into optical density, transmittance, or reflectance. Results of analysis are available on the screen simultaneously with the image and can be printed or filed to the disk in several formats.

The archive image management system handles a combination of digitized images and measurements. For large-image archives, removable storage media (rewritable compact optical disk) and image compression can be used. Comparison of multiple records can be made by viewing portions or full data bases or visual images. Data bases are custom made by the user.
**Heating and Freezing Stage with Computer Interface**

The Linkham heating and freezing stage can quickly and quantitatively measure different material properties such as sample temperature, dimensions, enthalpy changes, and optical behavior as a function of temperature. It is computer controlled (Windows) and generates a video-text overlay that is visible and recorded on screen. It has a range of -196°C to 350°C and holds temperature to within 0.1°C indefinitely. The system can be integrated with image analysis. A dedicated microscope and workstation have been set up in the CAL microscopy room.

The heating-freezing stage is ideal for determining melting points, and any change in the sample, such as disintegration, efflorescence, or decomposition due to heat can be readily observed. The hot stage will be used in the study of surface coatings, including melting, glass transition, softening, purity, expansion and elastic behavior, oxidative stability, kinetics reaction progress, degree of cure, and vulcanization. The hot stage can also help to identify many organic compounds by measuring the melting point of eutectic formed when an unknown and a known are melted simultaneously.

**Semiautomatic Sample Grinder and Polisher**

This Beuhler semiautomatic sample grinder and polisher is used in the preparation of test specimens and samples removed from museum objects. The equipment allows auditable, reproducible results - the goal being to consistently reveal undeformed microstructure. The equipment selected allows the highest quality preparation of coating systems, polymers, and other composites. This grinder and polisher complements microtomy and other techniques available at CAL by overcoming the limitations of those techniques.
Analytical

Benchtop Gas Chromatograph-Mass Spectrometer

A Hewlett-Packard benchtop gas chromatograph-mass spectrometer (GC-MS) was purchased to assist CAL researchers in the analysis and identification of individual compounds in complex organic materials such as oils, resins, waxes, gums, and the degradation products of these materials, proteins, archaeological food residues, pollutants, polymers, and additives such as plasticizers and antioxidants. The results can be applied in many different ways, including identification of unknown materials, analysis of materials for technical studies, evaluations of the effects of treatments on artifacts, monitoring of the rate of degradation of materials and the effects of the environment on preservation, evaluation of modern materials for use in treatment or display, and forensic problems involving the determination of the causes of deterioration of museum objects. It is often used as a second stage for more specific identification after general classification by Fourier transform infrared spectroscopy.

Attenuated Total Reflectance Attachment

In recent years most, if not all, of the infrared analysis at CAL has shifted to microsample analysis, using the Fourier transform infrared spectroscopy (FTIR) microscope. CAL's new Spectra-Tech attenuated total reflectance (ATR) attachment attaches to the present upgraded FTIR to permit micro-ATR capability, thus complementing the transmission and direct reflectance methods to which CAL has been limited in the past and which do not provide the capability of surface layer analysis.

ATR is a method for surface layer analysis by infrared spectroscopy in which a collimated infrared beam penetrates a surface in contact with a suitable prism to a depth of about one micrometer. By concentrating the infrared beam at the sample surface, a spectrum of the surface, rather than the bulk of the sample, is obtained, and interference from total absorbers in the bulk can be overcome.

General Purpose Centrifuge

This Fisher Scientific variable speed centrifuge supports a variety of CAL's needs for centrifugation up to individual volumes of 100 milliliters. Specific applications include, but are not limited to, biological solutions in support of the biogeochemistry program, clay mineralogical separations for ceramic characterization, and phytolithic separations for ancient environmental reconstruction.
Environmental Monitoring

Two-Stage Dew-Point Hygrometers

Two General Eastern two-stage dew-point meters were purchased to support the environmental experimental research at CAL. CAL researchers have found that reliable and accurate environmental monitoring is possible only with dew-point meters that can sample the ambient air without changing the moisture content. These two pieces of equipment were purchased to assist with current research and with future efforts. An immediate application of the dew-point meters is in the determination of the relative humidity in environmental chambers. These measurements will be used to establish the relative humidity and temperature tolerances of a wide range of cultural materials used in museum exhibition, transportation, and storage environments.

Computing

File Server

A Nortec AST 90 Manhattan series computer with four gigabytes of storage was purchased to serve as the file server for the CAL Novell local area network.
Staff


Mary T. Baker, Research Organic Chemist. B.S. (1980); Ph.D. (1986) University of Connecticut. Areas of interest: magnetic media, primarily videotape; natural and synthetic modern rubber; archeological rubber; synthetic coatings and modern paints; chemical and physical studies of modern polymers, primarily plastics.


Ronald L. Bishop, Research Coordinator/Senior Research Archaeologist; Manager, Smithsonian Archaeometric Research Collections and Records (SARCAR). B.A. (1965) San Francisco State University; Ph.D. (1975) Southern Illinois University. Areas of interest: archaeology of Meso- and Central America; ancient materials characterization; exchange systems; quantitative methods.


**Gail L. Goriesky**, Publication Specialist. B.A. (1969) Michigan State University; additional studies University of Mannheim, Germany; San Francisco Art Institute; San Francisco State University; Goethe Institute, Rothenburg o.d. Tauber, Germany. Areas of interest: desktop publishing.


Pamela B. Vandiver, Senior Ceramic Scientist. B.A. (1967) Scripps College; M.A. (1971) Pacific Lutheran University; S.M. (1983) and Ph.D. (1985) Massachusetts Institute of Technology. Areas of interest: the analysis, reconstruction, and explanation of conservatism and innovation in craft technologies and material culture, especially Paleolithic ceramic, soft stone, and pigment use; Neolithic plaster and pottery techniques; early glass; slag and glaze technology in Eurasia using the methodologies and techniques of archaeology and materials science; site resource survey.


Publications by Staff


Presentations by Staff and Interns

**Alexander, Ingrid**


"Painting Techniques from Ancient Times to the Present." Lecture, Johns Hopkins University, Baltimore, MD, April 1995.

"The Artistic Climate at the Court of Urbino." Lecture, Art History Department, Tel-Aviv University, Tel-Aviv, Israel, April 1995.


**Baker, Mary T.**


**Beaubien, Harriet F.**
"Orientation to On-Site Conservation at Harappa (Pakistan)." Lecture, Conservation Analytical Laboratory, Smithsonian Institution, Washington, DC, January 1995.


Beaubien, Harriet F., Emily P. Kaplan, and Katherine A. Holbrow

Blackman, M. James
"Nuclear Archaeology: The Use of Neutron Activation Analysis in the Chemical Analysis of Archaeological Artifacts." Lecture, American Association for the Advancement of Science, Atlanta, GA, February 1995.

Erhardt, David


Grissom, Carol A.

Joel, Emile C., Joan J. Taylor, and Robert Ixer

McCormick-Goodhart, Mark H., Charles S. Tumosa, Marion F. Mecklenburg, and David Erhardt
Mecklenburg, Marion F., Charles S. Tumosa, and David Erhardt

Méry, Sophie, and M. James Blackman

Richard, Mervyn, Marion F. Mecklenburg, and Charles S. Tumosa

Redford, Scott, and M. James Blackman

Robb, Andrew


Tennison, Heather

Tumosa, Charles S., and Marion F. Mecklenburg

**Tumosa, Charles S., Marion F. Mecklenburg, and Mark H. McCormick-Goodhart**


**Tumosa, Charles S., David Erhardt, Marion F. Mecklenburg, and Mark H. McCormick-Goodhart**


**Tuross, Noreen C.**


**Tsai, Fei-Wen**


"Condition Surveying and Treatment Options." Preservation Workshop, "Angels" project for the Society of American Archivists, for the Dinosaur Illustration File, Department of Paleobiology, Division of Invertebrate Paleontology, National Museum of Natural History, September 1995.

**Tsang, Jia-Sun**


van der Reyden, Dianne L.


Vandiver, Pamela B.
"Reconstructing and Interpreting the Technology of Ancient Ceramics." Lecture, Instituto de Fisica, Universidad Nacional Autonomidad de Mexico, Mexico City, Mexico, January 1995.


Wachowiak, Melvin J., Jr.

Williams, Donald C.


Grants

Smithsonian Institution Funding

Computer Pool, $11,925
- Network File Server, $11,925

Research Equipment Pool, $123,000
- Benchtop GC-MS, $67,002
- Image Analysis System, $26,598
- ATR Attachment, $7,125
- Two-Stage Dew-Point Hygrometers (2), $15,063
- Centrifuge, $7,212

van der Reyden, Dianne and Paul Theerman, Preservation Officer
- Research Resources Program, $30,000

External Funding

Beaubien, Harriet F.
- Archaeological Conservation Internship Program, Samuel H. Kress Foundation, $2,500

Industrial Steel Corporation donation to Paper Conservation Laboratory of $10,000-worth of steel cabinets for storage of archival materials.

U.S. National Park Service Equipment Purchase Agreement, $13,400
- Heating and Freezing Stage with Computer Interface, $10,033
- Automatic Polisher, $3,36
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