SYMPOSIUM II

Materials Issues in Art and Archaeology VI

November 26 – 30, 2001

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* Invited paper

SESSION II1: PRESERVATION SCIENCE AND CONSERVATION I
Chairs: Jennifer L. Mass and Karen Trentelman
Monday Morning, November 26, 2001
Independence East (Sheraton)

8:30 AM OPENING REMARKS

8:45 AM II1.1
A MATERIALS-SCIENCE EVALUATION OF THE CLEANING OF THE SISTINE CHAPEL CEILING. Michael Douma, Michael Henchman, Brandeis Univ, Dept of Chemistry, Waltham, MA.

Traditional evaluations of the cleaning of wall paintings rely on the informed opinions of art historians who are connoisseurs. Thus for the case of the cleaning of the Sistine Chapel ceiling, much heat (but little light) has been generated by the contrary opinions of Prof. Kathleen Weil-Garris Brandt (affirmative) and Prof. James Beck (negative). The questioning bystander gains little objective sense as to the present status of this debate or its possible outcome. Only objective methods, based on materials science rather than the eye of the observer, can produce conclusions free from subjective taint. We have used calibrated images of the highest quality for the ceiling before cleaning (Okamura, 1980) and after (Okamura, 1991). After adjusting the luminosity of both images to be equivalent, the difference image of the two reveals any non-uniformity in the cleaning. For all but one of the figures which we have examined on the ceiling, the cleaning is found to be convincingly uniform. In one case, that of the ignudo between the prophets Joel and Zechariah, the non-uniformity we have found indicates that more than dirt has been removed. We conclude that, in all but one case, only dirt has been removed in the cleaning. In one case, the ignudo discussed above and cited by Beck, there is evidence that some of Michelangelo's original image has been removed from the upper right arm. We further apply this approach is to the virtual cleaning of paintings where the varnish has yellowed.

9:00 AM II1.2
FIB/TEM ANALYSIS OF PAINT LAYERS FROM THOMAS EAKINS' "CRUCIFIXION". Andrew Lins, Philadelphia Museum of Art, Philadelphia, PA; Lucille A. Giannuzzi, University of Central Florida, Mechanical Materials and Aerospace Engineering, Orlando, FL; Frederick A. Stevie, Cirent Semiconductor (Agere Systems), Orlando, FL; Beth Price, Mark Tucker, and Nica Gutman, Philadelphia Museum of Art, Philadelphia, PA.

Many issues in the examination, treatment, and authentication of works of art depend on the accurate characterization of thin layers, the thinnest of which may challenge the resolution and detection limits of instrumentation routinely used for such analyses, primarily SEM-EDS and EPMA. Thin layers — 5 micrometers and less — have been the focus of recent conservation analysis in preparation for a major retrospective of Thomas Eakins' works. Interpretation of many Eakins paintings are complicated by mechanical and chemical cleaning procedures performed after the artist's death in 1916. Recent advances in Focused Ion Beam (FIB) technology provide means for preparing specimens of thin layers that can be analyzed directly by transmission electron microscopy (TEM) yielding resolution in the nanometer range or better. This paper describes initial work undertaken to elucidate the inorganic components in the uppermost paint layers from Eakins' "Crucifixion," dated 1880. Using TEM, we have observed a pigment free zone in the top 1 mm of a lead white paint layer overlayed by a Pb-rich nanocrystalline region with a thickness of 0.5 micrometers or less. An analysis of samples from two paintings which were subjected to mild cleaning operations do not show nanocrystalline Pb-rich precipitates. These results suggest that the "Crucifixion" painting may have been subjected to a more aggressive cleaning treatment which entrained Pb-rich material — not resolvable by traditional analytical techniques — in a surface film. The use of FIB/TEM has enabled unambiguous identification of the thin paint surface layers and offers enormous promise for understanding the original processing and subsequent alteration of artists' materials on aging.

9:15 AM II1.3
TREATMENT AND ANALYSIS OF A PAINT CHIP FROM "WATERLILIES" A FIRE DAMAGED MONET. Sharon Miller, Bruce Banks, NASA Glenn Research Center, Cleveland, OH; Greg Tollis, Cleveland State University, Cleveland, OH.

A museum fire in 1959 severely damaged a Monet "Waterlilies" panel that was on display. The surface of the painting was very dark with areas of blistering and charring. Over the years, traditional techniques have been found to be ineffective at removal of the soot and char from the surface. The painting, which is now in the care of the New York University (NYU) Conservation Center of the Institute of Fine Arts, was the subject of a study to determine if atomic oxygen treatment could remove the soot and char without damaging the fragile painting underneath. For test purposes, a small chip of paint was removed from the edge of the painting by a conservator at NYU and supplied to NASA Glenn Research Center for treatment and analysis. The diffuse spectral reflectance at three locations on the paint chip was monitored at intervals during the treatment process. Photodocumentation of the chip during treatment was also performed. The contrast was calculated from the spectral reflectance data as a function of treatment duration. Results of the testing indicated that the contrast improved as a result of the treatment, and the differentiation of colors on the surface was significantly improved. Soot and char were able to be removed without visibly affecting the gross surface features such as impasto areas. These results look promising for the treatment of the "Waterlilies" painting.

9:30 AM II1.4
THE CONDITION AND CLEANING OF ACRYLIC PAINTINGS. Alison Murray, Celina Contreras de Berenfeld, Elizabeth Jablonski, Tracey Klein, Queen's University, Art Conservation Program, Department of Art, Kingston, CANADA.

Artists, with their well known proclivity for experimentation and working with new media, have been eager to use modern materials such as acrylic paints. Artistic innovation often presents new conservation challenges, however. This research is part of ongoing interdisciplinary work that examines the conservation of modern artists' materials from the point of view the conservator and the materials scientist. The damage seen by conservators who work on acrylic paintings will be described as well as the conservation treatments that conservators have undertaken. In the experimental section of this paper, different cleaning methods will be investigated, focusing on the use of detergent solutions. Naturally aged acrylics from various manufacturers will be cleaned with different detergent solutions. The effects will be evaluated using mechanical testing, as well as surface morphological examination and chemical analysis. The goal of this work is to develop safe and effective cleaning treatments for works of art produced with acrylic paints.

9:45 AM II1.5
MECHANICAL PROPERTIES OF AGING ARTISTS' OIL PAINTS. Marion F. Mecklenburg, Charles S. Tumosa, Smithsonian Center for Materials Research and Education, Suitland, MD.

The mechanical properties of artists' oil paints as determined by a stress-strain curve are difficult to measure because of the need to hold the environment constant for long periods of time. To overcome this problem chambers were constructed to hold constant environments of temperature and/or relative humidity. Oil paints were cast on polyester films and removed at periodic intervals for tensile testing. As the paint films aged, the breaking strain and stress as well as the stiffness of the films could be followed. Specimens were made in the traditional manner from pigments mixed with cold pressed linseed oil. Several commercial artists' oil paints were also cast. Plots of the mechanical behavior of the paints followed a logarithmic pattern when plotted against time and this enabled predictions of the mechanical behavior of very old paints.

10:30 AM *II1.6
THE INCORPORATION OF LASER ABLATION INTO X-RAY ANALYTICAL SYSTEMS TO REDUCE SAMPLING REQUIREMENTS AND IMPROVE RESULTS WHEN WORKING WITH ART AND ARCHAEOLOGICAL OBJECTS. Meg Abraham, Los Angeles County Museum of Art, Los Angeles, CA; Geoff Grime, Peter Northover, Oxford University Department of Materials, UNITED KINGDOM.

The variation of the composition of the corrosion layers and the original base metal on art and archaeological objects can provide the archaeologists and curators with valuable information relating to the manufacture and history of the object. In some cases the corrosion layers on ancient metal objects can be very thick (on the order of millimetres) and so destructive methods such as sampling are currently used to characterise the underlying metal and the corrosion layer where possible. We will describe the use of a focused high power pulsed Nd:YAG laser to ablate the corrosion layer in a series of controlled steps while monitoring the composition of the exposed surface using focused proton-induced X-ray emission (PIXE) and RBS. The diameter of the spot cleaned for analysis is on the order of the analytical beam spot (in this case 500 microns) and sampling is limited to the removal of the corrosion only. Therefore, intrusion into the art object is minimal. Further, the sequential analysis of the corrosion during the ablation cleaning gives increased information about the history of the object being studied.

11:00 AM *II1.7
EXTRACTION OF MATERIAL FROM OIL PAINTS BY SOLVENTS. David Erhardt, Roland H. Cunningham, Smithsonian Institution, Smithsonian Center for Materials Research and Education, Suitland, MD; Sirpa Räsänen, Institute of Arts and Design, Vantaa, FINLAND.

Drying oils used to formulate oil paints consist primarily of polyunsaturated glycerides, along with smaller amounts of mono- and diglycerides, free fatty acids, and other compounds such as sterols. The drying of oils occurs through an oxidative crosslinking process that also produces smaller scission products such as short chain fatty acids and diacids. Compounds that are not attached to the crosslinked oil matrix include glycerin, the unreactive free saturated fatty acids and their glycerides, soaps of fatty acids produced by reaction with metal ions from the pigment, and scission products. As the oil ages, additional soluble material is produced by hydrolysis of glyceride esters. These relatively low molecular weight compounds can be extracted by exposure to solvents, as occurs during the cleaning of paintings. Excessive extraction of material can embrittle the paint film and affect the appearance of the paint. This paper examines the types and amounts of compounds extracted from oil paint films as a function of solvent, exposure time, pigment, and age of the paint. The results indicate that solvents vary more in the speed that they extract material than in their selectivity. The composition of the extracts is consistent with predictions based on the mechanisms of the drying and aging processes. These results confirm the importance of using the least polar solvent possible to clean paintings and to formulate varnishes.

11:30 AM *II1.8
CONTROLLING CRYSTALLIZATION PRESSURE VIA MINERAL SURFACE MODIFICATION. Nicholas Tsui, Nerissa Alleyne, Lia Gustafson, Lucia Linares, George W. Scherer, Robert J. Flatt, and Richard Register Princeton University, Princeton, NJ.

Crystallization pressure exists because the growing crystal of ice or salt repels the mineral surface of the pore; rather than making contact, the crystal sustains a thin film of liquid between itself and the pore wall. If the interfacial energy between the crystal and pore wall were small (i.e., if the contact angle between the two solids were small), then there would be little or no repulsion. In that case, the crystal would form a dry contact with the wall and stop growing, so there would be no pressure to do damage to the porous body. We have found a class of polymer that can be applied as a coating on the surface of the pores of limestone, and which provides remarkable protection against crystallization damage in a sulfate test. These polymers are not water-soluble, so they will not be washed away by rainwater. Results will be presented to quantify the degree of protection provided, along with microscopic examination of the distribution of salt within the stone during successive cycles.

SESSION II2: PRESERVATION SCIENCE AND CONSERVATION II
Chair: Charles S. Tumosa
Monday Afternoon, November 26, 2001
Independence East (Sheraton)

2:00 PM *II2.1
THE CHARACTERIZATION AND CONSERVATION OF AGED ALUMINUM ALLOYS: BUCKMINSTER FULLER'S DYMAXION HOUSE. Karen Trentelman, Detroit Institute of Arts, Detroit, MI; James Ashby, Henry Ford Museum-Greenfield Village, Dearborn, MI.

The Dymaxion House, a unique historic aluminum dwelling structure designed by Buckminster Fuller, will be exhibited in the Henry Ford Museum beginning in the fall of 2001. Built in the 1940s, the house was constructed of modern materials, most notably aluminum, which formed the walls, roof and many of the structural elements. However, after nearly half a century of outdoor exposure, many of the aluminum components exhibit corrosion, some severe, including surface pitting, exfoliation, and filiform corrosion. Furthermore, although not necessarily visible, the physical and mechanical properties of the aluminum alloys may also have changed with age. The challenge faced in the reconstruction of the Dymaxion House was to preserve the original structure as much as possible while also accommodating the needs of exhibition (i.e. to restore the visual appearance and ensure sufficient structural integrity to allow the entrance of visitors). Analysis of the corrosion products, types of corrosion, and metallographic structure of the aged aluminum was used in determining the most appropriate course of treatment. Furthermore, the Dymaxion House has provided a unique and valuable opportunity to study the characteristics of aluminum alloys that have been naturally aged for a period of time much longer than practical for laboratory experiments.

2:30 PM II2.2
CRYSTALLIZATION DAMAGE BY SODIUM SULFATE. Robert J. Flatt, Nicholas Tsui, George W. Scherer, Princeton University, Dept of Civil and Environmental Engineering, Princeton, NJ.

Sodium sulfate is known to be very destructive when it crystallizes inside of pores. Much data has been presented and many authors have advanced explanations as to the cause of this important damage. An overview of reported data and explanations is presented. The respective importance of the various existing explanations is given consideration and when possible quantified based on calculations involving realistic physical parameters.
It will be demonstrated that pressures from the crystallization sodium sulfate can be predicted with fair agreement from ideal solution thermodynamics, while those from sodium chloride cannot. Furthermore, it will be argued that the during the impregnation of a stone containing thenardite, the dissolution of this mineral produces supersaturations with respect to mirabilite sufficient to generate stresses capable of propagating strength limiting flaws. A similar argument will be made for tests that involve temperature cycles of sodium sulfate containing stones. In the case of evaporation, it has been recently reported that mirabilite and thenardite can be precipitated simultaneously at 20°C. This observation indicates that supersaturation with respect to mirabilite is once again very high and can be quantified using thenardite solubility. Results indicate that in this case, precipitation of mirabilite alone is capable of generating stresses larger than the tensile strength of most stones.

2:45 PM II2.3
DESIGN AND EVALUATION OF RESTORATION MORTARS FOR HISTORIC MASONRY USING TRADITIONAL MATERIALS AND PRODUCTION TECHNIQUES. Antonia Moropoulou, Asterios Bakolas, Petros Moundoulas, Eleni Aggelakopoulou, Sofia Anagnostopoulou, National Technical University of Athens, Department of Chemical Engineering, Section of Materials Science and Engineering, Athens, GREECE.

Cement based mortars used for historic masonry repair interventions presented unsatisfactory results, due to their chemical and physico-mechanical incompatibility to original building units. In the present research work, several syntheses of restoration mortars are produced using traditional techniques and materials such as binders (lime putty, lime powder, natural hydraulic lime), pozzolanic additives (natural and artificial pozzolanas) and aggregates (sand and crushed brick). The technical characteristics of the fresh mortars were determined as far as their performance during setting and hardening, using mechanical tests (compressive and flexural) at the time of one, three and nine months of curing. Mercury intrusion porosimetry and water absorption coefficient measurement were accomplished at the time of nine months curing, in order to evaluate mortars microstructural characteristics. The kinetic of carbonation and development of hydraulic phases is evaluated using thermal analysis (DTA-TG), at the time of nine months. The obtained results indicate that the mortars with aerial lime and artificial pozzolana present the best mechanical and microstructural performance. The lime-natural pozzolana and hydraulic lime mortars, also, exhibit a satisfactory behavior. Furthermore, the use of ceramic aggregates produces lightweight mortars, compatible to historic ones.

3:00 PM II2.4
HYGRIC SWELLING OF PORTLAND BROWNSTONE. Inmaculada Jimenez Gonzalez, Robert J. Flatt and George W. Scherer, Princeton University, Departement of Civil and Environmental Engineering, Princeton, NJ.

Portland Brownstone (PB) is a widely used building material, particularly in New York City, but it is susceptible to severe deterioration from weathering. We have measured the swelling strain of PB in aqueous solutions to determine the effect of ionic strength (of NaCl and CaCl2) and water activity (in isopropanol solutions). We have also measured the stress exerted during swelling when the expansion is constrained. These data permit calculation of the stresses produced during wetting/drying cycles. The results are used to assess the importance of this mechanism in deterioration of PB.

3:45 PM II2.5
ASSESSMENT OF CLEANING CONSERVATION INTERVENTIONS ON ARCHITECTURAL SURFACES USING AN INTEGRATED METHODOLOGY. Antonia Moropoulou, Ekaterini T. Delegou, Nicolas P. Avdelidis, National Technical University of Athens, Dept of Chemical Engineering, Section of Materials Science and Engineering, Athens, GREECE.

In this work, pilot cleaning interventions applied by a wet micro blasting method on architectural surfaces of three historic buildings, were evaluated in situ and in lab. The investigation was performed on characteristic materials surfaces (marbles and porous stone) of the following historic buildings: Athens Academy and National Library of Greece in Athens center polluted urban environment and Bank of Greece in Piraeus marine environment. Characterization of the facades materials and decay diagnosis was attained. In addition, the cleaning methods efficiency was evaluated based on the acceptability

of the physicochemical and esthetical characteristics' alterations of the cleaned architectural surfaces. In particular, the architectural surfaces were examined in situ by the means of fiber optics microscopy, infrared thermography and colorimetry, as well as in the laboratory by optical microscopy, X-ray diffraction, scanning electron microscopy with energy dispersion by X-ray analysis, mercury intrusion porosimetry, Fourier transform infrared spectroscopy, conductivity and pH measurements. All measurements - analyses were applied before and after the pilot cleaning interventions. Finally, the results of this study contribute to the development of an integrated methodology for the assessment of cleaning interventions applied on architectural surfaces.

4:00 PM II2.6
RHEOLOGY OPTIMIZATION OF PARTICLE MODIFIED CONSOLIDANTS. Matilde E. Acerra, Ana I. Garcia, Pamela Charles, Lena Aggelakopoulou, Robert J. Flatt, George W. Scherer, Princeton University, Departement of Civil and Environmental Engineering, Princeton, NJ.

Ethylsilicate-based consolidants are used to restore strength to degraded stones. One of the limitations of strength development using these products is their reported cracking behavior during drying. Particle Modified Consolidants (PMCs) have been proposed as a means of limiting the degree of cracking. The presence of particles physically limits the silicate network from shrinking under capillary pressures. In addition, the network maintains a higher permeability. When the particles used are pigments, it is also conceivable to adjust the consolidant color. Moreover, a careful choice of particles should allow matching the thermal dilatation of the consolidant to that of the stone.
An important limitation to further development of these PMCs has been the ability to avoid particle agglomeration in the dispersion. When agglomerates are present, not only do they increase the viscosity but they also can block pore entrances, preventing more consolidant from entering the stone. For many dispersions, agglomeration can be dealt with by adding organic polymers to modify the interparticle force balance. A downside in the case of stone is the unknown resistance of these organics to biota. In this work we examine the feasibility of adding nano-silica particles to the PMC dispersion to create, by adsorption onto pigment particles, a layer of low dielectric constant that acts as a steric barrier to agglomeration. Calculations indicate that a silica barrier of 10-20 nm should allow the pigment particles to be separated by Brownian motion. Rheology data confirm this expectation; more careful examination indicates that a fraction of small agglomerates remains, preventing impregnation when the percolating pore size of the porous network is on the order of the size of those agglomerates. Mix proportioning as well as better mixing procedures are studied in order to remedy this limitation.

SESSION II3: IN-ROOM POSTER SESSION
PRESERVATION SCIENCE AND CONSERVATION
Monday Afternoon, November 26, 2001
4:00 PM
Independence East (Sheraton)

II3.1
SIMULATED STANDARDS FOR THE CHARACTERIZATION OF DOLOMITIC MORTARS. Cristina Montoya, Javier Lanas, Mikel Arandigoyen, Ióigo Navarro, Pedro J. García, José I. Alvarez, Department of Chemistry and Soil Science, University of Navarra, Pamplona, SPAIN.

In order to clarify the possibilities of appearance of several compounds in dolomitic mortars (specially hydromagnesite), as well as the suitability of the X-ray diffraction (XRD) and thermogravimetric and thermodifferential simultaneous analysis (TGA-sDTA) in their determination, different patterns from phases that could be present in mortars of these characteristics have been prepared and studied by these techniques. The standards were prepared from: hydromagnesite (HY) with calcite in weight:weight proportions 1:1 to 1:5; HY with calcite and quartz in proportions 1:1:1 and 1:6:12; HY with quartz, 1:1 and 1:2; HY with portlandite (calcium hydroxide), 1:1 and 1:2; HY with portlandite and quartz, in 1:6:12, and HY with magnesium oxide in 1:1, 1:2 and 2:1. The XRD results have shown that it is possible to detect HY and the other compounds, but when the HY is mixed, the intensity of its diffraction peaks is very weak, even not detectable in some cases. The poor crystallinity of the HY could be the reason of this drop in intensity. Therefore thermal studies were necessary to find HY phases in low weight percentages. The TGA-sDTA results led to establish the experimental conditions most suitable for thermal studies. A high CO_2 pressure around the sample was required for the occurrence of an exothermic phenomenon at $\sim$500°C. This high pressure was guaranteed in the present work as follows: static air atmosphere, packed sample, high heating rate (20°C/min), and alumina crucibles with holed lids in order to establish a self-generated atmosphere. The set of phenomena of the thermal behavior of hydromagnesite phases has been clearly established in contradiction to some references of the literature; specially, the exothermic peak at $\sim$500°C, which denounces the crystallization of magnesium carbonate from the amorphous phase, has been sharply observed.

II3.2
CHARACTERIZATION OF ANCIENT DOLOMITIC BINDING MATERIALS FROM ZAMARCE, IN NAVARRE, SPAIN. Cristina Montoya, Javier Lanas, Mikel Arandigoyen, Ioigo Navarro, Pedro J. Garcia, José I. Alvarez, Department of Chemistry and Soil Science, University of Navarra, Pamplona, SPAIN.

Dolomitic lime mortars were less employed than lime mortars for the building of historical monuments in the old Kingdom of Navarre. However, regarding the differences in their behavior (setting, thermal behavior) and in their compounds which could be found, an unquestionable scientific interest has been established. Ten ancient mortars of dolomitic origin, used in the construction of the church of Santa Mara de Zamarce (1141-1167) in Navarre, Spain, have been studied in order to define their composition and to characterize the type of binder employed. A complete characterization has been carried out including: morphological examination (visually and using optical microscopy); chemical analysis (majority components and soluble salts); mineralogical studies (grain size distribution and X-ray diffraction, XRD); and thermal studies (thermogravimetric and thermodifferential simultaneous analysis, TGA-sDTA). Dolomite and calcite, as binders, and quartz, as aggregate, have been found as the major phases. Also gypsum phases have been detected in significant amounts in two of the samples. Complex silicates were also found: muscovite, anorthite and orthoclase. These silicates were probably added together with the siliceous aggregate. The important variability of the studied samples has confirmed that the choice of the raw materials and their preparation were not taken carefully. Thermal behavior of the samples has shown the endothermic peaks related to calcite and dolomite decarbonations. Also the dehydration peaks of the gypsum phases have been found. A slight endothermic effect could also be attributed to the polymorfic transition of the α-quartz. No hydromagnesite phases have been detected either by means of thermal analysis or by the other analytical techniques. Finally, the approximate indications of the original composition of the raw materials mixtures are presented. Advice in order to establish standards for the employment of new materials in the process of restoration have been also given.

II3.3
PARTIALLY FLUORINATED ACRYLIC COPOLYMERS AS COATINGS FOR STONE PROTECTION: CHARACTERIZATION AND SURFACE PROPERTIES. Marco Brugnara, Claudio Della Volpe, Dept. of Materials Engineering University of Trento, ITALY; R. Peruzzi, T. Poli, L. Toniolo, Centro CNR "Gino Bozza" Conservation Works of Art, Politecnico di Milano, ITALY.

In the framework of Italian C.N.R. target project Safeguard of Cultural Heritage a specific research headline is devoted to design and synthesize new polymeric materials for the protection of stones in buildings and artifacts. Their protection efficiency is evaluated in terms of surface properties (dynamic contact angles), water absorption, water vapour permeability and colorimetric characteristics. It is shown that the presence of fluorine has a positive influence on the protective action of the polymer, increasing the water repellency of the coated stone. In this paper the protective performances of two new fluorinated acrylic copolymers, based on the monomers 1H,1H,2H,2H-perfluorodecyl methacrylate (XFDM) and 1,1,1,3,3,3-hexafluoroisopropyl methacrylate (HFIM) and applied on two different stone materials (a white marble and a calcarenite), are evaluated and compared with Paraloid B72, a commercial copolymer ethyl-methacrylate/methyl-acrylate (EM/MA) by Rhom & Haas, and its partially fluorinated homologous 2,2,2-trifluoroethylmethacrylate/methyl-acrylate (TFEM/MA). The copolymers were applied on a series of stone specimens and tested according to the Italian UNI-Normal protocol. The measurements of capillary water absorption, static contact angles, colour variation and water vapour permeability have been carried out before and after accelerated photo-ageing. The obtained data are interpreted on the basis of a thermodynamic study on the combined effects of surface roughness and heterogeneity; measurements, carried out by the Wilhelmy technique, showed that the unsatisfactory behaviour is correlated to a not homogeneous distribution of the coating and to the roughness of the surface. The work aims at showing how the thermodynamic behaviour of polymer/stone interface influence the protective performances and enlightens the prevalent importance of the receding contact angle and hysteresis. It shows a direct correlation between the hydrophobic properties of the coating and the fluorine content, confirming the expected high efficiency of fluorinated polymers as protective agents. Nevertheless the real distribution of the coating is often the decisive factor.

II3.4
DURABILITY CHARACTERISTICS OF MEDIEVAL BRICK MASONRY IN RELATION TO THE PHYSICAL, MECHANICAL AND RAW MATERIALS PROPERTIES OF ITS COMPONENTS BRICK AND MORTAR. S. Sarp Tuncoku, Dept of Civil Engr, Cumhuriyet Univ, Sivas; Emine N. Caner-Saltik, Materials Conservation Laboratory, Graduate Program in Restoration, Dept of Architecture, Middle East Technical Univ, Ankara, TURKEY.

The durability characteristics of three medieval brick masonry structures that are in relatively good state of preservation have been studied by the analyses of their brick and mortar components in relation to their physical and mechanical properties, and raw materials properties which have formed them. The physical and mechanical properties of small sized samples have been studied by using RILEM and ISRM-Point Load standard test methods and ultrasonic velocity measurements. Drying rates have been determined. The brick masonry was light and porous, the bulk density being 1.42 to 1.72 g/cm^3, and the total porosity being 34 to 48 percent by volume. Uniaxial compressive strengths of the bricks and the mortars are in the range of 27-32 MPa, 8- 20 MPa respectively. Ultrasonic velocity measurements varied in the range of 1190 to 1376 m/s, in mortars. The mineral composition and firing temperature of the bricks have been analyzed by XRD, FTIR and TGA. The mortars have been analyzed for the properties of the binder and the aggregates. The binder lime has been examined by the analyses of the white solid lumps of variable size in the matrix. They consisted of pure micritic calcite as revealed by TGA, SEM coupled with EDX, FTIR, and XRD. The non-calcareous aggregates form around 30 percent by weight of the mortars. Finest aggregates less than 125 micrometers diameter form a large portion and have been identified as opal-A, with some quartz, feldspars and mica. High pozzolanic activity have been determined in them by conductivity measurements in the saturated calcium hydroxide solution. The bricks were also found to have considerable pozzolanic activity. The durability characteristics of the historic brick masonry have been discussed in terms of measured parameters such as the ratio of wet to dry strength, the ratio of the dry strength to porosity plus swelling strain and pore size distribution. The importance of raw materials properties of the components affecting durability and earthquake resistance of the masonry have been discussed.

II3.5
NEUTRON-INDUCTED AUTORADIOGRAPHY IN THE STUDY OF OIL PAINTINGS BY TINTORETTO, MARIESCHI AND BELLOTTO. Ewa Panczyk, Antoni Kalicki, Luzja Rowinska, Bozena Sartowska, Lech Walis, Institute of Nuclear Chemistry and Technology, Warsaw, POLAND; Krzysztof Pytel, Institute of Atomic Energy, Swierk/Warsaw, POLAND; Maria Ligeza, Academy of Fine Arts, Cracow, POLAND.

A complex technological investigations of 14th-18th centuries Venetian paintings from the collection of the National Museum in Warsaw have been performed in connection with the Serenissima-Light of Venice. Paintings of Venetian masters of 14th-18th century in the light of new technological and historian investigations and maintance works' exhibition. After analysis the X-ray radiographs of the paintings, several of them, a complex structure of which had justitified the use of neutron autoradiography have been selected to obtain indisputable information about over-painting (Tintoretto) or either confirmation or contradiction their authenticity (Marischi, Bellotto). The paintings were irradiated in the 'Maria' reactor at Swierk near Warsaw on a especially constructed test stand. The thermal column and neutron guide tube are not aveilabe at Maria reactor. Therefore, a special block scattering thermal neutrons from the adjacent stream has been used. The scattering block, in the form of tunnel with inserts of polyethylene film is schielded from three sides with a 120 mm thick layer of graphite. To obtain a uniform of irradiating and shifting, exposure process is computer controlled. Surface distribution of radionuclides was detected by using large X-ray films, mechanically pressed to the face of the paintings. The autoradiograms have been recorded in sequences within two months from terminating irradiation of the paintings in the reactor. Identification of the radionuclides, responsible for blackening X-ray film has been performed using a gamma - radiation spectrometer. The report presents results obtained for the following paintings: J. Tintoretto - Portrait of a Venetian Admiral, M. Marieschi - Architectural fantasy and Doge's Palace in Venice, Canaletto a.k.a. Bellotto - Architectural fantasy with self-portrait of the author.

II3.6
A NEW METHOD OF RESTORATION OF METALLIC ARCHEOLOGICAL OBJECTS. Razmik Malkhasyan, Ruzanna Shakhverdyan, Scientific Production Enterprise 'Atom' Ministry of Industry Republic of Armenia, Yerevan, ARMENIA.

Quantum-chemical technology developed by in Scientific-Production Enterprise "ATOM" allows different chemical processes to take place in strongly non-equilibrium conditions by the means of internal energy of excited molecules. These processes can basically take place at room temperature. By this technology, vibrationally excited gaseous molecules of hydrogen with excitement energy up to 2.2eV at room temperature let us restore metal archeological objects from 7th-9th centuries a.c. (Dvin). Iron containing totally oxidized brittle objects of dark brown color obtained malleability on recovered surface and had grayish steel-blue shiny color after restoration. Copper containing oxidized objects of bluish green color after quantum-chemical restoration obtained normal reddish color of metallic copper and even some signs of ornaments and images could be observed that could not be seen before restoration on oxidized initial samples. Quantum-chemical restoration was carried out on different metal containing objects and on some of them unexpected phenomena were observed: isolation of foamy organic compounds, generic analysis of which would let us enrich the information about genesis of these objects. The quantum-chemical technology unlike ordinary chemical methods working with gaseous reagents and in the conditions of vacuum does not form other contaminating by-products on the surface of restoring objects. In the given method a low-temperature process of removing oxygen (restoration) absolutely opposite to the natural inculcation of oxygen into metals (oxidation) is implemented.

II3.7
GLASS-CERAMICS PREPARED BY WASTE FLUORESCENT GLASS CULLET AND SHELL. Yeon-Hum Yun, Chung-Han Yoon, Chonnam National Univ, Dept of Mineral & Energy Resource Engineering, Kwangju, SOUTH KOREA; Bo-An Kang, Chonnam National Univ, Dept of Ceramic Engineering, Kwangju, SOUTH KOREA; Yun-Ho Kim, Naju College, Dept of Enviornment, Naju, SOUTH KOREA; Kyu-Seog Hwang, Nambu Univ, School of Automotive & Mechanical Engineering, Kwangju, SOUTH KOREA.

Many unsalable and unuseful waste fluorescent glasses containing harmful Hg to human body and sea shell are currently varied without any recycling process. To use waste fluorescent glass and to resolve environmental problems, we prepared glass-ceramics reinforced by β-wollastonite. Fluorescent glass cullet and shell were used as starting materials. Powder mixture of cullet and shell was melted at 1300°C for 1h and quenched in water bath. Pressed specimens after grinding were annealed at 800, 900 and 1000°C for 1h, respectively. β-wollastonite, gehlenite and sodium calcium silicate crystals were observed by X-ray diffraction study. Surface morphology, chemical composition, chemical durability and mechanical strength were also examined.

SESSION II4: ARCHAEOLOGICAL SCIENCE AND ARCHAEOMETRY I

Chair: James R. Druzik
Tuesday Morning, November 27, 2001
Independence East (Sheraton)

8:45 AM II4.1
INVESTIGATING CERAMIC TECHNOLOGY DURING ARCHAEOLOGICAL FIELD SEASONS. Robert C. Henrickson, National Museum of Natural History, Anthropology, Smithsonian Institution, Washington, DC.

Investigation of many aspects of ancient ceramic production technologies is feasible during an archaeological field season, and requires little equipment. Field analyses should provide basic data which complement prior or subsequent laboratory work. Observation should focus on description of the assemblage or industry as a whole, using independent attributes which also provide information on production. I have used the system discussed here to record up to 60,000 sherds in the course of a eight-week field season at Gordion (Turkey). Gross data from such large corpora contribute to a better characterization of the overall industry, and aid in study of changing trends. Descriptive variables such as color, inclusions (temper'), variable textures within the paste, surface finish, hardness, and decorative techniques and style (motifs and organization) provide technological data. Residual surface traces, the surfaces of breaks themselves, and their overall patterning relative to both the vessel shape and size provide forming and finishing data; gross vessel weight may also be helpful. Later statistical study can explore inter-relationships of variables, but only if they have been recorded independently. Field equipment needs are simple: low power magnification, camera, drawing supplies. Subsequent laboratory analysis of samples, including determining chemical composition of pastes by INAA, residual forming traces through xeroradiography, and original firing temperatures by refiring, complement the field data. After ten years of fieldwork, combined with laboratory collaborations, a database of almost 400,000 sherds has enabled tracing the development of ceramic production over a span of 1500 years at

Gordion, the changing exploitation of local resources by the potters in the local industry, and the effects of the changing ethnic composition of the population and political and economic roles of the city.

9:00 AM II4.2
RECONSTRUCTING THE MATERIALS AND TECHNOLOGY OF EGYPTIAN FAIENCE. Patricia Griffin, Cleveland Museum of Art, Cleveland, OH.

This paper focuses on a research project undertaken at the Cleveland Museum of Art to study and characterize its collection of more than one hundred Egyptian artifacts made from faience or a related pyrotechnology. An overview of the project is presented here. A multi-faceted approach to the study of these materials was designed. Examination procedures used to study the collection included microscopy (surface examination using a low-powered microscope and microstructural characterization of exposed fracture surfaces or small samples using a scanning electron microscope, structural analysis using Xero-radiography, and nondestructive semi-quantitative compositional analysis of glazes and pastes using x-ray fluorescence spectroscopy. Hardness testing using fine metal points graded to the Mohs scale, Munsell color evaluations and qualitative gloss determinations were also employed. Replication experimentation was used extensively to understand visual features remaining on the surfaces of objects, to provide comparison standards for examination of fracture surfaces with magnification, and to test the validity of theories on paste recipes and forming practices. The primary goal of the project was to provide accurate descriptions of the materials and technology of each object as was possible. This included characterization of technological features such as glaze (probable application method, composition, color, and gloss), paste (grain size, color, hardness, composition, and extent of vitrification) and forming methods (modeling, molding, template, cores, wet working and/or dry working). Careful documentation of these features enabled detailed technological descriptions to be prepared for each artifact. This work also elucidated many aspects of faience production as it may have been practiced in ancient Egypt, and suggested directions for further study. It is hoped that technological criteria for dating artifacts that can not be securely dated using traditional typological art historical criteria can be developed using careful documentation of characteristics of the paste, glaze and forming processes.

9:15 AM II4.3
CASE STUDIES IN RECONTRUCTING THE MATERIALS AND TECHNOLOGY OF ANCIENT EGYPTIAN FAIENCE. Patricia Griffin, Cleveland Museum of Art, Cleveland, OH.

This paper focuses on the reconstruction of the original appearance, and the materials and methods of manufacture of several masterpieces of Egyptian faience or frit technology in the collection of the Cleveland Museum of Art. Over the course of several millenia, the Egyptians developed a number of versatile non-clay ceramic materials, including Egyptian faience and the related variants of vitreous faience, glassy faience and Egyptian blue. All contained primarily silica, with lesser amounts of alkali, lime and an inorganic colorant such as copper. Firing produced a silicate body bound by a soda-lime-silicate glass, often covered with a continuous glassy layer or glaze on the exterior surface. The use of these materials evolved from simple beads and figurines to complicated sculptural forms and vessels. Subtle adjustments to the unfired pastes, including variations in grain size; moisture content; alkali content; and the use of specific additives such as frit, clay or burnt lime- enabled a wide range of artifact types to be achieved. Combining glazing methods enabled an extraordinary range of surface effects. The artifact reconstructions will be presented as a series of technical studies in a case study format. They draw upon the data generated by detailed and systematic examination of the more than one hundred artifacts in the CMAs collection. The primary examination techniques used for this study included surface examination using a low-powered microscope; microstructural characterization of exposed fracture surfaces on objects or small samples using a scanning electron microscope; structural analysis using Xero-radiography; and nondestructive semi-quantitative compositional analysis of glazes and pastes using x-ray fluorescence spectroscopy. Replication experimentation was important for understanding visual features remaining on the surfaces of objects; testing the validity of theories on paste recipes and forming practices; and providing comparison standards for examination of fracture surfaces with magnification.

9:30 AM II4.4
EARLY HISTORIC PERIOD (6TH CENTURY B.C. TO 6TH CENTURY A.D.) CERAMIC SMOKING PIPES FROM BUDHIGARH, IN THE KALAHANDI DISTRICT OF ORISSA, INDIA. Blythe McCarthy, Smithsonian Institution, Freer Gallery of Art/Arthur M. Sackler Gallery, Washington, DC; Christine Downie, Queens University, Art Conservation Program, Kingston, CANADA; Pradeep Mohanty, Dept. of Archaeology, Deccan College Research Institute, Pune, INDIA.

Among ceramics found at early historic sites in the Kalahandi district of India are a great variety of terracotta smoking pipes or hukka. The pipes are fashioned from fine, well levigated clay with extensive surface decoration. Their intricacy makes them the most distinctive art form of the area. Found at the majority of sites in the region, they are of special interest, as they predate the introduction of tobacco to the area. To determine their method of manufacture, and investigate the possibility of local manufacture, an initial study was conducted of a small number of pipes from the site of Budhigarh. The pipes, along with clay from the site (used extensively by modern potters), were studied using x-ray radiography, petrography, XRD and ICP.

9:45 AM II4.5
Abstract Withdrawn.

10:30 AM *II4.6
NEW APPROACHES TO THE CHARACTERIZATION AND INTERPRETATION OF OBSIDIAN FROM THE MEDITERRANEAN ISLAND SOURCES. Robert H. Tykot, Univ of South Florida, Dept of Anthropology, Tampa, FL.

Geochemical fingerprinting of obsidian sources was first applied in the Mediterranean region nearly four decades ago. Since then, a number of analytical methods (e.g. INAA, XRF, SEM/Microprobe, ICP-MS) have proven successful in distinguishing the Mediterranean island sources of Giali, Lipari, Melos, Palmarola, Pantelleria, and Sardinia. Moreover, recent geoarchaeological surveys of the central Mediterranean sources have resulted in the more precise location and documentation of each obsidian flow or outcrop, and multiple chemical groups have been identified on at least three of the islands. The ability to specifically attribute artifacts to one of five obsidian flows in the Monte Arci region of Sardinia, for example, has enabled the study of specific patterns of source exploitation and the trade mechanisms which resulted in the distribution of obsidian hundreds of kilometers away during the Neolithic period (ca. 6000-3000 BC). Results are presented here from the chemical analysis of significant numbers of artifacts from many sites throughout the central Mediterranean as part of the largest and most comprehensive study of obsidian sources and trade in this region. Analyses of large numbers of artifacts demonstrate the differential use of island subsources, which may be attributed to factors such as access (e.g. topography, distance from coast), size and frequency of nodules, and mechanical and visual properties. The patterns of source exploitation revealed by this study specifically support a down-the-line model of obsidian trade during the neolithic period. In addition, the spatial and chronological patterns of obsidian distribution may be used to address such issues as the colonization of the islands; the introduction of neolithic economies; and the increasing social complexity of neolithic and bronze age societies in the central Mediterranean.

11:00 AM II4.7
ANCIENT RAW COPPER FROM PRIMARY SMELTING SITES IN CYPRUS. Peter J. Northover, Walter Fasnacht, Section Inorganic Analytical Chemistry and Characterization of Solids, Swiss Federal Laboratories for Materials Testing and Research, Duebendorf, SWITZERLAND.

Finds of metallic copper from various primary smelting sites in the Sia-Valley in Cyprus have been analysed by ICP-OES for their composition and by optical and electron microscopy for metallograpy. Results show characteristic fingerprints for each individual site which allow an assignement to specific types of orebodies and geological matrices. Different zones of the Cyprus Ophiolite Complex were exploited in different periods in antiquity but also contemporaneously, especially in the first millenium BC. There is no such thing as a linear, evolutionary development of ancient copper production in Cyprus. Using the example of Agia Varvara-Almyras, an Iron Age copper smelting site and the only complete chain of operation of ancient Cypriote metal working, it is demonstrated how analytical work can guide future field surveys to find ancient furnaces, slag heaps and mines. The goal of the Almyras Project is to reconstruct the complete history of copper working in a well defined Cypriots mining district over the last 4000 years.

11:15 AM II4.8
ANALYZING STYLE AND TECHNOLOGY IN THE EASTERN WOODLANDS. Christina Rieth, Division of Research and Collections, New York State Museum, Albany, NY.

Changes in ceramic typology are often used to document spatial and temporal changes in settlement patterns during the Early Late Prehistoric Period (A.D. 700-1300). In north-central Pennsylvania and southern New York these changes largely center around two different types: Clemson Island and Owasco. Despite reported differences, the

high degree of stylistic similarity between assemblages often makes it difficult to distinguish between types limiting their use in prehistoric settlement studies. In this study, trace element analysis is employed to determine if compositional profiles correspond with identified stylistic types. The results of this study suggest that there does not appear to be a clear distinction between ceramic types and clay deposits exploited by the Early Late Prehistoric occupants of the region. Instead, differences in the technological attributes of these containers may more accurately reflect the occupation of villages and camps near specific material resource zones.

11:30 AM *II4.9
Abstract Withdrawn.

SESSION II5: ARCHAEOLOGICAL SCIENCE AND ARCHAEOMETRY II
Chair: Robert H. Tykot
Tuesday Afternoon, November 27, 2001
Independence East (Sheraton)

1:30 PM II5.1
ARCHAEOLOGICAL INVESTIGATIONS: THE USE OF COMPUTER-ASSISTED OPTICAL STEREOLOGY IN EXAMINING THE STEEL OF RMS TITANIC. Lauren B. Sickels-Taves, Michael S. Sheehan, Eastern Michigan University, Dept. of Geography & Geology, Ypsilanti, MI.

In April 1912, the RMS Titanic struck an iceberg in the North Atlantic and sank with great loss of life. Almost a century later, the story of the Titanic still captures the imagination. To date, however, this event has received little attention from the archaeological community. Considerable debate has surrounded explanations for this tragic event. Recent research at the National Institute for Science & Technology (NIST) has focused on the steel used to construct the great liner and holds great promise for scholars attempting to understand the conditions that contributed to the loss of Titanic. The objective of the research reported here is to extend the knowledge and evaluate the quantity and quality of impurities in the steel used to construct Titanics hull that might have made the structure susceptible to severe damage related to oblique impact. A technique which is relatively new to archaeological science, computer-assisted optical stereology, is used to analyze images generated by standard light, and scanning electron, microscopy. The results of this study will contribute to materials analysis in archaeology in a number of ways. First, assessment of the steel from Titanic's hull aids in our ability to explain the disastrous effects of the iceberg during the collision. Secondly, it will provide a measure of the utility of relatively inexpensive techniques in the analysis of metallic artifacts recovered from archaeological contexts.

1:45 PM II5.2
A COMPLETELY NONDESTRUCTIVE TECHNIQUE FOR MEASURING LEAD ISOTOPE RATIOS IN GLAZED POTTERY. Susan Reslewic, James H. Burton, Univ of Wisconsin-Madison, Laboratory for Archaeological Chemistry, Dept of Anthropology, Madison, WI.

Measuring the lead isotope ratios in lead-glazed pottery aids in understanding the production and distribution of of these ceramics. We report on a new, completely nondestructive technique using EDTA extraction and ICP-MS to measure lead isotope ratios in glazed wares. Our results on glazed pottery from archaeological contexts primarily in the American Southwest supports the data gathered from alternative methods to measure lead isotope ratios. In particular, our results on a class of glazed pottery known as majolica supports previous research that uses lead isotope data to make inferences on the production and distribution of majolica in 17th - 18th century New Spain. Our research has relevance for researchers interested in nondestructive, high resolution methods to measure lead isotope ratios in glazed ceramics found in an array of archaeological contexts.

2:00 PM II5.3
EXAMINATION OF GILDED BRONZE USING NONDESTRUCTIVE EDDY CURRENT TECHNIQUES. Johanna R. Bernstein, The Johns Hopkins Univ, Dept of MS&E, Baltimore, MD; Blythe McCarthy, Smithsonian Institution, Freer Gallery of Art, Washington, DC.

In the examination of gilded bronze objects, analysis of the thickness of the gilding layer, the condition of the substrate and the gilding method is often difficult without taking samples. The resulting information is vital to research on ancient metalworking and can answer questions of authentication. In this study, a nondestructive eddy current method is used to characterize gilding layers on bronze. Eddy current methods are typically used in the automotive, power and aerospace industries for flaw inspection and alloy selection. In this method, the interaction of metal and a probe shifts the probe impedance which is measured and correlated to properties of the metal. Results are presented which show that eddy current testing can characterize a gilding layer by thickness and by composition.

2:15 PM II5.4
THE USE OF ELECTRON OPTICAL AND X-RAY ANALYTICAL METHODS IN ARCHAEOMETALLURGY. Michael Notis, Center of Excellence for Artifact Analysis, Department of Materials Science & Engineering, Lehigh University, Bethlehem, PA.

Application of SEM, EPMA, TEM and AEM to the study of archaeometallurgical objects will be reviewed. The spatial resolution and minimum mass fraction for microchemical analysis for the variety of electron optical and x-ray analytical methods will be discussed and compared. Particular attention will focus on the study of microstructural and microchemical analysis of remnant or "ghost" structures in both ferrous and non-ferrous corrosion layers in a series of artifacts ranging from steel, to cast iron, to high tin bronze.

2:30 PM II5.5
ACHIEVING HIGH SPATIAL RESOLUTION IN THE ELEMENTAL MAPPING OF METAL SAMPLES FROM ARCHAEOLOGICAL CONTEXTSs. Scott Lea, Don Baer, W.R. Wiley Environmental Molecular Sciences Laboratory, Pacific Northwest National Laboratory, Richland, WA; E. Paparazzo, Istituto di Strutture della Materia del CNR, Area della Ricerca di Roma, Roma, ITALY; Peter Northover, Chris Salter, Dept of Materials, Oxford Univ, Oxford, UNITED KINGDOM.

Improving the characterisation of archaeological artifacts brings a need to understand better the relationships between composition, structure and properties. With archaeological material there is also a requirement to consider the effects of ageing and environmental interactions in altering the original structure and composition, both in the bulk and, at the surface. However, curatorial constraints and, frequently, the condition of the objects prevent sampling methods required for the most powerful means of structural analysis of materials, the transmission electron microscope with the possibility of images at atomic resolution. With the samples normally available we must find other means of maximising spatial resolution in microchemical and microstructural analysis of both bulk and surface regions of samples. This paper describes ways in which this is being achieved for elemental analysis using electron probe microanalysis (EPMA), at spatial resolutions down to 250-300nm, and scanning Auger microscopy at resolutions of 10-20nm, but only from the surface layers of atoms. The ways in which the instruments are operated to achieve this will be described, examples given and the data discussed. For EPMA those examples will include the characterisation of very thin multilayer precious metal coatings on corroded substrates, and the fine structure of slag inclusions in ancient iron. For SAM the same example of plating will be examined. together with a study of intergranular corrosion in bronze. In this last example, the corrosion paths are too narrow for adequate mapping with the electron microprobe, whereas SAM, through its mapping capability and identification of chemical species, offers the opportunity to study internal corrosion in relation to bulk corrosion species. While it is not cost effective to apply this level of effort to every sample in a project, a subset of representative samples should be so examined to enhance the interpretation of more routine analysis and microscopy.

LABORATORY FIELD TRIPS
Museum of Fine Arts,
Fogg Museum or MIT Media Lab
Tuesday, November 27, 2001
3:00 p.m. - 5:00 p.m.
Signup, schedule and maps available in symposium meeting room.

SESSION II6: WEATHERING, DATING, TECHNOLOGY AND AUTHENTICATION
Chair: Pamela Vandiver
Wednesday Morning, November 28, 2001
Independence East (Sheraton)

9:00 AM II6.1
AN INVESTIGATION INTO THE NATURE OF AN UNUSUAL BLACK PATINA ON A GROUP OF EGYPTIAN BRONZE ARTIFACTS IN THE ROYAL ONTARIO MUSEUM COLLECTION.

Alison Whyte, Alison Murray, Queen's Univ, Art Conservation Program, Dept of Art, Kingston, CANADA.

The focus of this research is the analysis of a distinctive black patina on a select group of Egyptian bronzes in the Royal Ontario Museum (ROM) collection. Dark patinas are not uncommon on archaeological bronzes; however, careful examination of these objects from the ROM collection reveals subtle differences in colour and texture between their patina. These discrepancies have raised the question of the authenticity of the patina on these artifacts. It is possible that the differences in appearance are due to some form of modern cleaning and re-patination treatment. The purpose of this project was to determine the authenticity of the patina by establishing both its composition and the process by which this layer was formed on the surface of the objects. A cross-section sample from one artifact was analysed using optical, metallurgical, and scanning electron microscopy in order to clarify the relationship between the patina layer and the body metal. In addition, energy dispersive spectrometry was employed to establish the chemical composition of the body metal. Surface samples were removed from all of the objects and subjected to x-ray diffraction in order to identify the compounds present in the patina. Fourier transform infrared spectroscopy was used to establish if any organic compounds ware present in the surface layers of the bronzes. Although further analysis is required, the results of this research suggest that the patina surface may have formed naturally.

9:15 AM II6.2
AUTHENTICATION OF A 15TH CENTURY BUDDHIST SCULPTURE. Karen M. McNamara, Worcester Polytechnic Institute, Department of Chemical Engineering, Worcester, MA; Lawrence Becker, Sara Numberg, Worcester Art Museum, Worcester, MA.

When evaluated in the context of the objects history, materials techniques can yield knowledge not only on material resources and fabrication techniques, but also on aspects of daily life in a given era, such as religious and social customs or trade and travel. Making the connection between science and history requires the investigator to explore seemingly unrelated disciplines and synthesize them in order to gain progress in understanding. This is the great benefit of interdisciplinary study. Thus interdisciplinary learning becomes an important part of both research and education. The authentication of a bronze sculpture which had been donated to the Worcester Art Museum, not only involved, but required simultaneous study of the technical issues of piece as well as the cultural issues of Thai religious customs and technological expertise in the 15th century. We will present the results of materials characterization including trace impurity analysis, scanning electron microscopy, and X-ray diffraction of samples obtained from the piece. When viewed in the context of our understanding of the culture, we will show that all of these tests lend credibility to the authenticity of the object. Critical to this understanding is the inseparable connection between science and the object both now and at the time of its time of creation. We also discuss further characterization techniques which would strengthen these conclusion.

9:30 AM II6.3
Abstract Withdrawn.

9:45 AM II6.4
THE IDENTIFICATION OF CORROSION PRODUCTS ON TIN INGOTS EXCAVATED FROM THE 14th CENTURY LATE BRONZE AGE SHIPWRECK AT ULU BURUN (KAS), TURKEY. Laura Lipcsei, Alison Murray, Queen's Univ, Art Conservation Program, Dept of Art, Kingston, CANADA; Reginald W. Smith, Queen's Univ, Dept of Materials and Metallurgical Engineering, Kingston, CANADA; Mahmut A. Savas, on leave from Bogazici Univ, Dept of Mechanical Engineering, Istanbul, TURKEY.

The purpose of this study was to investigate the deterioration of tin ingots recovered from the late 14th century B.C. shipwreck off Ulu Burun (Kas) Turkey. As so little elemental tin has been preserved and excavated from underwater sites to date, the Ulu Burun ingots offer a unique opportunity to study the corrosion products and deterioration of ancient tin artifacts from a natural marine environment. The current investigation had four major objectives: 1) to identify corrosion products; 2) to confirm or refute the presence of 'tin pest', which has been asserted to be one of the major reasons for the disintegration of the ingots and which is a topic of much controversy in the conservation and museum communities; 3) to obtain information about the site environment in which the Ulu Burun artifacts have been found and 4) to contribute to the overall understanding of marine tin corrosion. It is hoped that the data obtained from this research will help conservators devise viable treatment methods and long term storage and preservation policies for tin artifacts in general. Instrumental techniques such as x-ray diffraction, x-ray fluorescence, atomic absorption, inductively coupled plasma emission spectroscopy, energy dispersive spectroscopy, and Fourier transform infrared spectroscopy were used to analyze the ingots. The results of the analysis have identified characteristic elements and corrosion products that were expected to be found on ancient tin artifacts found in a marine environment. The presence of the controversial tin disease was confirmed in two of the six samples tested.

10:30 AM II6.5
A MATERIALS INVESTIGATION INTO THE METAL COMPOSITION, COATING STRUCTURES AND TREATMENT HISTORY OF FOUR MING DYNASTY CAST IRON STATUES. Elizabeth A. Moffatt, Senior Conservation Scientist, Canadian Conservation Institute, Ottawa, CANADA; Aaron Shugar, Research Fellow, Institute of Archaeology, London, UNITED KINGDOM; Jane Sirois, Conservation Scientist, Canadian Conservation Institute, Ottawa, CANADA; Susan Stock, Metals Conservator, Royal Ontario Museum, Toronto, CANADA.

This paper presents the results and implications of the investigation of four 'iron' statues dated by inscription to the Ming Dynasty, China, in the year 1491 A.D. The four objects come from a group of 8 statues, part of the The George Crofts Collection, received by the Royal Ontario Museum in 1921. The statues have always been considered important but, the renewed interest in, and the improved methods of scientific examination of Chinese metalwork have significantly increased their importance to specialists who study in this field. Prior conservation and treatment of the objects were not recorded and remain unknown. The investigation therefore, was also intended to determine if any prior treatment had been done, as well as to contribute to an understanding of the present condition of the object. During visual examination and simple surface cleaning, it became apparent that the objects had some form of surface decoration and polychromy. On closer examination gilding, lacquer, and traces of pigment around the hat, eyes, and garment were visible. Two metal samples were taken, one sample was taken for metallography and chemical compositional analysis, and the second sample was taken for experimental work on dating metal by the Isotrace Laboratories at the University of Toronto. Additional samples were taken from the surface of the four objects to confirm and identify the composition of the observed decoration by the Canadian Conservation Institute in Ottawa. Surface corrosion was also sampled for identification. The results reveal that the object is a white cast iron product and was fully decorated with multiple colors and gilding as well as being sequentially lacquered. Recommendations for the cleaning and conservation of these objects are given.

10:45 AM *II6.6
RENAISSANCE ENAMELED JEWELRY AND 19TH CENTURY RENAISSANCE REVIVAL: CHARACTERIZATION OF ENAMEL COMPOSITIONS. Mark T. Wypyski, The Metropolitan Museum of Art, Sherman Fairchild Ctr for Objects Conservation, New York, NY.

Enamels from European Renaissance gold jewelry dating from the sixteenth and seventeenth centuries, and Renaissance style objects from the nineteenth century were quantitatively analyzed using energy dispersive X-ray spectrometry. Differences were observed in the overall compositions, as well as in the colorants and opacifiers used, of the Renaissance period enamels and the late nineteenth century enamels. Enamels from the early nineteenth century, however, appeared to be essentially the same as those used during the Renaissance. The differences found in the enamel compositions provide a set of objective compositional criteria to help distinguish between authentic Renaissance period enameled objects and later enamels done in the style of the Renaissance.

11:15 AM II6.7
AMS RADIOCARBON DATING OF A WESTERN HAN DYNASTY(3^{rd}–1^{st} CENTURY BC) LACQUER-COATED CERAMIC JAR. G.W.L. Hodgins, University of Oxford, Oxford Radiocarbon Accelerator Unit, Oxford, UNITED KINGDOM, University of Georgia, Center for Applied Isotope Studies, Athens, GA; E.F. Farrell, Harvard University, Strauss Center for Conservation, Cambridge, MA; R.D. Mowry, Harvard University, Arthur M. Sackler Museum, Cambridge, MA.

The chronometric dating of ceramic objects is normally achieved by thermoluminscence techniques. Here we report a radiocarbon date measured on a Chinese ceramic *hu* jar (Harvard University Art Museums LTL1.2001.23 a,b) using samples obtained from a lacquer coating present on its outer surface. The coating was preliminarily identified as Urishi by a comparison of its FTIR absorption spectrum to absorption spectra obtained from modern and ancient lacquer standards. The material was found to be insoluble in a variety of solvents, mineral acids, and bases. Combustion and elemental analysis revealed that 64% of the coating mass was carbon. ^{14}C measurement by AMS was carried out on a 3.9 mg sample of chemically cleaned lacquer. This measurement generated a date of 2191± 38 BP.

Calibration of this measurement placed the age of the jar between 390 BC and 160 BC at the 95% confidence interval. The calibrated date agreed with stylistic evidence that the jar was produced during the Western Han period (206 BC–AD 9). The historical literature on Urishi composition, its high carbon content, its apparent chemical stability, and the small sample required for ^{14}C accelerator mass spectrometry suggests that other lacquer-coated objects might be dated using a similar approach.

11:30 AM II6.8
THERMOLUMINESCENCE DATING OF ANCIENT MOSAIC GLASSES: ROLE OF ANTIMONATE CRYSTALS. Anna Galli, Marco Martini, Emanuela Sibilia, Istituto Nazionale di Fisica della Materia-INFM and Dipartimento di Scienza dei Materiali, Universita degli Studi di Milano-Bicocca, Milan, ITALY.

Ancient mosaic glass tesserae gathered from different parts of the Mediterranean basin, both in Italy and Greece, have been analysed. On the basis of the compositional results, modern glasses have been prepared and similarly studied by comparison. Each sample has been characterised through its chemical composition, by Inductively Coupled Plasma - Optical Emission Spectroscopy (ICP-OES) and its thermoluminescent (TL) behaviour. The samples have been analysed through their TL glow-curves and emission spectra. TL protocols have been developed to test the sensitivity and the sensitivity changes, the optical bleaching and the signal regeneration by sunlight. The data obtained have been handled by exploratory multivariate method (HCA and PCA). The TL sensitivity and the temperature of the maximum of the main TL peak have been chosen as parameters describing the TL characteristics of the samples. From the principal components obtained it can be observed that TL sensitivity and antimony oxide content are correlated. Sb2O5, used as opacifier by the glassmakers, forms with CaO microcrystals of $CaSb_2O_6$ dispersed in the amorphous glass matrix. Their presence in our samples has been confirmed by X-ray diffraction measurements. It is concluded that an important role is played by these crystals in the TL produced in mosaic glasses.

11:45 AM II6.9
A 15,000 YEAR-OLD CERAMIC HUMAN-FIGURINE FROM MAINA IN SOUTH SIBERIA. Pamela Vandiver, Smithsonian Center for Materials Research and Education, Washington, DC; and S.A. Vasil'ev, Institute of Archaeology, St. Petersburg, RUSSIA.

The ceramic technology used to construct and fire an image of a human figurine 15,000 years ago at Maininskaia on the Yenesei River in southern Siberia is reconstructed using x-ray, microscopy and chemical studies. Excavation and dating evidence is provided. Comparative studies of the clayey soils at the site add contextual and environmental evidence to establish this remarkable technology.

SESSION II7: ARCHEOMATERIALS, TECHNOLOGY AND SOCIETY I
Chair: Martha Goodway
Wednesday Afternoon, November 28, 2001
Independence East (Sheraton)

2:00 PM *II7.1
RED STREAK BURNISHED CERAMICS FROM CENTRAL AND SOUTH ASIA: PETROGRAPHIC ANALYSIS, CHRONOLOGY, AND DISTRIBUTION. Charles C. Kolb, National Endowment for the Humanities. Washington, DC.

Archaeological excavations in the mid-1960s in the region of Aq Kupruk, located in the Balkh River drainage of northern Afghanistan, produced abundant archaeological materials in well-stratified contexts dating from the Upper Paleolithic through contemporary nomadic occupations. Ceramics dating to the Neolithic period, the Bronze and Early and Late Iron Ages were represented in abundance, among them 43 new, undefined wares associated, in the main, with Iron Age contexts (ca. 1 BCE to CE 700). Sarmatian, Parthian, Sasanian, Yueh-chi/Kushan, Gupta, Hephthalite, and Turkestan nomadic cultures, traders and raiders, among others, used the Balkh River gorge and various mountain passes to transit the Hindu Kush (western Himalayas) thereby connecting the cultures of the Turkestan Plain and the present day Commonwealth of Independent States (the former Soviet Central Asia) and the Indo-Pakistan Subcontinent and southeastern Iran. Red Streak Burnished ceramics (identified initially by Kolb 1967, 1972, 1983) and dating 1 BCE to CE 200 was produced in plate-bowl and in several bowl and jar forms and was a significant new ware that seemingly had affinities to Roman Arretine ceramics and derivatives found in Southwest Asia and Indian Subcontinent. Philene Kalb (1973) documented the presence of the ceramic in southern Afghanistan. Since the 1970s similar ceramics have been identified at sites in former Bactria and at Merv, Turkmenistan (Herrmann, Kurbansakhatov, and Simpson 1997, 1998, 1999, 2000). Ceramic technical analyses including thin section petrography has assisted in a reassessment of the chronological and distribution studies. The ware is characterized in terms of ranges and modes of fabric and slip colors, paste texture, hardness, non-plastics, firing temperatures, vessel types, and decoration. Problems and prospects for further research are also considered.

2:30 PM II7.2
ORGANIZATION OF FLINT SICKLE BLADE PRODUCTION AT AN EARLY BRONZE AGE WORKSHOP IN ANATOLIA. Britt Hartenberger, Boston Univ, Dept of Archaeology, Boston, MA.

A specialized workshop for the manufacture of flint sickle blades has recently been excavated at the site of Titris Hoyuk in southeastern Anatolia. This paper will examine the sequence of production for the blades as well as the social context of this craft within the site. The workshop is the first example found containing evidence of the complete sequence of production for the 'Canaanean blade,' a type commonly used across the Near East in this period. Since bronze was still new and relatively expensive, high-quality flint was used to manufacture sickle blades. Tabular flint was imported in the form of large slabs from several sources in the nearby hills. Specialists then prepared the blade cores, removed the blades, and then traded the final products to local farmers. A range of manufacturing debris has been found to illustrate the production sequence, including chunks of raw flint, core-shaping pieces, debitage pits, and stacks of exhausted and used cores. The large sample of over 1000 blade cores collected ensures a sizable data set for statistical analyses. Several types of raw flint were utilized for making the blades and production appears to vary slightly by these material types. The workshop is located within a household setting and is the only area within the excavated site containing debris from this craft. Spatial analyses of the types of flint used within the household workshop reveal its division into largely distinct areas for domestic versus specialist craft activities. The placement of the workshop in the suburbs far from the site's administrative center may indicate that its activities were independent of any elite. An estimate of the volume of blades produced combined with the location of the workshop at a major regional center suggest that it also supplied blades to other sites in the region.

2:45 PM II7.3
ARCHAEOLOGICAL INTERPRETATIONS OF PIXE DATA: CASES OF GOLD AND GRANULATION IN THE MEDITERRANEAN BRONZE AGE. Thea A. Politis, Reading University, Archaeology Department, Reading, UNITED KINGDOM; Meg H. Abraham, Los Angeles County Museum of Art, Conservation Department, Los Angeles, CA; J. Peter Northover, Oxford University, Department of Materials, Oxford, UNITED KINGDOM.

PIXE analysis of Bronze Age Mediterranean granulated gold objects obtained using the Oxford University proton microprobe will be discussed in light of the archaeological context. Using modern granulated objects with known smithing processes as points of comparison and calibration, it will be demonstrated how information on ancient joining practices may be accurately gauged using the PIXE technique. The importance of characterizing objects of known provenance will be emphasized in a discussion of archaeological context. It will be shown how PIXE analyses of this type of object can add new depths to our understanding of specific social, cultural and technological relationships in the past when properly applied.

3:30 PM II7.4
BATCH MATERIAL PROCESSING AND GLASSMAKING TECHNOLOGY OF 9TH CENTURY B.C. ARTIFACTS EXCAVATED FROM THE SITE OF HASANLU, NORTHWEST IRAN. Colleen P. Stapleton, Univ of Georgia, Dept of Geology, Athens, GA.

The site of Hasanlu is located southwest of Lake Urmia (Lake Rezaiyeh) in the province of Azerbaijan, northwest Iran. Excavations, by Dr. R. H. Dyson of the University of Pennsylvania, of the Iron Age levels at Hasanlu yielded a large number of glass beads, as well as vessels, architectural and furniture features. Sampling of many of these pieces was limited to weathered areas, requiring the use of a micro-analytical technique, electron microprobe with wavelength dispersive detectors, to identify and examine unaltered areas. The glasses are soda-lime-silica in composition, containing about 17-21 wt% soda and 2-8 wt% lime. Most of the glasses analyzed to date contain greater than 1-6 wt% of magnesia and 1-4 wt% potash, indicative of a plant ash source of alkali. Several glasses contain less than 1 wt% each of magnesia and potash, suggesting that these may have been made with a mineral alkali source such as natron. A number of the glasses contain inclusions of partly reacted batch materials. In black, copper-colored blue, and opaque yellow glasses, large, 0.2 mm diameter, droplets of alkali sulfates exhibit features that indicate that they were an immiscible liquid coexisting with a

surrounding silicate liquid. These sulfate droplets, which appear to be relatively common in the glasses found at Hasanlu, are probably the scum or "gall" that can form during melting of poorly prepared plant ash. Remnants of original raw colorants occur in a few glasses. A copper-colored blue glass contains plagioclase feldspar with metallic copper in the lining of fractures, suggestive of the type of geological formation from which the colorant originated. Many of the black glasses contain polymetallic sulfides of different combinations of lead, copper, antimony, and iron. These inclusions are used to interpret the origin and processing of batch materials, and the conditions under which the materials were melted.

3:45 PM II7.5
THE CHARACTERISATION OF A BRONZE AGE WEAPON HOARD. Peter Northover, Sue Bridgford, Oxford University, Dept of Materials, Oxford, UNITED KINGDOM.

The study described in this paper is based on the proposition that all events in the life of a bronze artifact from the moment it was cast to the time it became available for characterisation leaves a trace that can be identified and measured by one or more metallographic methods. The hoard presented here was found at Waterden, Norfolk, England by metal detecting after it was partly scattered by the plough, and partly by excavation. The hoard comprises over 140 fragments of swords and spearheads; it is important for understanding the evolution of the Bronze Age sword in Britain and also for understanding the destruction and deposition of weapons in weapon-only assemblages. Besides a review of the hoard from a typological perspective four methods of examination were used: a) surface study for manufacturing traces. combat damage, possible cremation, and damage in the ground or at recovery; b) radiography of all fragments c) compositional analysis by electron microprobe analysis d) optical metallography and microhardness testing. This is the first occasion in which these techniques have been combined in the investigation of a whole hoard as opposed to a single finds. It has proved possible to divide the results of each technique into a number of simple categories so that correlations can be made. It can be shown that, in common with some other contemporary finds, that the weapons have been broken up and subjected to further alteration by fire, although here the fire had only a limited effect. Correlations can also be made between the typology, composition, microstructure and radiographic texture (e,g, porosity). The extent of combat damage on the destroyed weapons will also be defined.

SESSION II8: IN-ROOM POSTER SESSION
ARCHAEOLOGICAL SCIENCE AND EDUCATION
Wednesday Afternoon, November 28, 2001
4:00 PM
Independence East (Sheraton)

II8.1
DRESSING TECHNOLOGY FOR THE SILVER ORE IN "IWAMI SILVER MINE" SITE, JAPAN. Ryu Murakami, Nara National Institute for Cultural Properties, Kinomotocho, Kashihara, Nara, JAPAN; Jun Takada, Toshiyuki Torigoe, Okayama University, Tsushimanaka, Okayama, JAPAN; Iwao Matsumoto, Yoshio Toya, Shouji Morioka, Shimane Prefecture Education Committee, Tonomachi, Matsue, Shimane, JAPAN; Haruo Oguni, Hiromi Endou, Ken-ichi Nakada, Oda City Education Committee, Odacho, Oda, Shimane, JAPAN.

In the middle of the 16th century, Japan was a kingdom of the biggest silver mine in the world. "Iwami Silver Mine" located in Shimane prefecture was the representative silver mine in Japan. In this site, it became clear that the remains of mining and smelting existed through the excavation continued intermittently since 1983. Scientific investigations of the excavated relics have been done since 1996. In the present study we found that these relics scrapped until smelting from mining of the silver ore were classified into two types; "the materials which don't change in quality by heating process (dressing process)" and "the materials which change in quality by heating process (smelting process)". The low grade ore, waste, and tailings (waste after the gravity concentration) were thrown away in the dressing process, while the furnace (smelting and refining), the furnace wall, tuyere (blast pipe), slag (smelter remains) in the smelting process. Since any one has never paid attention to these waste or tails scrapped in the dressing process until now there are no systematically investigations on them. This scientific study aims to make clear dressing technology and estimation of ore grade at that time. In this report, the results of the waste after gravity concentration in the silver smelting process are described.

II8.2
REPRODUCTION OF JAPANESE TRADITIONAL PIGMENT BASED ON IRON OXIDE POWDERS WITH YELLOWISH RED COLOR. Hiroshi Asaoka, Makoto Nakanishi, Tatsuo Fujii, Jun Takada, Okayama Univ, Dept of Applied Chemistry, Okayama, JAPAN; Ryu Murakami, Nara National Cultural Properties Research Institute, JAPAN.

Iron oxide, α-Fe_2O_3 formed in the environment is known to be a primitive red pigment worldwide. The oxide has been called "bengara" in Japan. In the beginning of the 17th century, artificial "bengara" having very beautiful yellowish red color was produced in Japan and used for potteries, textiles and paintings. The works of the potter Kakiemon had a greater influence on European porcelains. However the preparation of "bengara" needed traditional and highly skilled craft has been stopped since about 1970 because of environmental pollution. The beautiful "bengara" is on the brink of extinction now. We investigated origin of the red colors of the "bengara" by using solid-state chemical approaches. The traditional "bengara" was analyzed by SEM, EDS, XRD and VSM. All particles had spherical shape with diameter of 100 $\sim$ 150 nm. They contained 5% Al and 10% Si impurities and their crystallinity was not so good. We also tried to synthesize iron oxide from iron sulfate ($FeSO_4$-$7H_2O$) to reproduce the "bengara" color. $FeSO_4$-$7H_2O$ was mixed with 0 $\sim$ 20% Al_2O_3 or SiO_2 and was then heat-treated at 600 $\sim$ 800°C for 1 hours. Color of the synthesized oxide changed from yellowish red to dark red with increasing the heat-treatment temperature from 600 to 800°C. But the impurity species, Al_2O_3 or SiO_2, had little influence on the color. All particles had spherical shape and their diameter was increased from 50 nm to 150 nm with increasing the temperature.

II8.3
THE RELATIONSHIP BETWEEN MICROSTRUCTURE AND MECHANICAL PROPERTIES OF LATE 19TH/EARLY 20TH CENTURY WROUGHT IRON USING THE GENERALIZED METHOD OF CELLS MODEL (GMC). Jennifer J. Hooper, The Johns Hopkins University, Department of Materials Science and Engineering, Baltimore, MD; Lori Graham, The Johns Hopkins University, Department of Civil Engineering, Baltimore, MD; Tim Foecke, National Institute of Standards and Technology, Gaithersburg, MD; Timothy P. Weihs, The Johns Hopkins University, Department of Materials Science and Engineering, Baltimore, MD.

The discovery of the RMS Titanic has led to a number of scientific studies, one of which addresses the role that the structural materials played in the sinking of the ship. Chemical, microstructural, and mechanical analysis of the hull steel suggests a state-of-the-art material for 1912 with adequate fracture toughness for the application. However, the quality of the wrought iron rivets may have been an important factor in the opening of the steel plates during flooding. Preliminary studies of Titanic wrought iron rivets revealed an orthotropic, inhomogeneous composite material composed of glassy iron silicate (slag) particles embedded in a ferrite matrix. To date, very little is understood about the properties of wrought iron from that period. Therefore, in order to assess the quality of the Titanic material, contemporary wrought iron was obtained from additional late 19th/early 20th century buildings, bridges, and ships for comparison. Image analysis completed on the Titanic wrought iron microstructure shows a high slag content that is very coarse and unevenly distributed, leading to regions of mechanical weakness along the rivet's loading axis. These results will be presented and compared with similar studies on additional period samples. To investigate the quality standards for the production of late 19th/early 20th century wrought iron, a detailed analysis was made of the relationship between the microstructural features and the mechanical behavior, using a combination of mechanical testing and micromechanical modeling. In modeling we used the Generalized Method of Cells (GMC) to predict the mechanical response of composites with variable microstructural properties. The GMC tool is used to generate the effective inelastic behavior of the composite from the individual constituent properties. Results to date will be presented.

II8.4
TECHNOLOGICAL INVESTIGATION OF ANCIENT DECORATED LUSTER MAJOLICAS. Giuseppina Padeletti, ICMAT-CNR, Rome, ITALY; Paolo Fermo, Franco Cariati, Dept of Inorganic Chemistry, Univ. of Milan, ITALY; Antonio Sgamellotti, Dept of Inorganic Chemistry, Univ of Perugia, ITALY.

Luster was one of the more sophisticated technique for the decoration of majolicas during Renaissance period. Luster consists of a thin metallic film containing silver, copper and other substances like iron oxide and cinnabar applied in a reducing atmosphere on a previously glazed ceramic. In this way beautiful iridescent reflections of different colours (in particular gold and red) are obtained. The study and the characterization of luster decorated majolicas is of great interest for archaeologist, but also offers possibilities to produce today, following ancient examples, pottery with outstanding decoration since nowadays Italian artisans are interested in the reproduction of the ancient recipes and procedures. Moreover it can even suggest new procedures to obtain uniform thin metallic films for technological applications. A

technological investigation has been carried out on the luster layers using numerous and different analytical technique such as XRD, SEM-EDX, TEM, ICP-OES and UV-Vis reflectance spectroscopy. Luster film has resulted to be formed by copper and silver cluster of nanometric dimension. The colour and the properties of the luster films depend on the elemental composition of the impasto applied on the ceramic surface but also on other factors such as the metallic nanoclusters dimension and the firing temperature. Furthermore the characterization of the glaze underlying the luster shows that its composition is an important factor in order to achieve beautiful iridescence effects.

II8.5
METALLOGRAPHIC ANALYSIS OF OBJECTS RESCUED FROM HISTORICAL SITES IN RIO DE JANEIRO STATE. Guadalupe Campos, Guillermo Solorzano, Department of Materials Science and Metallurgy, PUC-Rio, BRAZIL.

This work has as objective the metallografic analysis of ferrous and non-ferrous archeological objects by means of light opical (LOM) and scanning electron microscopy (SEM) tecnhiques, aiming to characterize their nature, composition and manufacturing procedure. The ferrous artifacts correspond to a scythe, a sword, a lock handle, a mattock and a cooking pot. The two first are based on steel that have been thermo-mechanically processed, althought with different carbon content and cooling treatments, thereby yielding to different microstructures. These microstructures are well correlated with the function of the object at there time period. It is interpreted that scythe has been produced in Brazil while the sword has a european origin.

II8.6
TWO CHANDELIERS DISHES FROM KAVAT-KALA. Aysulu Iskanderova, Isulu Iskanderova, Makset Karlibaev, Karakalpak State Museum of Regional Studies, Nukus, Karakalpakstan, UZBEKISTAN.

In the exposition of Karakalpak State Museum of Art some chandeliers dishes found at the territory of Kavat-Kala are showed. Two of them are interesting and they are close to each other by materials and technique. Interior of 1st dish was designed with golden-brown colour. Three sitting men in robes are represented there. One of the men holds stalk (of 'Life Tree'). Also on this section some peacock are represented. On the middle section an artist represented a man with traditional hat, rider and birds. Exterior of the dish is ornamented with Arabic words by 'Nash' style. 2d dish has a form of basin and sides of the dish formed like crimped (corrugated). The background has light-green colour. The chandeliers ornament was made with golden-brown colour. On the centre of the dish there is a festoon rosette filled with small 'flowers' and flourishes. Inner surface of lowes part (bottom of the dish) and also sides of the dish has medallions filled with crosses. Between the medallions there are Arabic words by 'Nash' style. Exterior of the dish is designed with plant ornaments. Represented theme of the chandeliers ceramics of medieval Khwarezm is close to ceramics of medieval Iran and the Southern Turkmenistan.

II8.7
COLLABORATIONS BETWEEN WPI & THE WORCESTER ART MUSEUM. Karen M. McNamara, Worcester Polytechnic Institute, Department of Chemical Engineering, Worcester, MA; Lawrence Becker, Philip Klausmeyer, Worcester Art Museum, Worcester, MA.

The curriculum at the Worcester Polytechnic Institute is unique in the field of technological and scientific education in that it contains a heavy emphasis on the interactions of science and society. The study of art and historical objects is an excellent example of the type of interdisciplinary study, which flourishes at WPI. Through research collaborations with the Worcester Art Museum, our laboratory has completed projects involving the characterization/authentication of pieces in the museums collections. This work has been carried out, primarily, by undergraduate students as their senior theses in Materials Characterization. In this presentation, I will highlight the results of these projects. One project authenticated a piece that is now the center of the museums Thailand collection. Another restored one of the Antioch Mosaics on the computer. In all, I have advised over half a dozen projects in conjunction with the museum, and students have examined objects from ancient Egypt, Greece, and Rome. The most recent project has examined the effects of aging on pigment analysis, identifying serious problems with the currently accepted staining procedures. Critical to the success of each of these studies was the enthusiastic participation of the Museum's Conservation Staff. With the experience garnered from several years of working with the Museum, and a background in art history, I have gone on to develop an engineering elective course in the Materials Science of Art Objects. This is a technical course, focusing on the use of highly specialized materials characterization tools, and to my knowledge, the only course of its kind. There is also great potential to modify the course content to provide a more introductory level syllabus geared toward K-12 and non-technical majors as well. This course has been offered at WPI several times and has met with extraordinary success.

II8.8
IS PHRYGIAN BLACK GLOSS A SINTERED SLIP WARE? Robert C. Henrickson, National Museum of Natural History, Anthropology, Smithsonian Institution, Washington, DC; Pamela Vandiver, Smithsonian Center for Materials Research and Education, Washington, DC.

Potters at Gordion (Turkey) produced a distinctive fine ware with a black gloss finish ca 800-500 BC. Local production is likely since INAA shows the chemical composition of the paste matches that of coarser wares and local clay samples. The fine levigated paste was thrown or moulded to form vessels, finished with a slip, and a wash added to further darken the surface during reduction firing. Several lines of evidence suggest a sintered slip. Hardness and refiring tests indicate an original firing temperature >800-900 C. Chemical composition is appropriate. SEM examinations of the paste, slip, and wash structure provide further data. No burnish or polish marks are found anywhere on the vessels. After foreign conquests (Persians ca 550 BC, Greeks ca 330 BC), this production technology disappeared as the local ceramic industry underwent dramatic change, and imported fine wares displaced the local ones.

SESSION II9: ARCHEOMATERIALS, TECHNOLOGY AND SOCIETY II

Chair: Chandra L. Reedy
Thursday Morning, November 29, 2001
Independence East (Sheraton)

9:00 AM II9.1
Abstract Withdrawn.

9:15 AM II9.2
EXPERIMENTAL INVESTIGATION OF SILVERING IN LATE ROMAN COINAGE. Constantina Vlachou, Gerry McDonnell, Rob Janaway, Department of Archaeological Sciences, University of Bradford, UNITED KINGDOM.

Roman Coinage suffered from severe debasement during the 3rd century AD. By 213 AD the fineness of the Roman silver coin had been reduced to 50% Ag and by 250 AD to just 5% Ag. By that time, the production of complex copper alloy (Cu-Sn-Pb-Ag) coins with a silvered surface, became common practice. One of the most characteristic examples was a new coin, the nummus, introduced by Diocletian, in his monetary reform (AD 293). Previous analyses of this coin did not solve key technological issues and in particular, the silvering process. The British Museum kindly allowed further research at Bradford to examine coins from Copes Archive in more detail utilizing XRF, SEM-EDS metallography and LA-ICP-MS. Metallographic and SEM examination of 59 coins, revealed that the silver layer survived in 22 coins. It was very difficult to trace because its thickness was approximately a few microns and in some cases it was present under the corrosion layer. Results derived from the LA-ICP-MS research have demonstrated, for the first time, the presence of Hg in the surface layers of these coins. A review of ancient sources and modern literature, indicated possible methods which might have been used for the production of the plating. A programme of plating experiments was undertaken to examine the application characteristics of each method and the properties of the resulted plating. Finally, synthesis and comparison of the results from the examination of the archaeological sample and the experimental work will be presented.

9:30 AM II9.3
THE EARLY HISTORY OF GLASSMAKING IN THE VENETIAN LAGOON: A MICROCHEMICAL INVESTIGATION. Jennifer Mass, Winterthur Museum, Winterthur, DE; Albert Ammerman, Dept of Classics, Colgate University, Hamilton, NY; John Hunt, Cornell Center for Materials Research, Cornell University, Ithaca, NY.

The technological achievements of the Renaissance Venetian glassmaking industry are internationally renowned, but little is known about the medieval and Byzantine origins of this industry. The compositions of well-dated Byzantine and early medieval glass finds from the Venetian lagoon were characterized by electron probe microanalysis (EPMA). The microchemical data was used in conjunction with archaeological evidence for glass production in these periods to gain insight into the early history of Venetian glassmaking. While Venice's industry is often considered to have grown out of Roman Imperial industries in the Northern Adriatic, it was also undoubtedly influenced by Venice's many interactions with Levantine glassmaking industries. These industries were sources of important glassmaking raw materials (such as cullet and plant ashes) that Venetian merchants imported from the late medieval period into the

Renaissance period. Our preliminary data on the Byzantine Venetian glasses reveals that a decline in Roman-style glassmaking technology during this period contributed to the necessity for Venice's late medieval technological innovations. The glasses analyzed for this study are of particular significance because they were excavated from Torcello (an island located five miles to the northwest of the Rialtine islands that make up modern Venice). Torcello is the site of the earliest evidence for post-Roman glassmaking in the Northern Adriatic — the remains of an early medieval glassmaking furnace complex. The Torcello furnace, which dates from the 8th-9th centuries AD, was found in the courtyard of the island's Basilica of Santa Maria Assunta. Recent excavations beneath the Basilica have revealed a continuum of glass finds that date from the Roman Imperial period up through the time of the Torcello furnace. Analysis of these finds has allowed us to gain insight into the transition period between the height of Roman glassmaking technology and the rise of Venetian glassmaking technology at this important site.

9:45 AM II9.4
THE TECHNOLOGICAL TRADITION OF KOREAN BLACK WARE AND THE INDIGENOUS DEVELOPMENT OF GLAZE TECHNOLOGY DURING THE FIRST MILLENNIUM A.D. Jennifer J. Hooper, The Johns Hopkins University, Department of Materials Science and Engineering, Baltimore, MD; Pamela B. Vandiver, Smithsonian Center for Materials Research and Education, Washington, DC.

A collection of 74 black ware shards excavated from kiln site in South Korea and dating from the 3rd-13th centuries were studied using optical microscopy, scanning electron microscopy, and electron beam microprobe analysis to determine the range of technological variability in composition, microstructure and firing temperature. Materials analysis provided a means of deconstructing and reconstructing the development of (1) consistent high temperature firing, (2) unintentional ash glazing on black ware, (3) intentionally applied black glazes, (4) the relationship of grey and black glazes to green and white ones. The research addresses issues of the influence of high-firing technology on glaze development and the development and continuity of the black glaze tradition. In addition, the black glazed Onggi ware of the late 19th century was compared to the earlier black-glaze tradition, once stabilized in composition in Koryo dynasty, and results suggest a technological connection with the earlier tradition.

10:30 AM II9.5
ANALYSIS OF CIZHOU MONOCHROME GREEN ENAMELS AND LEAD GLAZES FROM GUANTAI KILN IN NORTHERN CHINA, SONG TO JIN DYNASTY. Liu Wei, Peking University, Dept of Archaeology, Beijing, CHINA; Blythe McCarthy, Smithsonian Institution, Freer Gallery of Art/Arthur M. Sackler Gallery, Washington, DC.

Recent excavations at Guantai kiln in Hebei Province in northern China uncovered several examples, dating from ca. twelfth century A.D., of a ware that has a low-fired, green, lead-silicate glaze (enamel) applied to its entire surface over a higher fired transparent glaze. This green enamel is found on vessels with underlying carved slip and/or black painted decorative layers. The ware is the first known example in China of the application of a low temperature enamel applied over a high-fired glaze. It is believed to be an integral step in the development of the Chinese overglaze enamelling techniques that were perfected in southern China in the later Yuan and Ming dynasties. To better understand the development of the green monochrome enameled wares, the composition and microstructure of several lead glazes, green monochrome overglaze enamels and the underlying high-fired glazes from Guantai kiln were analyzed using electron microprobe analysis and scanning electron microscopy. Similarities in composition, thickness and microstructure of both the enamels and the underlying high-fired glazes to other lead glazes and high-fired glazes from the site were found. The enamels studied from the later part of the twelfth century formed a narrower compositional grouping than the lead glazes, indicating that increased control of the enameling technique was attained. Although like the later Jin dynasty painted enamels, the composition of the Guantai green monochrome enamels falls near the eutectic point of the lead-silica-alumina phase diagram, the monochrome enamels are thicker and have a composition distinct from that published for painted enamels from sites other than Guantai.

10:45 AM II9.6
TEXTILE-CLAY LAMINATES: A NEW-FOUND CRAFT TECHNOLOGY FROM ANCIENT MESOAMERICA. Harriet F. Beaubien, Smithsonian Center for Materials Research and Education, Suitland, MD; Emily Kaplan, Smithsonian National Museum of the American Indian, Cultural Resources Center, Suitland, MD; Monica Shah, Shah Conservation, Anchorage, AK.

Two Maya-period sites in Guatemala, Aguateca and Las Pacayas, have recently yielded fragments composed of a previously unknown material – a laminate formed from layers of woven cloth and clay slip. On-site and laboratory conservation efforts enabled the Aguateca finds to be identified as ceremonial headdress elements. Materials analysis and replication experimentation have elucidated technological aspects of this material, and demonstrate its suitability for fabricating elaborate, lightweight items such as these.

11:00 AM II9.7
AN ETHNOARCHAEOLOGICAL PERSPECTIVE ON THE CHEMICAL AND MATERIAL RESIDUES OF COMMUNAL FEASTING AT LATE CLASSIC EL COYOTE, NORTHWEST HONDURAS. E. Christian Wells, Arizona State Univ, Dept of Anthropology, Tempe, AZ; Patricia A. Urban, Dept of Anthropology, Kenyon College, Gambier, OH.

Recent archaeological studies of feasting have made significant contributions to our theoretical understanding of the social roles of communal consumption yet have made far more limited progress in discerning the relevant diagnostic criteria of such events and their manifestations in the cultural material record. This paper examines data on the quantitative, context-specific distribution of artifacts and associated chemical patterning in anthropogenic sediments in the main civic-ceremonial plaza at the Late Classic site of El Coyote in Northwestern Honduras. Based on ethnoarchaeological comparisons drawn from a multi-elemental chemical study of plaza soils in the nearby modern-day village of Petoa, aspects of the organizational principles of communal feasting at El Coyote are inferred. The results demonstrate that comparative, chemical analyses of modern and prehistoric anthrosols, along with considerations of associated patterns of artifact distribution, can greatly enhance our understanding of some of the spatial and social characteristics of ancient feasts.

11:15 AM *II9.8
PAINTED QERO CUPS FROM THE INKA AND COLONIAL PERIODS IN PERU: AN ANALYTICAL STUDY OF PIGMENTS AND MEDIA. Richard Newman, Michele Derrick, Museum of Fine Arts, Scientific Research Lab, Boston, MA.

Qeros are wooden drinking vessels that have been used for millenia in the Andean region for ritual consumption of maize beer. Nearly all qeros produced during the Inca (c. 1470-1532) period were decorated with carved geometric motifs. From the cusp of the Inka-Colonial (1532-1821) periods, painted decoration became more common. Most of this painted decoration actually consists of thin layers of a pigmented rubbery material that was cut out and inlaid into shallow carved cavities rather than brushed in a liquid state onto the wooden substrate. For this project, nearly 350 samples of 'paint' from about 50 qero cups in the collections of the Brooklyn Museum of Art, National Museum of the American Indian (Smithsonian Institution), Metropolitan Museum of Art, and American Museum of Natural History were analyzed. The study of the paints is a part of a larger study of the technology of over 150 qeros housed in these four collections. Samples from a few cups in Peruvian collections have also been analyzed. Nearly two dozen different pigments have been identified, including mineral, synthetic inorganic compounds, and natural dyestuffs. The binder consisted of an unusual natural resin (commonly called mopa mopa) which was usually mixed with a semi-drying oil. This resin, which was used during the Inka period and continued to be used through the Colonial period and later, came from a tree that grows in the montana of southwest Colombia, a region that was part of the northernmost extension of the Inka empire.

SESSION II10: HISTORIC TECHNOLOGIES AND MODERN CRAFT
Chairs: Blythe McCarthy and Peter J. Northover
Thursday Afternoon, November 29, 2001
Independence East (Sheraton)

1:30 PM *II10.1
TECHNICAL STUDIES ON RENAISSANCE BRONZES. Billie Milam Weisman, Frederick R. Weisman Art Foundation, Los Angeles, CA; Chandra L. Reedy, University of Delaware, Museum Studies Program, Newark, DE.

The merging of art production and technological innovation during the Renaissance led to some of the worlds most renowned master works in bronze. To date, most technical studies on Renaissance bronzes have been based on either the examination of a few examples by one artist, or of single examples by a few artists. The objective of the present study was to conduct a comprehensive investigation of comparative examination and analysis on fifty bronze sculptures which are attributed to a wide variety of workshops and individual artists. The sculptures are housed in the permanent collection of the Kunsthistorisches Museum in Vienna, Austria, and were shown in the

museums 1987 exhibition, Renaissance Master Bronzes. Technical analysis included identifying and characterizing casting and fabricating techniques through visual surficial examination; studying x-radiographs; and identifying clay core-materials through thin section petrography. The results of these studies were subsequently compared to technical treatises/accounts of bronze techniques by three Renaissance artist-scholars: Biringuccio (ca. 1540), Vasari (ca. 1550), and Cellini (ca. 1568). The present investigation shows a strong correlation between its technical results and those set forth by the above scholars from the Renaissance period. The findings of this research and comparison indicate that many methods and procedures in Renaissance bronze production were not standardized. Rather, there is shown to have been a wide range of technical variation. The broad variance is demonstrated through numerous processes, including: modes of separate cast-piece attachment, armature construction, chaplet insertion, selection of clay core and additive bulk materials, and removal of clay-core portions after casting. The variance is also evident in the quality and extent of surficial tooling and/or chasing, and in the visual appearance of patinas. As a result of this study, we are beginning to develop a better understanding of the nature of bronze sculpture technology during the Renaissance period.

2:00 PM II10.2
NON-DESTRUCTIVE ANALYSIS OF NINETEENTH CENTURY SCOTTISH CALOTYPE NEGATIVES AND SALT PRINTS.
Katherine Eremin, James Tate, Alison Morrison-Low, National Museums of Scotland, Edinburgh, UNITED KINGDOM; James Berry, Sara Stevenson, National Galleries of Scotland, Edinburgh, UNITED KINGDOM.

In 1839 William Henry Fox Talbot announced and patented the Calotype process to fix the image seen in a camera obscura. Sir David Brewster introduced this process to Scotland and after much correspondence with Talbot, John Adamson took the first successful Scottish portrait photograph in 1842 in St Andrews. The technique was used to produce a large corpus of negatives and positives by John Adamson and his brother Robert, who worked with the artist David Octavius Hill from 1843 to 1847. Although none of these photographers documented their processes, Talbot used a range of chemical processes. Visual differences between the Scottish images suggest several different processes were employed. A selection of negatives and positives in the collections of the National Museums of Scotland and the National Galleries of Scotland were analysed non-destructively to identify the techniques used. Many of the negatives and a few of the positives are of known date, allowing investigation of chronological variations in process. A number of modern positive and negative images prepared using known chemical processes were also analysed and the results compared to those from the nineteenth century originals. Air-path x-ray fluorescence (XRF) analysis enabled the images to be divided into groups based on the levels of bromide, iodide and silver and the chemicals used for sensitising the paper and fixing the images to be inferred. The groups were further subdivided on the basis of other elements such as cobalt, iron, zinc and copper. Small images were also examined using a controlled pressure scanning electron microscopy with energy dispersive microanalysis (CP-SEM-EDX), revealing sulphur and chlorine, and other light elements which could not be detected by air-path XRF. SEM examination allowed identification of the actual species present and assessment of the size and distribution of the particles of silver or silver halide.

2:15 PM II10.3
METAL ALLOYS OF THE LAST CENTURY.
Martha Goodway, Smithsonian Center for Materials Research and Education, Washington, DC.

The twentieth century can be looked back upon as a period in which a number of metals unknown to previous centuries were introduced. These were not only alloys in unusual combinations of well known metals, but also elements unavailable earlier. Some of these have had their day and exist now only as museum exhibits, which are sometimes also preservation problems in museum collections. Examples include cadmium plating, certain zinc die casting alloys, and weathering steels. Many metals lost their traditional applications. An example are copper alloys that were superceded by stainless steel, while copper itself gained an entirely new application with the spread of electricity, which depended upon an economic conductive material. And the semimetals and elements such as uranium that had been of interest only to the ceramist at the start of the century are now the bases of inustries unforseen only a hundred years ago.

2:30 PM II10.4
THE WROUGHT IRON WIRE FROM THE WHEELING SUSPENSION BRIDGE: A METALLURGICAL EXAMINATION.
Wayne L. Elban, Loyola College, Dept of Electrical Engr and Engr Sci, Baltimore, MD; Martha Goodway, Smithsonian Center for Matls Research and Education, Washington, DC.

The Wheeling Suspension Bridge was constructed in 1849 over the Ohio River as part of the National Road linking the east coast with the interior of the US. This was just before the introduction of the Bessemer process opened the Age of Steel, so the wire for the suspension cables was manufactured by a local Wheeling firm, Joseph Bodley and Co., from wrought iron. Samples were examined metallurgically by optical microscopy and SEM for features such as inclusions, grain size and morphology, and hardness (DPH) measured as a proxy for strength; these were then compared with earlier observations made of iron wire of finer gauge drawn for musical instuments.

2:45 PM II10.5
THE TECHNOLOGICAL ANALYSIS OF RMS TITANIC'S COAL: THE ENHANCEMENT OF ARCHAEOLOGICAL RESEARCH.
Michael S. Sheehan, Lauren B. Sickels-Taves, Eastern Michigan University, Dept of Geography & Geology, Ypsilanti, MI.

Analysis of the chemical composition of materials obtained from archaeological sites can yield information about events in the past that are not available from any other source. This research focuses on coal recovered from the debris field created when RMS Titanic sank on 15 April 1912. The primary objectives are to evaluate the variety of different sources of coal represented in the Titanic sample, and to identify the specific location of these sources. Although much has been written about this significant historical event, the information regarding the sources of coal used to power the great liner is vague and incomplete. This information is important because at the time of the sinking, a coal strike was in full force, which compelled the White Star Line to reallocate resources and reorganize its transatlantic services. These responses to the coal strike had a significant impact on the size and constituency of the passenger list for Titanics maiden voyage. The methods used to evaluate the research objectives include a variety of trace element, petrographic, and palynological analyses. The results of this study provide critical insight into the socio-economic circumstances that contributed to the enormity of the disaster. In addition, identification of coal source areas will aid the efforts of scholars trying to assess the response of early 20th century corporate entities to significant labor disputes.

3:30 PM II10.6
RECOVERING AND RE-DISCOVERING CRAFT.
Pamela Vandiver, Smithsonian Center for Materials Research and Education, Washington, DC.

Many studies have shown that craft involves know-how, practice and problem solving that can be recovered from various artifact assemblages and contexts within archaeological sites. The types of conclusions differ with sample size and variability, methods of study and collection organization in the field as well as the results of resource survey and landscape reconstruction. Questions generated through analysis of materials and properties often generate questions that can only be answered by replicative experiments, re-integration of the craft into the archaeological context and re-discovery of the conjectured details of process and performance.

3:45 PM II10.7
EGYPTIAN FAIENCE: A PROCESS FOR OBTAINING DETAIL AND CLARITY BY REFIRING.
Carolyn Riccardelli, Jennifer Mass, and Jonathan Thornton, Buffalo State College, Art Conservation Department, Buffalo, NY.

Egyptian faience manufacture began in the Predynastic period (4800-4300 BC) and continued for the next five millennia, not only in Egypt but also in North Africa, Central Asia, and the Aegean. The earliest examples of faience have a limited palette of turquoise-blue and green. Throughout its long history in Egypt, faience objects became more complex and were often decorated with an expanded palette of red, black, and yellow. This polychrome decoration was often accomplished by inlaying one color of paste into another. Inlay during the New Kingdom period is often characterized by a small void, or parting line, around the added color. Inlaid faience from this period is found both with and without such a parting line. Because the distinctive parting line has been difficult to reproduce, the line appears to be deliberate. This inlay technique reveals a fundamental understanding of the materials' characteristics before, during, and after firing; and knowledge of how to manipulate these characteristics. The research presented in this paper is an attempt to identify Egyptian faience inlay techniques by characterizing the properties of a set of standard reproductions. The most aesthetically successful reproductions were produced with pre-fired components. A series of experiments was performed to quantify changes in glaze color, glaze gloss, and depth of glaze penetration upon refiring. Data was gathered from replicated samples and cross-sections using SEM EDS, UV-vis spectrophotometry, colorimetry, and optical microscopy. Visual

comparisons were made between cross-sections of replicated inlays and examples of broken ancient Egyptian faience inlays.

4:00 PM *II10.8
A NEW APPROACH TO EGYPTIAN CORE VESSEL TECHNOLOGY. Dudley F. Giberson, Jr., Joppa Glassworks, Inc., Warner, NH.

An analysis of core vessel technology is presented from a manufacturing point of view. Observation and analysis of the physical characteristics of ancient Egyptian core vessels led to a many year series of replications that have included novel furnace design, methods of working glass and treatment of raw materials. The presentation will be accompanied by a video presentation and demonstration on the last day of the conference.

4:30 PM *II10.9
PRACTICAL BLOOMERY SMELTING. Lee Sauder, Woods Creek Forge, Lexington, VA; Skip Williams, Dept. of Interdisciplinary Studies, Washington & Lee University, Lexington, VA.

After a brief introduction to bloomery smelting, Sauder & Williams will give a step-by step description of the procedure for the following days smelting program. Finally, they will briefly summarize some of the more interesting discoveries of their experimental research.

SESSION II11: ANCIENT TECHNOLOGIES
WORKSHOP AND DEMONSTRATION
Chairs: Pamela Vandiver and Martha Goodway
Friday Afternoon, November 30, 2001

SESSION II11: ANCIENT TECHNOLOGIES
WORKSHOP AND DEMONSTRATION
Chairs: Pamela Vandiver and Martha Goodway

- **Date:** Friday, November 30, 2001
- **Time:** 10:00 a.m. to 5:00 p.m.
- **Location:** To be held off-site at M.I.T.

Experiments described in Session II10 will be replicated by the authors, including the 3500-year-old pyrotechnologies of Egyptian faience, faience inlay and glass core vessel manufacture, and in the 2000-year old technologies of bloomery iron-smelting and Roman-style glass-blowing.

Sign-up, schedule and maps available in symposium meeting room on Thursday afternoon during session II10.