The art of Raman

Advantages

- In situ analysis using optical fiber probe up to 100 m from instrument
- Non-destructive
- 1 µm spatial resolution using microscope
- No sample preparation

Identify pigments

In situ analysis of a 12th century fresco in the S. Pietro di Avigliana church in Turin, Italy. Pigments are identified from their Raman spectra enabling sympathetic restoration.

Identify pigments

Repair of a damaged wall-painting of St. Merkourios in Protato church, Greece. Analysis of small particles of paint (≤ 1 mm²) with a Renishaw Raman microscope identifies the original pigments.

Investigate authenticity

Renishaw’s Raman system provides evidence for the Vinland Map being a very clever forgery. In situ analysis of materials used on the map allows dating of the artwork.

Other applications

- Gemstones
- Corrosion processes
- Ceramics
- Marble
- Surface treatments

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40th International Symposium on Archaeometry

ISA 2014

May 19-23, 2014
Los Angeles, California

Program and Abstract Book

Organizing Institutions
Getty Conservation Institute
Cotsen Institute of Archaeology
University of California Los Angeles
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Ceramics, Glazes, Glass and Vitreous Materials
Josefina Pérez-Arantegui and Patrick Degryse

Forensic Science Investigations in Art and Archaeology
Ioanna Kakoulli

Human Environment Interactions and Bio-Materials
Bioarchaeology
Henk Kars

Metals and Metallurgical Ceramics
Dave Killick and David Scott

Remote Sensing, Geophysical Prospection and Field Archaeology
Luis Barba and Rob Sternberg

Stone, Plaster and Pigments
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Introduction

In the last several decades, the application of the physical sciences to study, interpret and present cultural heritage has made great strides. This burgeoning field has been given several names with the most prominent being: archaeometry, archaeological science and cultural heritage science. At its core, it is an interdisciplinary field of research bringing together art historians, archaeologists and anthropologists with chemists, physicists and engineers to better understand and interpret the archaeological record. It has become well established that basic and applied science has tremendous value as aids to understand ancient human condition and agency through the interrogation of the material culture. This growing research effort has been directed towards the study of ancient materials as products of human activity such as pottery, glass, metals as well as the study of human remains. Despite the incredible potential, the focus has remained on what science can do for archaeology and not on the more complex issues imposed by the limitations of analysis and interpretation of a heterogeneous, fragile and inconsistent nature of the archaeological record.

The International Symposium on Archaeometry (ISA) continues to be the premier conference on application of the physical sciences to archaeology. At this 40th ISA in Los Angeles, we are aiming to influence the future trends in archaeometry by addressing long standing challenges as well as looking into current subjects of importance to the archaeological and archaeometric community. At the 40th ISA we have two special sessions: 1) Forensic Science Investigations in Art and Archaeology and 2) The Context of the Transition from Bronze to Iron in the Ancient Mediterranean. In addition to the standard sessions, we believe that these new sessions will lend themselves to a fresh discussion of the significant issues and new directions in this interdisciplinary field of research. The symposium will be further enhanced by the inclusion of two excellent keynote presentations titled: 1) Small Compositional Groups, Production Events and the Organisation of Production by Ian Freestone, University College London and 2) The DNA sequencing revolution: new opportunities for biomolecular archaeology by Terry Brown, University of Manchester.

We would like to take this opportunity to thank the many individuals who worked diligently to make this symposium a success including the conveners who reviewed all of the 370 submitted abstracts. We would also like to acknowledge all of the sponsors who believe in the mission of ISA and who make it possible for us to continue the work that we do.

On behalf of the standing committee, the local organizing committee and the organizing institutions, it gives us great pleasure to welcome you to the 40th International Symposium on Archaeometry.

Wishing you all a very informative and enjoyable symposium!

Ioanna Kakoulli and Marc Walton
Co-Chairs, ISA 2014
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12:40 – 12:45 PM
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68. King, A. - Combined SEM and Raman spectroscopy: a powerful analytical tool for archaeometry

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4:50 – 5:10 PM
70. Li, S., Rehren, T., Qin, D., Chen, J. - Crucible or Furnace—A comparative study of silver production traditions in north and south China

5:10 – 5:30 PM
71. Leroy, S., Hendrickson, M., Delquié-Katic, E., Vega, E., Dillmann, P. - Iron and the Khmer Empire, Cambodia (9th to 15th c.): first study on the sourcing and dating of iron construction materials of Angkor

5:30 – 5:50 PM
72. Green, T.R., Ameje, J., Grinenborn, D., Rutz, J. - Archaeometallurgy of Metal Finds from the Medieval "Royal" Burials of Durbi Takshiyel, Northern Nigeria

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74. Snuip, A., Urban, R., Schertman, E. - Copper production at El Coyote Honduras: The first evidence for copper smelting in Central America

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75. Martinon-Torres, M., Uribe, M.A. - Goldsmiths or Wax Sculptors? Individual Skill and Social Agency in Muisca metalwork (Colombia, AD 600-1800)

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9:00 – 9:20 AM
SESSION Ceramics, Glasses, Glass and Vitreous Materials Chairperson: Hector Neff

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9:40 – 10:00 AM
77. Conte, S., Arletti, R., Mermati, F. - First Archaeometric Data of Glass from Sarno Necropolis (9th - 6th Century BC)

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78. Devulder, V., Vanhaecke, F., Shortland, A., Mattlin, D., Degryse, P. - Baron isotopic Composition of Roman Natron Glasses to Provenance the Flux Raw Material

10:00 – 10:20 AM

10:20 – 10:40 AM
80. Ferranti, R., Bracci, S., Memmi Turbanti, L., Plocio, M., Vilarigues, M., Troehra, M. - Characterization and contemporary replicae of Art Nouveau coloured glass

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11:00 – 11:20 AM
82. Gioioso, E. - Glass and Diagrams: a Review (Romain and Medieval glasses from the Mediterranean area)

11:20AM – 12:00 PM  Coffee Break/Plants

12:00 – 1:00 PM
Prizes and Closing Ceremony

1:00 PM  End of the Symposium

1:30 PM  Offsite Excursion 1: Eames House
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86. Archeological materials of the submerged site of Baia (Naples, Italy): production technology of mortars and bricks.

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CERAMICS, GLAZES, GLASS AND VITREOUS MATERIALS

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107. Granite mortars from O Incio  
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108. Identifi6cation of provenance markers in Lapis Lazuli: a study on rocks and artworks  
Gianluca Gariani, Debora Angelici, Alessandro Lo Giudice, Alessandro Be, Alessandro Burchi, Thomas Calligaro, Silvia Calusi, Lorenzo Mariano Gallo, Nicla Gelli, Lorenzo Giuntini, Maria Cristina Guidotti, Clare Pacheco, Giovanni Pratesi, Chiara Ricci, Francesco Taccetti, Gloria Vaggelli

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118. Obsidian Economy In Neolithic Corsica: Insights From The Phase III Level Of Renagjhu  
Marie Orange, Francois-Xavier Le Bourdonnec, Andre D’Anna, Ludovic Bellot-Gurlet, Anja Scheffers, Gerard Poupée, Carlo Luglié, Renaud Joannes-Boyau

119. Creations of Highly Prized Products to Inland Eastern Iberia during the Roman Republican Period (2nd and 1st centuries BC): the Case of Egyptian Blue Pigment through Its Archaeometric Study  
José Pérez-Arenasguí, Andrea Gil, Loudres Ventó-C, Marius Vendrell, José Antonio Pérez

120. Catching Neolithic Humans Red-Handed: the Procurement of Colouring Materials In N.-W. Mediterranean Neolithic  
Jean Victor Pradeau, Didier Binder, Chrystèle Vérati, Jean-Marc Lardeaux, Ludovic Bellot-Gurlet, Paolo Piccardo, Stéphane Dubernet, Yannick Lefrati, Marine Gay

121. Provenance study of marbles used as covering slabs in the archaeologically submerged site of Baia (Naples, Italy): the case of the “Villa con ingresso a protiro”  
Michela Ricca, Mauro Francesco La Russa, Silvestro Antonio Russo, Donatella Barca, Barbara Davide, Gino Mircolo

122. Material Analysis on 17th century Armenian Wall Painting in New Juffles-Ishafan  
A. Sasanii, F. C. Petrucci, C. Vaccaro, A. Murray

123. Elemental and Isotopic Variability In Mogollon-Datil Province Obsidian, Western New Mexico  
M. Steven Shankley

124. Investigations of Blue in the Pre-historic Palette: Analysis of Azurite from Neolithic Çatalhöyük, Turkey  
Ina M. St. George

125. Non-Destructive pXRF Sourcing of Neolithic Obsidian Artifacts from the Tavoliere, Italy  
Robert H. Tykot, Keri Brown

126. Studying Obsidian Sources and Trade in the Gamo Caste System in Southwestern Ethiopia  
Robert H. Tykot, Kathryn J. Arthur, Matthew Curtis, Mauro Colotti, Pierluigi Pieruccini, Sean Stretton

127. Marble: From Sculptures in Algeria: Is From Local Sources or Elsewhere?  
Robert H. Tykot, Jessica A. Morgan, John J. Herrmann, Jr., Annew les van den Hoek

128. Analysis of Paintings in the Prehistoric Genovese Cave (Levanzo, Egadi Islands, Sicily)  
Robert H. Tykot, Andrea Vianello, Kyle P. Freund

129. Weathering mechanism on the whitening jades of Neolithic China  
Rong Wang, Weishan-Zhang

130. Technology of the Hubian Wall-Painting: A Reconstruction of the Past through the Painting Materials and Techniques  
Dobrochna Zielinska, Barbara Wagner, Agnieszka Kijowska

CERAMICS, GLAZES, GLASS AND VITREOUS MATERIALS

131. Preliminary Results of Petrographic Analysis of Halaf and Ubaid Sherds from Tell Ziyadeh, Syria  
Yukiko Tonoike

132. Analysis of archaeological pottery from Maranhão (Brazil) by six atomic and nuclear analytical methods  

133. A Study of Bronze Age Pottery from Al-Khider Site, Kuwait: Chemical and Petrographic Characterization  
Hasan Ashkanani, Robert H. Tykot, Mary Omby

134. A Chemical Characterization of Dilmun Pottery from Bronze Age Sites (tell F3) in Kuwait and (NE Temple) Bahrain Using Non-Destructive XRF analysis  
Hasan Ashkanani, Robert H. Tykot

135. Early Iron Age Ceramics from Eastern Tanzania: A Compositional and Technological Approach  
Enrica Bonato, Patrick Quinn, Lara Maritan
136. The Glass Tesserae of the Amathous Acropolis Basilica: an Archaeometric Study
Olivier Bonnerot, Andrea Ceglia

137. Characterisation of Byzantine Primary Glass Furnaces
Dieter Brems, Rebecca Scott, Veerle Devulder, Frank Vanhœecke, Patrick Degryse, Ian Freestone

138. Geochemical Heterogeneity of Sand Deposits and its Implications for the Provenance Determination of Roman Glass
Dieter Brems, Jente Pauwels, Patrick Degryse

139. pXRF Analysis of Neolithic Ceramics and Clay Sources in the Tavoliere, S.E. Italy: an Archaeometric Project with Social Archaeological Aims.
Keri A. Brown, Craig Alexander, Robert H. Tykot

140. Shooting Shards: Multi-period Pottery Classification with the p-XRF, from the excavations at Stromboli-San Vincenzo, Italy
Valentina Camb não, Effie Photos-Jones, Sara Tiziana Levi, Daniele Brunelli, Marta Clara Martinelli, Erica Camurri, Pamela Fragoliti, Giacomo Lomaro, Elena Lusuardi, Daniele Pantano

141. Shedding light on the glass industry in late antique Cyprus
Andrea Ceglia, Peter Cosyns, Wendy Meulebroeck, Karin Nys, Herman Terryn, Hugo Thienpont

142. Glass tesserae form the ‘Villa of the Antonines’ at the Ager Lanuvinus. Chemical composition, technology of glass production, and state of deterioration
Deborah Chair-Ayramonti, Gregory A. Pope, Laying Wu

143. Investigation on the Effects of Drying Time and Age of Glaze on a Macrocristalline Glaze & an Analysis of Spherulite Growth
Amanda Chau, Aaron Shugar, Jonathan Thornton

144. Investigating the Firing Protocol of Athenian Pottery Production: A Raman and colorimetric study of replicates and original samples
Iaria Cianchetta, Karen Trentelman, Jeff Maich, Marc Sebastian Walton

145. Characterization of Costa Rican Archaeological Ceramics from the Formative Period: Preliminary Electrochemical Studies
Gerardine Congeo Barbosa, Jean Sanabria Chinchilla, Francisco Corrales Ullés, Mavis Montero Villalobos

146. The Glass Road: Using Quantitative Analysis of Islamic Glass at Merv, Turkmenistan for Boundary Material Mapping of the Silk Road
Laura A. Conger

147. Archaeometric Comparison between the Early and Late Sasanian Period Ceramics at the Archaeological Site of Qasr Qal‘eh (North-Eastern Iran)
Maria Deghemehlis, Jebsyn, Nokandeh, Bahram Firoozmandi Shirejini

148. Copper and Antimony isotopic analysis via multi-collector ICP-mass spectrometry for provenancing ancient glass
Patrick Degryse, Lara Lobio, Domingo Gimeno, Andrew Shortland, Katherine Eremis, Frank Vanhœecke

149. Two pre-Columbian Pottery Productions of the Peruvian North Coast: An Archaeometrical Approach to Understanding Technical Traditions of the Mochica and Cajamarca Cultures
Nino Del Solar, Philipp Dollwetzel, Rémy Chapoulie, Luis Jaime Castillo

150. Home and Hearth: a Multidisciplinary Investigation of Stove Tiles in Post-Medieval Flanders (Belgium)
Katie Le Deunghé, Bart Vekemans, Wim De Clercq, Peter Vandenabeele, Laszlo Vincze

M. I. Diaz, M. I. Prudêncio

152. Assessing the Use of Elemental Compositional Data for Provenancing and Dating British Soft-Paste Porcelain from 1740-1820
Joanna Dunster, Andrew Shortland, Kelly Domoney

153. Archaeometrical characterization of red opaque glasses
Monica Gans, Veerle Devulder, Frank Vanhœecke, Domingo Gimeno, Olivier Bonnerot, Patrick Degryse, Marc Walton

FROM THE BRONZE AGE TO THE IRON AGE

154. Raman and infrared spectroscopies for the identification and provenance of resinous beads from Middle Bronze age Corinca. Insights of a Mycenaean influence
Eleonora Canobbio, Ludovic Beliot-Guirlet, Céline Paris, Joseph Césari, Franck Léandri, Céline Léandri, Kevin Peche-Quilichini

155. The Technology of Late Bronze Age/Early Iron Age Glass in the Mediterranean: Analytical Studies of Vitreous Materials from Lefkandi
Vassiliki Zachariades, Nikolaos Zacharias, John K. Papadopoulos

156. Not first but fast: on the Bronze-Iron Age transition in mainland Southeast Asia
T. O. Pycke

157. Beads Culture of Early Myanmar, Doorway to Southeast Asia
Terecce Tan

METALS AND METALLURGICAL CERAMICS

158. Persian Crucible Steel Production: Chahâh Tradition
Rahil Allipour, Thilo Behren

159. Tracking Technological Change in High Resolution: an XRF Study of Iron Age Copper Smelting in the Southern Levant
Erez Ben-Yosef, Thomas E. Levy

160. Experimental and Analytical Investigation of Black Bronze Alloys
Agnese Benzonieli, Ian Freestone, Marcos Martinez-Torres

161. An Unusual Example of Gold Cloisonné from Central Anatolia
Alice Boccia Paterakis, Sachhiro Omura, Ellen van Bork

162. Analytical Study of Andean Precolumbian Metallurgy by Energy Dispersive X-Ray Fluorescence
Jorge A. Bravo, Mirian E. Mejia, Mercedes Delgado, Alejandro L. Trujillo

163. Copper Supply During the Third Millennium BC (Late Neolithic and Bell Beaker) from the Pyrénées to the Western Alps
Florence Cattin, Matthieu Labaune, Aurelien Alcantara, Estelle Camizuli, Robin Furestier, Henri Gandois, Olivier Lemercier

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167. Low Tin Bronze Corrosion by Hydrosulfide (HS-) and Sulfide (S2-) Ions
Michelle Chan, Alexandre Capek, Simon J. Garrett

Jorge A. Bravo, Mirian E. Mejia, Mercedes Delgado, Alejandro L. Trujillo

169. Evidence of arsenical copper smelting of Bronze Age China: a preliminary study of slag discovered at the Laoniuo Site, Central Shaanxi
Kunlong Chen, Yanxiang Li, Lianjian Yue

170. New Insights to the Early 19th Century Naval Technology: Metallurgical Examination of the Cargo of a British Transport Lost Off Catalonia Coast, Spain
Nicolás Ciurlo
SESSION II
CNSI at UCLA, Wednesday to Thursday, May 21-22

ARCHAEO-CHRONOMETRY

169. The Aegean Early Bronze Age, Tracing the Absolute Timeframe - Looking for Boundaries
Theodora Arvaniti, Yannis Maniatis

170. Embracing In-Homogeneity in Archaeomagnetism: Implications for Sampling and Analysis
Eric Blumen, J. Royce Cox

171. Dating results of new palaeoenvironmental studies conducted in South Peloponnesus, Greece
John Christodoulakis, Yannis Bassiakos, Evangelos Tsakalos, Maria Kazantzaki

Martos Carre Asencio, Richard P. Evershed

173. The Rectorate Building of the University of Cagliari (18th century): metrological,chronological and materical analysis of masonries
Caterina Giannattasio, Silvana Maria Grillo

174. Rehydroxylation Dating of Pre-Hispanic and Colonial Fired-Clay Artifacts from Aguascalientes, Mexico
Beckett Laflin, Jose R. Alvarez, Jorge Baliamesa, Ana M. Peiz, Nicolas Caretta, Niklas Schulze, Manos Martinez, Eli Puch

175. Comparative Study of Two Etruscan Bucchero Amphoras
Elena Minin, A. Mazzina, S. Sokolov

176. Breaking Fad: Pushing the Boundaries of Metallurgical Communities at The Cenote Sagradro
Bryan Cockrell, José Luis Ruvalcaba Sil, Edith Ortiz Diaz

177. Reexamining the Archaeology of the Colorado Plateau (USA) Using Radiocarbon Dating of Collected Wood
Dana Drake Rosem, Ronald H. Tower, Gregory W.H. Hodges and Jeffrey S. Dean

178. Mill scale on historic wrought iron: characterisation and impact on corrosion behaviour
Nicola Emmerson, Eric Henderson, David Watkinson

179. Methodological Development for the Decomposition of Ancient Iron Slag for ICP-OES Analysis
Kim Ekelens, Elvira Vassileva, Philippe Muchez, Patrick Degryse

180. From sculptures to foundries: elemental compositional analysis to trace modern bronzes provenance
Monica Garcia, Francesca Casadio, Katherine Faber, Anne Leonard, Johanna Salvant, Marc Walton

181. Composite XRD, Metallography and RadiographyAnalysis of Metal and Corrosion Products for Luristan Bronzes, Iran
Zahra Karamad, Zahra Nikoei

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FORENSIC SCIENCE INVESTIGATIONS IN ART AND ARCHAEOLOGY

210. Application of VPSEM-μRS for SERS analysis of archaeological textiles
Rebecca Scott, Patrick Degryse, Phillipe Muchez

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207. Getting to the Root of It: Analysis of Human Skeletal Remains from the New Haven Green

208. The Characterization of the Lamp Oil and Burning Incense from a Tang Dynasty Tomb in China
Shuya Wei, Qinglin Ma, Shuhong Lou

HUMAN ENVIRONMENT INTERACTIONS AND BIO-MATERIALS BIOARCHAEOLOGY

209. DART-MS for Identification of Dye Colorants in Paracas Textiles
Ruth Ann Armitage, Kathryn Jakes, Calvin Day

210. Diet and origin of enslaved Africans in Brazil: A multi-isotopic study of individuals buried in the Pretos Novos Cemetery in Rio de Janeiro and in the Catedral da Se in Salvador
Murilo Q. R. Bastos, Roberto V. Santos, Robert H. Tykot

211. Non destructive identification and diagnosis of natural organic substances in cultural heritage: Insight from Raman and infrared signatures
Ludovic Bellot-Gurlet, Céline Daher, Céline Paris, Martine Regert

212. Hybridization of Agriculture in Neolithic Asia Minor: Reconstructing Human Diet and Disentangling Environmental Signals
Chelsea Budd, Rick Schulting, Necmi Kanlı, Sangül Alpaslan-Roodenberg, Ron Pinhasi, Malcolm Lillie

213. The use of stronithum isotopic data from human dental enamel as prima facie evidence for evaluating human provenance and mobility.
James H. Burton

214. Thermal degradation chemistry of archaeological pine pitch: alone and mixed with beeswax
Maria Porta Colombi, Celia Duea, Andreas Kurzwelt, Sibbja Orsini, Elekso Specti, Mario Rosaria Tiné

215. Biochemical Indicators of Diet in a Late Muisca Settlement in the Northern Andes: Stable Isotopes and Trace Elements

216. Pottery Function in Middle Neolithic Central-Western Mediterranean: an Integrated Use-wear and Biomolecular Approach to the Study of Vessels from the Bau Angius Site (Sardinia, Italy)
Laura Fanti, Carlo Lugli, Martine Regert

217. Chemical Analysis of Human Remains Recovered from Central Himalayan Range of Uttarakhand, India: Inferences for Preservatory Status and Dietary Reconstruction
Yogambar Singh Farswan

218. Migration or not? Diet evidence of stable isotope analysis of human and animal from the Qinglongquan site, China
Yi Guo, Yiliu Fan, Yaowu Hu, Junying Zhu, Changyu Li, Benjiamin Fuller, Michael P. Richards

219. The Holy Wells of Scotland: a geo-hydro-archaeological approach to their study
Alan J Hall, Alexander, Alan Stroud, Efie Photos-Jones

220. How to fit vegetation in a box? Building a palaeobotanical and chemical database for the project “Exsudarch”.
Auradre Henry, Claire Delthon, Arnaud Jouvenoux, Antoine Pasqualini, Maxime Rageot, Martine Regert

221. Anthraquinone Dye Colorants in Red Fibers from the Seip Mound, Ohio
Kathryn Jakes, Ruth Ann Armitage, Calvin Day

222. Paleoind and Society in Medieval Rural Communities from Basque Country (Spain)
Caroline Lebretto, Maite Iris García-Collado, Carmina Sirignano, Paola Ricci, Simona Altieri, Juan Antonio Quirós Castillo

223. Climate driven dietary and agricultural change in the late Eneolithic/early Bronze Age Ukrainian Stepppe recorded in organic residues in ceramic vessels
Simona Melito, Richard J. P. Verner, Elke Kaiser, Yuri Rassamakin, Wolftram Schier

224. Was the Climate Too Harsh for the Late Neolithic Farmers of Finland? Tracing Foraging-Farming through Organic Residues in Pottery
Miro Pääkkönen, Richard Evershed, Henrik Asplund

S. Pozo, L. Garcia, F. Carrerra, T. Rivas

226. Characterizing organic micro-residues by non- or micro-destructive method: new trends in mass spectrometry (DART TOF) combined with organic and inorganic analysis
M. Raged, K. Fernández, J.J. Filippi, L. Bellot-Gurlet, A.S. Le Hé, K. Pêche-Quichlin, M. Regert

227. The POMEDOR Project: People, Pottery and Food in the Medieval Eastern Mediterranean
S.Y. Wassman, A. Pecci, R.S. Gabrieli, E.J. Stern, J. Vroom and the POMEDOR collaboration

228. The Study of Hyena Coprolites from a Paleolithic Site of Central China
Wenjuan Wang, Guoding Song, Zhanqiang Li, YanWu

229. A Stable Isotopic Analysis of Dietary Patterns in Individuals Interred in the Late Neolithic/Copper Age Burials of Anta de Rego da Murta I and II (Alvaiázere, Portugal): Preliminary Results
Anna J. Waterman, Robert H. Tykot, Alexandra Figuerido

230. Identity, Mobility, and Childhood Origins of African Abductees at the End of the Transatlantic Slave Trade: a Strontium Isotopic Perspective
J. Watson, R.A. Bentley, K.A. Robson Brown, G.M. Nowell, A. Pearson, A.W.G. Pike

231. Geophysical studies of ancient tumulus in Azapa Valley, Arica, Chile
Miomir Korać, Snežana Golubović, Željko Jovanović

232. Contribution of new geophysical measurement of previously excavated Neolithic roundel area near Bylany.
Miomir Korać, Nemanja Mrđić

233. Roman Legionary fort Viminacium – Multidisciplinary Research
Miomir Korać, Snežana Golubović, Željko Jovanović

234. Geophysical studies of ancient tumulus in Azapa Valley, Arica, Chile
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235. Preliminary conservation issues study of unearthed marble ruins in the Plutonium of Hierapolis (Denizli, Turkey)
Anna J. Waterman, Robert H. Tykot, Alexandra Figuerido

236. Reconstructing Diet in Neolithic Greece using Stable Isotopes from Lipid Residues in Pottery
Helen Whelton, Mélanie Revillet-Salque, Kostas Kotsakis, Dushka Urem-Kotsou, Richard P. Evershed!

237. The relationship between archaeological site distribution and shoreline changes of Taiwan
Hsiao-chin Yang, Wen-shan Chen

238. MRI and NMR-MAUS study of reindeer skin tanning processes
Zhipeng Zhu, Andy Iltött, Torunn Klokneres, Cindie Kehlet, Eleonora Delfederico, Alexej Jerschow

REMOTE SENSING AND GEOPHYSICAL PROSPECTION AND FIELD ARCHAEOLOGY

239. Subsurface Survey and Spatial Analysis on Chalcolithic Settlements From Eastern Romania
Andrei Asadulescu, Ionuț Cristi Nicu, Radu Balaur, Stefan Caliniuc, Vasilie Cotugna, Cristian-Constantin Stoieru, Ona Mihaela Stoieru

240. Geophysical Audies of ancient tumulus in Azapa Valley, Arica, Chile
Luís Barba, Ivan Muñoz, Agustín Ortiz, Jorge Blancas

241. Geophysical studies for the location of a mammoth remains in Mexico City
Luís Barba, Ivan Muñoz, Agustín Ortiz, Jorge Blancas

242. Preliminary conservation issues study of unearthed marble ruins in the Plutonium of Hierapolis (Denizli, Turkey)
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Xiaogang Yang, Houzi Zou, Xiaoyong Huang, Yongwei Wang, Pujun Jin
The new XANES full-field imaging end-station will be introduced and its capabilities for cultural heritage field will be illustrated through experiments carried out on historical paintings. Painting model samples based on two layers of different Mn-based pigments were first prepared and analyzed in order to assess the potential of the method [2]. Both pigments were easily identified and localized, even when present as a mixture. Subsequent applications were then carried out with a particular focus on painting alterations. As an example, the cadmium yellow pigment degradation in Matisse’s painting Le Bonheur de Vivre, 1905-6, was characterized. Moreover, radiation damage issues are significantly reduced as exemplified with the study of a highly photosensitive pigment: Prussian Blue. This opens new possibilities for investigating its degradation as well as other radiation sensitive pigments. The set-up is largely applicable to a broad range of artistic materials, and successful analyses were already performed on fragments of glasses and ceramics [3], which will be presented as well.

References

2. Trace Element and Fluid Analyses for Identification of Marbles - Systematic Provenance Analysis of the Imperial Portraits

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The consequent investigation of 134 imperial portraits from Julius Caesar to Honorius demonstrates the rising success of Göktepe marble as the outstanding portrait marble starting approximately in Trajanic times. Through all the historical periods Göktepe accounts for 48% of the portraits investigated, second comes lycynites (21%), followed by Carrara with 10%.

3. Mural Paintings in Ancient Peru: The Case of Tambo Colorado, Pisco Valley

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Tambo Colorado is one of the most impressive archaeological sites in the southern Peruvian coast, because of its stunning architecture, its extraordinary pictorial decoration, and its strategic location in the section of the Great Inca Road. All these features are closely linked to the role this site played in the process of the Inca conquest on the coast, despite the importance that this involves, the site is not protected and at present is exposed to environmental factors and earthquakes that affect seriously its conservation. The Research Project Tambo Colorado consider necessary to conduct a comprehensive analysis encompassing the nature of the materials (archaeometric analysis) as well as a proper understanding of their conservation status of its architecture. In this regard interdisciplinary research provides the necessary tools to achieve these goals. For this reason our team is integrated by archaeometrics, engineer, conservators and archaeologists.

Due to of this interdisciplinary approach, one of the main project objectives is the study of painting technology developed by the artisans of the site. Indeed, there are very few data on this subject [1] [2]. We will characterize the materials used on the making of red, yellow, white and black mural painting, to determine the chemical nature of the processed pigments, their origin and how they were...
prepared. Also be will verify the use of these materials over time (pictorial moments), which can approach us to the understanding and development of this unique artistic expression in Peru.

4. Identification and Characterization of Painted Wall Plasters and Mortars at Villa Silin, Libya, Using a Range of Analytical Methods: “Part 2”

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Following the research that has been carried out on the characterization of Roman Plasters and Mortars at the Villa Silin, Libya and presented at ISA 2010 more research has been done on new samples of painted wall plasters and mortars collected from the site of the Villa in 2010. The new study aimed clarifying the similarities and/or the differences of the structure, composition and materials used for making the plasters and mortars particularly in the period the Villa was in use 2nd-5th century AD. As it is known the Villa consisted of three parts which had different functions so it possible that different technologies were applied in making the plasters and mortars according to their functions and also the time of application. Several methods were used as follows:

- DP: Optical microscopy for the initial examination of polished cross-sections to identify the structure and microanatomy of the plasters and mosaic mortars as well as the painted layers.
- MCT: Micro-chemical tests for identifying the type of the plasters and mortars, the presence of calcium aluminium silicates and water-soluble salts and the presence of sulphates, chlorides, carbonates, nitrates and nitrites.
- SEM: Standard methods for chemical analysis to identify the quantitative and qualitative composition of the plasters and mosaics mortar and their mixture.
- XRD: X-ray powder diffraction to identify the mineralogical composition of the plasters and mosaic mortars.
- SEM and EDS: Analytical Scanning electron microscope with energy dispersive X-ray analysis system to examine the micromorphology and determine the chemical composition of the plasters, mosaic mortars and their inclusions.
- PLM: Polarized light microscope to identify the internal structure.

The results have showed that the mixtures of plasters and mortars were varied. The identification of mineralogical compounds in the plasters and mortars clarify the differences in the mixture which were applied and related to the function and the decoration style. For example, both rooms had a different mixture compared to each other.

5. Characterization of plasters from different buildings of the Sacred Precinct of Tenochtitlan (Mexico City)

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In this work 40 lime plaster samples taken from different buildings of the Sacred Precinct of Tenochtitlan, the ancient capital of the Aztec empire (now Mexico City) were analyzed.

The plasters come from different buildings of this precinct, in particular from the Templo Mayor, the main pyramid of the precinct, and from Building A, B and D, small shrines located to the north of the Templo Mayor pyramid. For each building, the different constructive phases were sampled.

This work offers a petrographic and chemical characterization of the plasters and mortars and aims to provide information on the raw materials, their provenance, and the production technology used in the ancient capital of the Aztec empire.

The characterization of the samples was carried out through optical microscopy (OM), Scanning Electron Microscopy with Energy Dispersive X-ray Spectroscopy (SEM-EDS) and Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS).

Among the samples coming from the different buildings of the Sacred Precinct, similarities and differences in the building techniques and the raw materials employed were highlighted. The data collected show analogies among buildings and constructive phases identified in the Sacred Precinct and they provide evidence of the plastering and replacement practice in the same constructive phases were also identified.

The study of the samples also allowed to obtain information on the provenance of the raw materials and in particular the limestone used to produce the lime of the plasters. To obtain this information, LA-ICP-MS analyses were carried out on the lime and the binder of the samples. The results were compared with those of the limestone outcrops located in central Mexico, in particular in the modern states of Hidalgo (near Tula), Puebla and Morelos. This comparison showed that all the limestone used for the making of the plastered backgrounds comes from the Tula region, in contrast with that suggested by documentary sources.

6. An archaeometric study of Mortars taken from Rupestrian Churches in Cappadocia (Turkey)

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The work is part of a project supported by research grants from Italian Ministry of Education, University and Research PRIN 2010 “Rupestrian art and habitat in Cappadocia (Turkey) and in central and southern Italy. Rock, excavated architecture, painting: between knowledge, preservation and enhancement”. In Cappadocia, the project is aimed to understand the evolution of the techniques dating from the 6th until the 13th centuries and to identify continuities and changes in the historic use of materials, which can serve as markers of discrete stages in Cappadocia painting, which until now have been only vaguely defined.

The research concerns the archaeometric study for the identification of materials and techniques used from the 6th until the 13th centuries analyzing more than 40 churches in the Neweh district, especially in the areas near Göreme and Urgep, an important part of Turkey’s heritage due to its historical past. The Cappadocia region has been included in UNESCO World Heritage List since 1985 thanks to the geological landscape and rupestrian churches carved in “fairy chimneys”, earth pyramids produced by erosion of Miocone-Pliocene ignimbrites. These structures have hosted, since Neolithic Age, the populations of the area, especially the first
Christian monastic communities that created many of the rupestrian churches and the precious wall paintings inside. A multi-analytical approach was used on different mortars samples in order to characterize the features of the materials, defining the possible evolution of techniques over time. A second purpose of the work is concerned with the identification of the source area of calcareous raw materials used in the preparation of lime. With these aims, polarized optical microscopy, SEM-EDS, LA-ICP-MS, Raman and FT-IR spectroscopy were applied. Data obtained in terms of major and trace elements were compared with compositions of limestone samples collected from outcrops in the Sivas area.

A particular interest of our work concerned the identification of materials and techniques used for the painting from the 6th to 9th centuries, that displays the common characteristic of a thin, white plaster layer, characterized by the presence of a high gypsum content, applied directly to the rock support in one or two layer, usually by brush. A similar plaster is used in the painting of the New Tokali church (10th century) in the Open Air Museum of Göreme, the most famous rupestrian sites, and in the four layers of the patimpsest painting of the Forty Martyrs church (from 6th to 13th centuries) in Sahnıfevleri.

7. Validating Roman Descriptions of Harbor Concretes through Fine-Scale Archaeometric Studies

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Roman seawater harbor installations in the Bay of Pozzuoli near Naples were “made possible by the natural qualities of the local sand (ammos), which is well suited to lime and takes a firm set and solidity” (Strabo, Geography 5.4.6). Studies of the cementitious fabrics of these concretes provide new insights into the accuracy of ancient texts that describe the production of highly resilient and environmentally sustainable concretes two millennia after the construction of the Roman harbor structures.

8. GC/MS, Proteomics and Imaging techniques to reconstruct materials and techniques of the Western and Eastern Buddhas of the Bamyan valley (Afghanistan)

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This work describes the results obtained from the characterization of paint samples from the Western and Eastern Buddhas of Bamiyan (Afghanistan). These were 6th century monumental statues of two standing Buddhas carved into the side of a cliff in the Bamiyan valley in the Hazarajat region of central Afghanistan. Their core was central from fine ash, race external layers were modelled in clay and there are quite precise notes and drawings since the 1830's, describing size and style and even the modelling technique, but only in 1933 traces of paint were mentioned for the first time. The statues were destroyed in 2001, but clay fragments with paint layers are still available for investigation.

Polariised light microscopy (PLM), X-Ray Fluorescence (XRF), Scanning Electron Microscopy coupled with Energy Dispersive X-ray Spectroscopy (SEM-EDS and X-Ray Diffraction (XRD)) were used for the morphological analysis and inorganic content determination.

A Gas Chromatography-Mass Spectroscopy (GC/MS) analytical procedure was used for the characterization of the organic materials in the same paint microparticles. Results highlighted that saccharide and proteinaceous materials have been used as binders on the clay sculptures, but a discussion on the biological source of these binders is not.

A database of paint materials compatible with manuscripts and techniques of the Eastern Buddhas has been established to support the analytical evaluation of the data obtained. Proteomics was applied in order to unequivocally establish the source of the proteinaceous material identified by GC/MS, confirming and pushing forward the information obtained.

Synchrotron radiation techniques, both µFTIR and µXRF, were used to produce the elemental maps and high contrast chemical images of the paint layers to determine the spatial distribution of the materials identified. Results obtained from this multi analytical and multi disciplinary investigation enabled us to identify and locate in the sample build-up the painting materials used by the Asian painters. The combined interpretation of the results obtained shed light on the painting technique of the Giant Buddhas of Bamyan.

9. Angkorian Stone Materials from 9th century Harharalaya Workshop and the Temples of Bakong and Preah Kô

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In the 1990s two large unfinished stone triads that included Siva and two consorts (Umagagapatisvara) were relocated from a site near the 9th century Bakong temple to the Conservation d’Angkor storage facility in Siem Reap, Cambodia. When the sculptures were removed to protect them from looting, large amounts of sandstone debitage were also identified and earmarked the site as a potential sculpture workshop. With support of the Australian Research Council (ARC) between 2011 and 2013 a multidisciplinary program led by The University of Sydney conducted research at the Harharalaya workshop site, which included stratigraphic excavations to establish the size, layout, chronology and production output of the workshop. A progress report on the characterization of stone materials of the Harharalaya workshop was recently completed [1], and here we report on further research into the role of the Harharalaya workshop in the creation of the sculpture and architectural materials of the nearby Bakong and Preah Kô temples.

Many Angkorian freestanding sculptures and buildings were made of sandstone. Petrographic analyses are crucial for addressing fundamental questions related to selection and use of these materials. Standard petrographic methods using point counting were performed on thin sections. Key petrographic parameters such as grain size distribution and textural characteristics were recorded. The Harharalaya workshop sculpture workshop stone debitage samples were found to be compositionally similar to the feldspathic arenites of the Terrain Rouge formation, as compared to samples from the Hariharalaya Workshop stone debitage samples found in the same area. Petrographic analysis established that the Hariharalaya workshop stone debitage samples were found to be compositionally similar to the feldspathic arenites of the Terrain Rouge formation, as compared to samples previously studied from the Kulen quarry district [2]. This finding suggests that the geological source of the debitage is the Terrain Rouge formation. Stone architecture and architectural sculpture samples from the Bakong and Preah Kô temples show they were also composed of feldspathic arenite consistent with the Terrain Rouge formation. The majority of freestanding sculptures, however, are...
consistent with another sandstone formation currently known as the “Trissiac formation”. This formation has been recently been established as the major source for sculptural stone during the Bayon period, 12th to 13th centuries [3], but has not been previously documented in sculpture as early as the 9th century. A third group of sculptures are similar to a reference group of 9th - 10th sculptures; all from a currently unknown formation which may be related to the Triassic formation.

Possible reasons for the choice and use of sandstone from the Triassic formation for freestanding sculpture during the 9th century at Bakong and Preah Kōd need to be considered carefully. It seems unlikely that the freestanding sculptures found at the Bakong and Preah Kōd temples were created in the Preah Kōd style much later, during a 12th - 13th century “restoration”. Instead, the results of this study suggest the earliest use of this specific sandstone material to date, and that the stone was specifically chosen for freestanding sculpture rather than architecture.

Final interpretation awaits further historical analyses, and archaeological evidence on potential quarry locations, movement routes, and the traditions of stone usage.

References

10. Technical Examination of the Red Queen's Burial Offering of the Maya site of Palenque, Mexico

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In 1994, inside the Temple XIII of the Maya site of Palenque, Chiapas, it has been discovered the funerary precinct of an elite female personage, most probably the queen of the ruler K’inch Jánaab Pakal, called Tz’ak’ub’ Ajaw. In a simple sarcophagus, the human remains and the funerary offering were covered by cinnabar, for this reason the personage was called the Red Queen. The offering included a green stone mask, a headress, a diadem, pendants, necklaces composed by numerous beads, and ear ornaments. A secondary smaller mask was set beside the body. In contrast to many of the funerary burial masks of the Maya region, the main mask was composed by tesserae of malachite. This fact made a difference since there are few cases of the use of malachite, instead of jade or other green stones, for this kind of objects. Malachite was mainly used as a pigment, or raw material for obtaining metallic copper but its use for other purposes is rare in Mesoamerica.

In this work, it is presented a non-invasive technical examination of the funerary offering of the Red Queen. The study of the main mask was difficult due to small white remains at the surface of the tesserae. The experimental approach included an in situ analysis by color measurements, mineral identification by Infrared (FTIR) and Raman spectroscopies and X-ray Fluorescence for elemental analysis. A second non-destructive stage on the main mask only was carried out in our Pelletron Laboratory using Particle Induced X-ray Emission (PIXE) and Rutherford Backscattering Spectroscopy (RBS) for further elemental analysis. Samples of malachite from known sources of Chiapas region were also analyzed for provenance studies.

The main results indicate that most of the tesserae of the main mask are composed of malachite while the white remains correspond to calcite. Surprisingly, the white sciera of the eyes is white jadeite and the pupils fit jet-black amber mineral signature. In contrast, most of the Maya masks, the sciera is made from shells while the pupils are made of obsidian or specular hematite. The ear ornaments and most of the beads of the diadem are made of jadeite while the studied necklace beads are green quartz and chalcedony. The secondary mask was mainly manufactured using chalcedony also. These results indicate a special selection and the use of unique raw materials for the royal burial of the Red Queen, different from other ruler of the site, including her king K’inch Jánaab Pakal.

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11. Technological Development in Vinča Culture Pottery at the Dawn of the Metal Age

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The Serbian Neolithic/Chalcolithic site of Pločnik (c. 5200-4650 BC) has recently yielded some of the earliest known copper artefacts in Eurasia, significantly increasing our understanding of the rise of metallurgy in this part of the world. The rich material culture of Pločnik holds significant potential for the study of Vinča craft technology and innovation during the transition into the metal age. The site is also well known for Black Burnished Ware, a distinctive Vinča culture pottery. This study focuses on the development of pottery production technology leading up to and following the emergence of copper metallurgy at this important site. Our primary aim is to identify possible technological changes concomitant with the introduction of metalworking to Vinča culture society.

The study covers the full spectrum of Vinča pottery at Pločnik via thin section petrography, XRF, XRPD and SEM for characterisation and for identifying the raw materials and processes employed by early Chalcolithic ceramic production. Particular emphasis is on the pyrotechnology behind Black Burnished Graphite Painted Ware, which may have been a precursor to metal smelting pyrotechnology. Our initial XRF results allow for the revision of previous analysis on the firing temperatures of this particular ware and shed new light on their relation to pyrometallurgy. Moreover, thin section analyses indicate the presence of distinctive fabric groups, which reflect the use of different clay sources and technological procedures across the different building phases of the Vinča culture at Pločnik. We discuss also the possibility for pottery importation/exchange, on a regional and interregional scale, based on a systematic geological prospection of clay sources available.

Our research makes a significant contribution to the study of late Neolithic and early Chalcolithic communities in the Balkans at a time of major technological change. It also shows a plethora of choices applied in producing some of the most exceptional examples of the 5th millennium BC pottery in this part of Eurasia, demonstrating the remarkable craftsmanship as well as market demands at the time.

12. Tracing Grog, Pots and Neolithic Baltoscandian Corded Ware Culture Contacts (SEM-EDS, PIXE)

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Neolithic Corded Ware Culture Complex (i.e. Battle Axe culture) spread across the Baltic Sea region ca. 2900/2800-2300/2000 BCE, reaching its most northern sphere in southern Finland and Sweden, and Estonia. The Corded Ware material cultures in these three regions are distinctive yet interlinked, indicating possible arrival routes of the migration-associated culture. In Finland, the socio-economically revolutionary arrival of the Corded Ware Culture has been linked, e.g., to early cattle-breeding, and intensification of agriculture is denoted also in Estonia. A stylistic-technological transition is especially evident in the pottery craft, with grog-tempered pots representing an immediate and profound change in pottery craft traditions. In the Swedish Corded Ware style the type and shape of the beakers differ to a notable extent from the continental Corded Ware. Several special features (e.g. organic admixtures) also characterize the Estonian Corded Ware. Finland, on the other hand, seems to be an intermediate region, with common Corded Ware pottery and the regional version also found in Sweden.

Material culture strongly suggests an inter-regional knowledge transfer visible in ceramic traditions. The question remains, however, to what extent and direction actual material exchange, traceable by elemental analysis, occurred. Altogether 160 ceramic vessels from 24 archaeological sites in Finland, Sweden and Estonia were
analyzed by scanning electron microscopy with energy dispersive spectrometry (SEM-EDS) and particle induced X-ray emission (PIXE) to examine their provenance and technological adaptation. Elemental compositions of clay pastes in both ceramic bodies and the grog-tempers were determined by SEM-EDS. In addition, mineralogical and technological information was acquired. Trace elemental data provided by PIXE was employed for group discrimination.

The results reveal intensive cross-regional contacts and pottery exchange across the Baltic Sea during the Final Neolithic period, attested by pots identified as imports but notably primarily by the grog - the remaining essence of the majority of the exchanged pots - used to temper locally manufactured vessels. This illustrates archaeologically practically "invisible exchange," brought visible only by the elemental analysis of the grog temper. The results also highlight technological specialization between different manufacturing centers and diversity in potting traditions of the northern regions of the Corded Ware Culture Complex.

13. Compositional variability of archaeological ceramics in the Eastern Mediterranean and implications for the design of chemical provenance studies

Anno Hein and Vassilis Kilikoglou

Provenance studies of archaeological ceramics on the basis of the elemental composition, is a well established approach in archaeological science since the end of the 1950’s. The basic idea is that ceramics from a specific production place present a chemical composition distinct from ceramics produced at other places, due to the use of different raw materials and/or to different ways of clay paste modification. This composition may correspond to a local chemical pattern or a so-called "chemical fingerprint" of a production site or even a single "workshop". In an unbiased approach an arbitrary number of patterns may be related to a particular site and assignment of provenance depends on the straightforward comparison of the resulting patterns. In practice, however, a series of constraints has to be considered.

First, the natural inhomogeneity of raw material sources has to be considered. The "provenance postulate" assumes that 'chemical differences within a single source of material must be less than the chemical differences among different sources'. But case studies of clay deposits have shown, that particularly deposits from the same geological context sometimes present very similar chemical compositions, even though they can be considered as different in terms of geographical distance. Anyway, the natural range of element concentrations indeed is restricted in terms of correlations and in terms of absolute values. On the other hand case studies are reporting showing that specific accessory minerals, not homogenously distributed in the clay, can affect the element composition within a single clay source.

Secondly, the "human factor" has to be considered. The first step in the pottery production is the clay selection by the craftsman. It can be assumed that craftsmen within the same cultural context try to select raw materials with similar physical properties, potentially belonging to similar geological contexts, even if they are producing at different places. Modification of the clay paste affected the chemical composition and its variability as well, for example by mixing different raw materials. Finally, the chemical composition of a ceramic object has been potentially altered by environmental factors between end of its use and its discovery. The third category of constraints are the analytical parameters, the subgroups of elements, the concentrations of which are determined, the analytical precision and in the case that the results are compared with reference data the analytical accuracy. This has become a very important issue, since an increasing number of lab-based and portable techniques, with very different efficiencies and precisions are routinely applied on ceramic studies.

In the present paper the above described constraints will be examined using the example of the Eastern Mediterranean Region. For this reason the ceraDAT database will be evaluated, comprising more than 7000 records of archaeological ceramics from the region, from the Neolithic Period until the Byzantine Period, and more than 200 records of raw materials.

14. Provenance of Late Punic and Roman-Byzantine ceramic materials at Carthage (Tunisia). A view from the mercantile harbor and Tophet.

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The region of North Africa and specifically ancient Africa Proconsularis (parts of modern day Tunisia, Algeria and Libya) has been a major player in Mediterranean trade systems during the Punic and Roman periods. One of the key sites in North Africa is the ancient city of Carthage. From its establishment in roughly 800 BC, Carthage developed into a hub for Mediterranean trade by the end of the 6th century BC. It immediately became the center of commerce for a large network of colonies in the Western Mediterranean. During the late 4th or 3rd century BC, two interconnected man-made harbors (mercantile and military) were constructed south of the Punic city to comply with both commercial and environmental needs. Problematic in this respect is the seemingly homogenous nature of the ceramic materials which are currently only in rare cases being traced back to their exact place of origin. An multidisciplinary type-chronological, mineralogical (optical mineralogy) and chemical approach (SEM-EDS, ICP-OES) is conducted to gain exact knowledge on the composition of clay raw materials and ceramics of Late Punic and Roman Carthage, its hinterland and the wider North African region.

Trace element geochemistry is considered to be crucial in facilitating the determination of provenance of ceramics and thus design a model for production and distribution. Ultimately, this paper proposes new archaeometric signatures for sourcing North African ceramic materials.

15. Looking for the Main Production Site of Middle Byzantine Pottery

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The 12th and 13th centuries AD saw the diffusion in the whole Mediterranean area of a single, long-lasting production of Byzantine ceramics. Chemical analyses showed that this main “middle-Byzantine production” included several types of wares, which co-exist or follow one another and are commonly used as dating tools in archaeological contexts. Its economic importance is made clear by its large diffusion, which includes most major sites, especially harbours, from southern France to the Levant, from the Crimea to Cyprus. But the most striking point is its presence in shipwrecks. In the Aegean, Eastern Mediterranean and Black sea, we only know of a handful of shipwrecks dated back to this period which carried significant quantities of table wares. The cargoes of all except one consist of wares belonging typologically to the main “middle-Byzantine production”. Its origin was investigated by WD-XRF at the “Laboratoire de Céramologie” in Lyon, whose large chemical database on Eastern Mediterranean medieval pottery includes material from many workshops. Hypotheses were built upon a variety of sources, taking into account evidence from archaeological excavations and surveys, historical sources, petrographic and geochemical features. Three regions of potential origin were considered: Cyprus, especially Lapithos and the region of Famagusta; Central Greece, with the sites of Thebes and Chalkida; Western Anatolia, with the site of Anaia / Radikalesi. For all these sites, reference samples of local production (kiln furniture, unfinished or overfired wares) were available and could be used to define the corresponding chemical reference groups.

The results obtained are interpreted in the framework of maritime trade networks at the medieval period, with further perspectives on the evolution of dining habits in the Aegean and Eastern Mediterranean between the Byzantine and the Frankish rules.

1. for these aspects, see the poster presented on the POMEDOR project (poster P22B)
16. Technical Analysis of Safavid Ceramics

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The technology and materials employed for ceramics from the Islamic world have been well studied over the previous decades. However, whilst petrographic analysis has been undertaken for many Safavid ceramics (those originating from Iran between 1501 and 1722), elemental analysis of these has been limited to study of the cobalt-blue decoration to fingerprint and source the cobalt used. During an analytical survey of Islamic ceramics at the Harvard Art Museums, significant levels of barium were identified in two key Islamic pieces dated to the early 17th century. This raised concerns over their attribution as barium was not included in the rare published analyses of Safavid ceramics but had previously been reported for some 19th century Turkish ceramics. Whilst a Turk origin was ruled out on art historical grounds, the possibility that they were later 19th or even 20th century imitations had to be considered. This initiated a major analytical study of Safavid ceramics to produce a database of analytical results with which to compare our data.

17. Revisiting the Beginnings of Tin-opacified Islamic Glazes

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The generally accepted theory is that Islamic glazed pottery, involving cobalt blue and lustre decoration on a white tin-opacified glaze, first blossomed in Abbasid Iraq in the 9th century AD in response to the import of Chinese stonewares and porcelains. However, Oliver Watson has recently proposed that Islamic glazed pottery, frequently with opaque yellow and green decoration, first appeared in Egypt and Syria in the 8th century AD. The extent to which such stannate and tin oxide particles are preformed in the lead-tin-silica glazing mixtures, and the extent to which they crystallise from the glaze will also be considered.

18. Non-Destructive Analysis of Olmec Green Stone Figurines and Axes from La Venta’s Offering 4

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Considered as one of the earliest civilizations in Mesoamerica, the Olmec inhabited the lowlands at the Gulf of Mexico as early as 1600 BC until 400 BC and are considered to have laid the foundations for the civilizations that followed. Their homeland stretched over the present states of Veracruz and Tabasco, centered around the Coatzacoalcos river. The fertile soil present in these coastal plains, together with the transportation network provided by the many rivers, brought the Olmec civilization to its high and many cities were constructed from which the most important regional centers with temple complexes are San Lorenzo de Teneocihltlán, La Venta, Tres Zapotes, and Laguna de los Cerros.

After the decline of San Lorenzo, around 900 BC, La Venta became the most important city between the Coatzacoalcos and Mezcala river. It served both as a civic city as well as a ceremonial center, for which the great pyramid, one of the earliest known in Mesoamerica, and many offerings, complexes, and altars are still silent witnesses of its splendor. Among the many offerings found at La Venta, a group of 16 figurines and 6 axes, set in a ceremonial arrangement, was brought to the surface. These pieces appeared to be ritually buried however the purpose of this still remains subject of speculation. In this work, we present an extensive investigation of this collection of Olmec objects, excavated at the archaeological site of La Venta. These pieces were studied by the wide variety of non-destructive techniques available within our ANDREAH project, such as XRF measurements, Raman, and FT-IR spectroscopy, and were used in-situ at the Museo Nacional de Antropología in Mexico City. Via these complementary techniques we were able to identify the minerals. Serpentines from different deposits, jadeite as well as one zoisite could be differentiated. Traces from cinnabar and hematite were found on the artifacts, corresponding with their ceremonial burial purpose. This research has been supported by grants from CONACyT 131944 MOVIL, PAPIIT IN402813 ARAMEH II and ICyTDF PICC010-57.

19. Provenance Analysis of 1500 Obsidian Artifacts from 40+ Sites in Sicily (Italy)

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Nearly 1500 obsidian artifacts from 41 sites in Sicily (Italy) dating from the Early Neolithic to the Bronze Age were analyzed non-destructively using a Bruker III-5 portable X-ray fluorescence spectrometer to determine their specific geological source and reconstruct transport/trade routes. This systematic, large-scale analytical program, which also included recording of the obsidian artifacts’ typology and technological features, was conducted in 2012 and 2013 with the permission of several museums and superintendencies. This pXRF instrument has been shown to distinguish all island sources in the Mediterranean, and the substrates on each, including Gabello and Canne Dentro on Lipari, and Balata dei Turchi and Lago di Venere...
on Pantelleria. The few previous analytical studies of obsidian in Sicily, including Grotta dell’Uzzo, the Milena territory, and Ustica, complement our research. These non-destructive analyses were conducted in Siracusa, Gela, Licata, Agrigento, Milena, Partanna, Marzala, Tindari, and on Lipari. The pXRF settings were 40 kV, 11 μA, and 120 seconds, with a filter specifically used to emphasize trace elements Rb, Sr, Y, Zr, and Nb. For most of the archaeological site assemblages, all of the recovered obsidian artifacts were examined and tested, while for a few with very large assemblages, a representative number of artifacts were selected. All artifacts tested came either from Lipari or Pantelleria, confirming visually-based predictions but also demonstrating for the first time that multiple subsources were used for each.

The large number of sites and artifacts tested allow us to assess variation based on location, time period, production methods, typology, and usage. Our interpretations consider that Pantelleria is 100 km to the southwest of Sicily, with no islands in between, while Lipari is only 30 km from the northeast coast of Sicily, with Vulcano along the way. We also consider the visual, physical and mechanical characteristics of obsidian artifacts: Lipari obsidian can be highly transparent and glassy, or opaque with phenocrysts, which affects sharpness, brittleness, and potentially their preferred usage, while Pantelleria obsidian is opaque and much less brittle. Both islands were important sources of obsidian despite their differences in location and quality of material. The high proportion of Pantelleria obsidian at one inland site suggests specific selection of this material. Finally, we integrate our obsidian data with other studies in southern Italy and Malta, to understand the socioeconomic nature of trade and contact in the Neolithic and Bronze Ages in the central Mediterranean.

20. Magnetic and Geochemical Characterization of Georeferenced Obsidian Samples from Four Source Areas in New Mexico

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To trace the pathways whereby obsidian was dispersed from its geologic source to archaeological sites where it was used, archaeological obsidian artifacts must be correlated to their geological sources. The most common approach has been to look at the trace element geochemistry of obsidians. Several studies have considered whether magnetic properties can be used to distinguish among different geologic sources of obsidian within a region or flow. This work is the result of a Keck Geology Consortium Project during the summer of 2013. We sampled four obsidian source areas in New Mexico: Mule Creek, Mt. Taylor, Obsidian Ridge, and Cerro del Medio. In each area, we collected samples from multiple localities. One of these localities in the Mule Creek area, here called west Antelope Creek, had been previously unknown. Approximately 3,000 unoriented samples were collected from all localities, the majority of which were georeferenced. Some were in situ from perlitic matrices; others were marekanites. These samples will give us the opportunity to explore intra-flow variability of properties, especially magnetic (Frahm and Feinberg, 2013). Some field measurements of magnetic susceptibility were made, but samples were brought back for laboratory analysis of geochemical, paleomagnetic, and rock magnetic properties. We are also attempting to prove the archaeological artifacts from each of the source areas. Most work will be completed in Spring, 2013, but results to date suggest that simple magnetic properties are able to discriminate among some but not all geologic sources shown here for the Southwest, even on a simple cross-plot of natural remanence against susceptibility. The newly found western Antelope Creek area and previously known Antelope Creek are magnetically distinct in a cross-plot of median destructive field against natural remanence; there is some suggestion of different chemical signatures. For all samples, there is commonly a characteristic (relative) direction of magnetization, with the overprint of a secondary component. Rock magnetic results suggest mostly pseudo-single domain titanomagnetite as the carrier of remanence, although there are some higher coercivity components.

21. First use of portable system coupling X-ray diffraction and X-ray fluorescence for in-situ analysis of prehistoric rock art - Rouffignac cave (France)

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Study of prehistoric art is playing a major role in our knowledge of the human evolution. In the past decades, the characterization of coloured materials was undertaken by taking small samples. This procedure had two main disadvantages: slight but existing damage of the paintings and limitation of the number of samples. Thanks to the advanced development of portable systems, in-situ analysis of pigment in cave can be now undertaken. A portable device combining X-ray diffraction and X-ray fluorescence has been used for the first time to analyse paintings and drawings performed more than 15 000 years ago in the prehistoric cave of Rouffignac (Dordogne, France). Crystalline structures as well as elemental concentrations of the pigments were determined. All the pigments analysed in the figures (mammals, ibex, rhino) are composed of manganese oxides. Two crystalline forms identified by XRD are present: pyrolusite (MnO2) and romanechite (BaZnMn5O10).

Concentrations in manganese, barium, iron, potassium and silicon were extracted from the XRF measurements. High values of barium are in agreement with the detection of romanechite. Three main groups of composition are observed: the frieze of the 10 mammoths of the Henri Breuil Gallery forms a first homogeneous group; the mammoths and ibex of the Great Ceiling as well as the rhinoceroses of the Henri Breuil Gallery have very close compositions forming together a second group characterized by the presence of pyrolusite and low amount of barium; the ibex of the Great Ceiling shows high concentration of barium and is composed of romanechite. As a result, we can observe a clear correlation between chemical composition and figures: the frieze of the 10 mammoths is homogenous in stylistic representation as well as in pigment composition, the rhinoceroses of the Breuil gallery have a chemical composition very similar to the animals of the Great Ceiling except the ibex which differs in term of style and composition.

22. Purple in Sumhuram, Oman (1st-2nd Century AD), Revealed by Mass Spectrometric and Chromatographic Techniques

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Pigments have always been materials of great interest to understand ancient raw materials and technologies, and trade routes. Thanks to the archaeological works carried out by the Italian Mission since 1997 (directed by Prof. A.
Avazini - University of Pisa in the area of Khor Rori (Oman), in particular, in the excavations carried out in Sumhuram, a large number of findings were brought to light. Sumhuram is the most important pre-Islamic harbor in the area, and the site is an excellent example for studying the activities of pre-Islamic Arabian cities. Among the huge amount of archaeological materials recovered in Sumhuram, several ceramic fragments (1st-2nd century AD) were of particular interest, all showing residues of a pink-violet substance. In order to reveal the nature of this pink-violet color, the substance was characterized by several analytical techniques: high-performance liquid chromatography (HPLC-DAD and HPLC-MS) and Laser Desorption-Ionization Mass Spectrometry (LDI-MS). Laser-based ionization techniques have revealed their ability as an analytical tool to study organic pigments by mass spectrometric analyses. The results of each methodology were also compared. The different analytical methods highlighted the presence of molecules like 6,6'-dibromoindigo, 6-monobromoindigo, 6,6'-dibromoindindrubin, 6- and 6'-monobromoindindrubin, indigo and indirubin. The results allowed us to assess that shell-fish purple, the so called Royal or Tyrian purple, was the source of the pink-violet substances found in the ceramic fragments brought to light in Sumhuram. This enabled us to draw hypotheses not only on the possible function of such ceramics in connection with the storage/ trade of purple, but also on the possibility that Sumhuram, being the most important pre-Islamic harbour in the area, was a centre for the production and the exchange of purple.

23. Technology and Indigeneity in Mughal Glazed Tile-Work

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In sixteenth and seventeenth century Mughal northern India, a ceramic or tile production centre was functioning at Delhi, manufacturing tiles with local characteristics, distinct from those found elsewhere in the region and in other Islamic lands. Compositional profiles of the Delhi tiles, determined through analyses, characterize this style of tile-work, and bring forth information on the technology involved in their manufacture. Overall, Mughal tiles from Delhi may still however be considered to belong to the family of Islamic stoneware ceramics. is known of the material character and technology of the Delhi tiles. In this study, forty tile samples sourced from a range of sixteenth and seventeenth century Mughal monuments at Delhi are analysed by SEM-EDS and EPMA-WDS, allowing a comprehensive picture to be gained on their characteristics and technology. All the tile bodies are stoneware comprising quartz-rich bodies with interparticulate glass, typical of Islamic ceramics. However, their high-alumina mineral soda glazes are unusual and bear a similarity with typical Indian/South Asian archaeological glass compositions, introducing an indigenous element in their character. Comparably thicker glaze layers and the absence of slips further distinguish these tiles from Persian productions. Variations in the alumina, potash, and magnesia contents over time, within overall largely uniform compositional characteristics, are indicative of the changing nature of raw material employed. Colorants are limited to oxides of copper and cobalt, and lead stannate. Arsenic oxide is detected in dark blue glazes coloured by cobalt, of possible local origin. The high arsenic:cobalt ratio of between 1.5:1 serves as an additional characteristic marker for tiles from this region. The clustered distribution of lead stannate particles in yellow and green glasses suggests the addition of the colorant to fritted glass powder, as in current traditional craft practice, rather than the employment of a pre-coloured fritted glass in the production of the tiles. Evidence from traditional glass and glazed pottery production centres in the vicinity of Delhi, at Jaipur and Jaipur respectively, sheds further light on raw material use and manufacturing processes. Investigations reveal that in Mughal northern India, a ceramic or tile production centre was functioning at Delhi, manufacturing tiles with local characteristics, distinct from those found elsewhere in the region and in other Islamic lands. Compositional profiles of the Delhi tiles, determined through analyses, characterize this style of tile-work, and bring forth information on the technology involved in their manufacture. Overall, Mughal tiles from Delhi may still however be considered to belong to the family of Islamic stoneware ceramics.

24. Plumbate Ceramic Ecology

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Recent archaeological fieldwork in southern Chiapas, Mexico has identified a pyro-industrial zone within the Pacific coastal mangrove forest where Plumbate pottery, a famed Mesoamerican tradeware of the Terminal Classic period (AD 800 - 1000), was produced. Plumbate is renowned not only for its broad distribution but also for its unique technology, which yielded the only true glaze ever produced in Mesoamerica. Some of the technological practices involved in Plumbate production can be gleaned from excavation of firing areas, but “ceramic ecology” has also been useful. Ceramic ecology focuses on the environmental context within which potters practiced their craft as a means to understand technological choices and how those choices may have evolved. In the present case we have implemented this approach by sampling raw materials adjacent to production sites and conducting experiments and analyses on the resulting raw materials. Specific resource choices have been identified via elemental analysis (XRF, LA-ICP-MS, and NAA). Paste and slip preparation have been explored through experimental levigation and addition of various locally available fluxing agents (salt and mangrove wood ash) to clay slips. Firing conditions have been explored by subjecting the prepared and unprepared raw materials to variable firing conditions and comparing the resulting mineralogical changes (identified by FTIR) to mineralogical characteristics of Plumbate pastes and slips. This work has reproduced some of the macroscopic characteristics of Plumbate and some of the specific elemental and mineralogical characteristics of the pastes and slips. This paper presents the results of these experiments and analyses and provides an updated assessment of the technological evolution of the Plumbate industry.

25. Paradise for Petrographers: Tracking Movements of Lapita Pottery (1200-900 cal BCE) between New Caledonia, Isle des Pins, the Loyalty Islands and Vanuatu

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The Lapita pottery style tracks the initial colonization of the western Pacific between ca. 1200 and ca. 600 cal BCE. Almost all provenance studies of Lapita pottery over the last forty years have been made by a single researcher using optical petrography (summarized in Dickinson 2006). The trace element chemistry of Pacific ceramic assemblages is often difficult to interpret because: (a) mineral grains are frequently mixed with coral sand in variable proportions and (b) heavy metals concentration in placers were often used as temper. Both effects confound attempts to develop “source profiles” for particular islands from trace elements, but are easily corrected for in ceramic petrography. Quantitative petrographic characterizations of sands from many Pacific islands, compiled from frequency counting of rock and mineral grains in thin section, are reported by Dickinson (2006). Most Pacific islands are effectively “point sources” for ceramic provenance and are best distinguished from each other by aggregating point-count data into triangular diagrams (Dickinson 2006). This approach is less suitable for larger and more geologically diverse islands like New Guinea, New Britain and New Caledonia. None of these have yet been subjected to systematic collection of potential temper sands. We report here the results of qualitative petrographic examination of 120 selected Lapita sherds from New Caledonia, the Isle des Pins (60 km from New Caledonia), the Loyalty Islands (100-120 km) and Vanuatu (400-600 km). These date between 1200 and 900 cal BCE.

New Caledonia is almost ideal terrain for qualitative ceramic petrography. Its geology is extraordinarily complex, including sedimentary units, metamorphic rocks of blueschist and greenschist facies, metabasalts, overthrust ophiolite sheets, and intrusive igneous units.
Detailed geological maps of the whole island are available. Even though we have not yet made any control collections of temper sands, we can in some cases narrow the region of manufacture of particular pots to within a few square kilometers. In most cases we can determine from which quadrant of the island a given sherds derives. Our preliminary findings show that Lapita pottery was moved up to 300 km along the coasts of New Caledonia, and that most of the samples studied to date from that area and the Loyalty Islands were made on New Caledonia. A few vessels from Ellice Island in Vanuatu contain metamorphic index minerals that can only have originated in New Caledonia.

Reference

26. Technological Change and Provenance of Glass in Early Islamic Palestine
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The focus of this project is on the major technological changes in glass production and technology that occurred after the Islamic conquests, notably the change from natron to plant ash technology in the 9th century. Major, minor and trace element data are presented for 96 glass samples taken from four sites in modern day Israel; Ahudhur, Ramla, Sepphoris and Be’er Sheva. The glass samples, most of which are from well-dated vessels, date from the 6th/7th to 12th centuries. Analysis was performed using LA-ICP-MS, allowing quantification of 57 elements, including major, rare earths and related elements down to sub-ppm concentrations.

Data was examined using graphical methods and compared to literature data. Results showed that Late Byzantine and Umayyad periods (late 6th-mid 8th centuries) were dominated by natron glass of three types; Levantine (22 samples), Egypt I (1 sample) and Egypt II (33 samples) as defined by Gratuzë and Freestone. Comparison of trace elements with other groups of known Egyptian and Palestinian origin confirms the assumed origins. Egypt II was dominant in Umayyad contexts, suggesting that this group was produced later than Levantine products and possibly that Palestinian manufacture of natron glass contracted or even ceased before the change to plant ash. Plant ash glass appeared in the Abbasid 9th century. Of the typical Syro-Palestinian types, with relatively low K2O and MgO, 16 samples are similar to those produced in the 10-11th century tank furnaces from Tyre and a further 10 samples resemble Henderson’s type E from Raqqa, Syria. 7 further samples are similar to colourless glass from Mshaf, Iran analysed by Brill. However, the lack of comparison trace element data for Raqqa and Mshaf means that the match is less robust for these sources. Interestingly, two plant ash samples typologically dating to the late Umayyad (mid 8th) and early 9th century compositionally resemble glass of Sasanian origin and also Henderson’s Raqqa type 4. These particularly early glasses possibly hint at the role of Mesopotamian technology in the production of the earliest plant ash glasses in Palestine. A further 2 natron and 3 plant ash samples could not be matched to known types.

These preliminary findings suggest that glass in early Islamic Palestine was dominated by several major raw material suppliers, very similar to the situation in the Roman and Byzantine periods, even after the transition to a plant ash technology. There is no evidence for a proliferation of small producers who made and shaped their own glass; rather the evidence suggests that the division between a small number of primary and large number of secondary producers continued.

27. Origin and Development of Blue-and-White Porcelain in Ancient China
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A large amount of evidence has shown that blue-and-white porcelain was successfully produced as early as the Tang Dynasty (618-907 AD.) in China. Though only very small quantity of Tang blue-and-white porcelain shards were discovered from the Tang stratum of Gongyi kiln site which covers Baihe kiln site and Huangye kiln site, they are precious especially in validating the producing area and birth time of Tang blue-and-white porcelain on the basis of archaeological stratigraphy.

In this study, the unearthed white porcelain and blue-and-white porcelain shards of Tang dynasty from Gongyi kiln site were selected as research objects. Glaze and body compositions are examined by energy-dispersive X-ray fluorescence. X-ray diffraction is employed to identify the crystalline phases in body. Microstructure and micro-area composition is studied using electron probe microanalyzer and light emission transmission electron microscope. The firing temperature of body is examined by dilatometer. Chromaticity is analyzed by Spectrophotometer. Bending strength of body is tested by universal testing machine. Apparent porosity, water absorption and bulk density of body are measured according to the corresponding national standard. Multivariate statistics method is applied to analyze the experimental data to investigate the regularity of the origin and development of blue-and-white porcelain.

The results show that white porcelain was derived from celadon on the basis of deliberate selection and disposal of raw materials, modification of body glaze recipes and high temperature firing technology for blue decoration on the white-glazed pottery. The well-developed white porcelain production provides body and glaze recipes and high temperature firing technology for the invention of blue-and-white porcelain. Blue and white porcelain breaks new ground for the under-glaze cobalt decoration, laying foundation for the prosperity of blue-and-white porcelains in the later Yuan, Ming and Qing Dynasties.

28. XRF Analysis of Vincennes-Sèvres Porcelain: Characterization, Dating and Attribution
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During the second half of the 18th century, Vincennes-Sèvres soft-paste porcelain dominated the European ceramic market in the market in the mid to late 18th century. Refined, ornate, high-status porcelain for royal households and ruling elites. In the 19th century, the popularity and demand for ‘old’ 18th century Sèvres escalated with the growing wealth of the middle classes, particularly in Britain. This demand inevitably exceeded supply and manifested itself in a flourishing market in copies, reproductions and fakes in the form of later decorated, surdecoré, or embellished pieces of genuine soft-paste Sèvres. For ceramics specialists, identifying surdecoré using connoisseurship techniques can be extremely difficult due to the exceptional quality of the applied decoration. This has led to a major analytical research study which has aimed to non-destructively characterize chemical composition of glazes, ground colours and gilding from genuine and later decorated 18th century Vincennes-Sèvres soft-paste porcelains.

127 soft-paste Vincennes-Sèvres porcelains dating from between c.1745 to the end of the production period in 1800 and 22 imitations or surdecoré pieces in The Wallace Collection, London. Original collections were analysed using handheld X-ray fluorescence. Analysis focused on glazes, ground colours (dark blue, turquoise, rose, green and yellow) and gilding. 39 hard-paste Sèvres porcelains dating from the early 1779 to 1842 were also analysed in order to characterize decoration technologies for each paste-type throughout the period of manufacture as an aid to dating.

Results showed that genuine soft-paste glazes dating from 1745 to the end of the period of manufacture exhibit consistent compositions. Imitations of 18th century soft-paste dark blue grounds could be distinguished by means of the zinc content. Faked turquoise grounds were found to have the same components as genuine grounds but with varying proportions of zinc, arsenic and antimony. Imitation rose grounds were readily distinguishable from genuine grounds by the absence of arsenic. In gilding,
comparative high levels of copper and the presence of bismuth were found to be useful indicators of later decoration. Chromium-based green enamels were also present in many of the later decorated pieces. Analysis of both soft and hard paste porcelains spanning the period of production 1745-1842 were also found to be useful in charting the dates at which different coloring pigments were introduced at Sèvres. Results of the study have subsequently been used to form a database against which objects with insecure provenance or attribution in public and private collections can be assessed.

29. How To Cook your Met(a)l: Reconstructing The World’s Earliest Metallurgy

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The earliest known metallurgy in the world is currently represented by a slag assemblage weighing just under 10g. These small pieces of copper slag, accompanied by slagged ceramic sherds, were discovered in three early to mid 5th millennium BC Vinča culture sites in Serbia and reveal the microstructure of the oldest metal making process worldwide. The provenance analysis also point at the exploitation of multiple local sources for making of the Vinča metal (Radivojević et al., 2010). However, such contribution to this debate is an attempt to reconstruct the earliest Vinča culture smelting process by running twelve controlled experiments in ten differently designed smelting installations. We used copper ores from the ancient mines of Đerol and Rudna Glava, already indicated as potential sources, successfully produced copper slag and copper metal, and carefully documented the debris from the smelting installations. All produced materials are compared and contrasted to the available Vinča culture production evidence, on both micro- and macro-scale. This pioneering attempt for early Balkan metallurgy provides a valuable contribution to the study of early and small-scale metallurgical activities worldwide. It also aids building of explanatory models for the organisation of metal production in the early stages of metallurgy.

Reference

30. Metal and Elites in Upper Mesopotamia - Uniqueness or Uniformity?

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The 3rd millennium in Upper Mesopotamia, located in what is today northern Iraq and eastern Syria, is a time of change and innovation. Especially between 2600 and 2350 BC the rather sudden appearance of the so-called city-states and the growth of complex urban societies suggests the power of a possibly newly established elite. This is underlined by monumental architecture, the formation of institutions and a complex administrative system supported by the tool of writing. However, the uniformity of this possible elite, regarding the contemporary appearance of city states within that region and their control of the urban life and also of the hinterland, appears to be more individual in terms of their metallurgy and metallurgical interests. Also, the proximity of many Upper Mesopotamian sites to neighbouring Anatolia, where copper and tin resources were widely available, suggests that this region may have worked as a transmitting area in development of skills and transport of material across Mesopotamia, giving Upper Mesopotamia a pioneering position within Mesopotamian metallurgy. Major metallurgical aspects comprise different typological production processes, such as the primary production of bronze and the refining of black copper, the deliberate choice of tin or arsenical bronzes, the use of leaded copper and the provenance of circulated metals during the 3rd millennium. This study examines how we can efficiently combine state of the art technologies to understand the metallurgy and the complexity of prehistoric societies. A comparison between EPM/WDX and pXRF analyses of metal artefacts and metallurgical debris from major Upper Mesopotamian sites in combination with LIA studies in comparison to Se/Te ratios frequently found in sulphides and possibly related to specific ore sources, explores the possibilities to time and cost-efficiently examine and identify large metallurgical inventories in regard to composition and provenance in general. In particular, this research makes a significant and original contribution to our factual knowledge about similarities and differences between ruling elites of different city states in Upper Mesopotamia and the role of metallurgy for their economic, political and social standing.

31. Aspects on the introduction of tin in the Aegean during the 2nd millennium BC

Yannis Bassiotos, George Mastrotheodoros and Liana Filippaki

The transition of the Aegean 3rd to 2nd millennium BC has seen radical alterations in the bronze-making practices, marked by the copper-alloy composition change from arsenical-copper to tin-bronze, a technological trend predominated during the followed MBA and LBA periods and thereafter. Tin bronze had been introduced in Anatolia and in the Levant since the beginnings of the EBA, unlike Aegean, where arsenical-copper was produced in metallurgical furnaces, as seen at Chryssomino, or in crucibles, during the entire 3rd millennium, based on indigenous copper and arsenic sources. In a previous paper we (Bassiotos, Tsielos 2012) have argued that the cessation of the flourishing 3rd millennium culture, that in supported local copper-ore sources, was owed to exhaustion of the available secondary cuprous raw materials. This aspect was mainly based on the note that the mentioned copper-production centers appear to be inoperative, with few exceptions, during the 2nd millennium. Analytical studies on Aegean MBA and LBA copper-based artefacts corroborate that aspect, demonstrating that in a rather increased percentage of studied ‘tin-bronze’ objects, the alloy contains arsenic also, at levels around 1% percent. Hence, in shortage of copper, recycling of formerly pure arsenical-copper objects, by adding tin at levels 5-10%, seems to be a reasonable adventure of the 2nd millennium Aegean societies; and this is further supported from contemporaneous excavated contexts with finds such as crucibles, crucible slags, moulds etc, indicating secondary metalworking activities, but in most cases no smelting. So far there are no data indicating that archaeologically exploitable tin-ores occur in the Greek peninsula or in the surrounding islands. However, tiny crystals of pure cassiterite, SnO2, have repeatedly been observed in crucible slags from Skyrkos/ Palamari IV strata (early 2nd millennium) and from other Aegean contexts of the first half of the 2nd millennium. It is, therefore, deduced that tin, either as crude metal or as monometallic cassiterite has entered the Aegean, probably before the import of the Cypriot copper (the latter is believed that entered around the 17th century).

The paper concludes that the exhaustion of the local Aegean copper-ores around the end of the 3rd millennium, inevitably imposed the import of pure copper in ingots, along with the import of tin (metallic or in almost-free-of-importurities cassiterite), the latter required for both ‘replacing’ the ‘missing’ (through evaporation) arsenic in the recycling processes and for solely tin-bronze producing in crucibles, leaving aside, for ever, the furnace smelting and the old-fashioned arsenical copper-alloy.

Reference
The interest of scholars in the ancient metallurgy in the Alpine region is a well-established tradition, but there is a lack of study of the region as a whole. Moreover, the distribution of different kinds of metal has usually been expressed in terms of space and time, without properly considering other factors, such as topographical elements and how metal moved. Recycling, in particular, has been often underestimated, whereas, as Bray and Pollard have demonstrated, there is evidence that it as a major factor in the transport and use material at the beginning of the Metal Age. This process can sometimes be recognised as a loss of traceable volatile elements according to the distance from the ore sources. Within this study we have used a GIS database to: - Understand the relationship between the composition of metal objects from the Copper Age (2200-1200 B.C.) to the Early Bronze Age (2200-1600 B.C.) and space, with a focus on transalpine contacts. - Verify the importance of topography, and in particular of the river system, in the movement of material. - Examine how metal moved, with a specific attention on recycling. Whereas in the Alpine Copper Age there was a situation of localised production, the beginning of the Bronze Age witnessed the appearance of big flows of metal. The distribution of different copper compositions, instead of localised production, the beginning of the Bronze Age

33. ICP-AES Analysis of Bronze age based Copper Artefacts from the West of France. The specific chemical signatures of hoards as a function of the region and the typology.

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Since a few years now, we have witnessed a real revival concerning the interest on chemical analyses of copper-based objects of the Bronze Age of Western Europe. The works in progress do not only focus on the identification of the copper’s origin, but try also to highlight the link between groups of objects, their typology and their localisation. The distinctive particularity of this region’s Bronze Age is the impressive number of objects found in land hoards, some of them gathering thousands of objects. Thus, during the whole Bronze Age, it’s more than an hundred thousand objects that have been deposited, the reasons of such a practice being almost unknown. The chemical analyses of copper-based artefacts that are being processed in the Rennes University follow a strict protocol in order to obtain the best representativity and avoid bias. Firstly, the consistency of each hoard is checked by analyzing a large number of its objects. Then, for each object, several analyses are performed in order to make sure that the metal is homogeneous. Thus, it is possible to see if the chemical signatures are really representative of the hoard and therefore if they can be used to trace the material signature. Several hoards from the north-western part of France have already been analyzed. It’s more than 700 analyses that have been done on hoards spanning from the Early Bronze Age to the First Iron Age. The results reveal that the chemical signature - based on trace elements comparison - for each period is different, indicating therefore probably that the ores were also different. Another result shows that recycling hasn’t been a major phenomenon. In front of the scale of the hoarding practice, new copper must have been regularly imported, this region having only limited copper resources, although it has abundant tin and lead ores. Finally it should be noted that the addition of lead in the alloy has begun at the beginning of the Middle Bronze Age, although it really expanded during the Final Bronze Age, to a major element of the alloy during the Iron Age. This new element modifies the signature by scattering them, and in turn this completely prevents to make the link object/ore via the chemical analyses, but also via the lead isotopes analyzes.

34. Elemental and Lead Isotopic Data of Copper Finds from the Singen Cemetery, Germany - A Methodological Approach to Investigate Early Bronze Age Trade Networks

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In the eastern Alps and the former jugoslavia, some early bronze hoards were found. More recently, we have worked in Germany on a hoard from the Singen Cemetery, Germany, and we have studied the copper objects using a combination of analytical techniques such as ICP-AES and ICP-MS, and also LIA. We report a trace element - Pb isotopic analytical (LIA) database on the “Singen Copper”, a peculiar type of copper found in the North Alpine realm, from its type locality, the Early Bronze Age Singen Cemetery (Germany).

We report a trace element - Pb isotopic analytical (LIA) database on the “Singen Copper”, a peculiar type of copper found in the North Alpine realm, from its type locality, the Early Bronze Age Singen Cemetery (Germany). What distinguishes “Singen Copper” from other early coeval copper types? (i) it is a discrete metal lot with a uniform provenance (if so, can its provenance be constrained?) (ii) was it manufactured by a special, unique metallurgical process that can be discriminated from others? Trace element concentrations can give clues on the ore types that were mined, but they can be modified (more or less intentionally) by metallurgical operations. A more robust indicator are the ratios of chemically similar elements (e.g. Cu/Ni, Bi/Sb, etc.), since they should remain nearly constant during metallurgical operations, and are expected to behave homogeneously in each mineral of a given mining area, but their partition amongst the different mineral species is known to cause strong inter-element fractionations. We tested the trace element ratio pattern proposed by geochemical arguments on the Brisselung mining area. Brisselung itself is not compatible with the Singen Copper objects, and we only report it because it is a rare instance of a mining area for which sufficient trace element analyses are available in the literature. We observe that As/Sb in fahlerz varies by a factor 1.8 above/ below median – As/Sb in enargite varies by a factor of 2.5 with a 10 times higher median. Most of the 102 analyzed metal objects from Singen are Sb-Ni-rich, corresponding to “antimony-nickel copper” of the literature. Other trace element concentrations vary by > 100 times, ratios by factors 50. Pb isotopic compositions are all significantly different from each other. They do not form a single linear array and require > 3 ore batches that certainly do not derive from one single mining area. Our data suggest a heterogeneous provenance of “Singen copper”. Archaelogical information limits the scope to Central European sources. LIA would require a diverse supply network from many mining localities, including possibly Bohemia. Trace element ratios show more heterogeneity than LIA; this can be explained either by deliberate selection of one particular ore mineral (from very many sources) or by processing of assorted ore minerals from a smaller number of sources, with the unintentional effect that the quality of the copper would not be constant, as the metallurgical properties of alloys would vary with trace element concentrations.

35. Time and context of change at the close of the Late Bronze Age and in the early Iron Age

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The precision and accuracy with which actors, events and forces can, or cannot, be tied together determines
One of the main aims of the special session entitled “The Context of the Transition from Bronze to Iron in the Ancient Mediterranean” is, according to the organizers “to better understand the social context for the decline of bronze as a strategic metal, the rise of iron use, and the role(s) of iron”. But is this really the case? Did bronze and copper actually cease to be strategic commodities? The great advantage of iron is that its ores are abundant and widely used commodity into the Roman Empire. And recent archaeological evidence from Jordan and now from Cyprus shows an intensification of copper production already in the first half of the first millennium BC.

The aim of this paper is to present what is currently known about the production and trade of copper from the Iron Age in the eastern Mediterranean. Unavoidably there will be a special focus on Cyprus, a well-known source of copper in the LBA, which according to recently accumulated evidence clearly continued to produce and probably export copper in the Iron Age.

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38. An Isotopic Trip through First Millennium BC Glass History
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In recent years, a growing interest has arisen for the period immediately after the Bronze Age/Iron Age transition in the first millennium BC. Glasses deserve special attention due to a significant evolution in the glassmaking process during that time. In the Late Bronze Age, plant ash glasses were produced in Egypt and Mesopotamia. During the ‘Dark Ages’ at the end of the Bronze Age, glass production fades away almost completely from the archaeological record and re-emerges several centuries later using different raw materials and technologies. From this period onwards, i.e. the early Iron Age, natron glass became the dominant type of ancient glass in the whole of the Mediterranean and Europe. However, considerable gaps in our knowledge exist concerning the locations of primary glass manufacture and glass trade/exchange in the Mediterranean during the first millennium BC.

This paper focuses on using isotopic geochemical research on first millennium BC glass artefacts from the Mediterranean, the Black Sea and Western Europe to investigate their primary provenance. The recent use of radiogenic isotopes, in particular those of strontium and neodymium, has created new opportunities in the attempt to unravel such provenancing issues. In essence, the isotopic composition of raw materials depends on their origin and geological age. This causes separate geographic areas to have different isotopic signatures. By comparing the isotopic data from the analysed samples with the signatures of later raw glasses from known production centres and suitable sand sources, it is possible to distinguish glasses produced in the eastern and western Mediterranean. This difference in isotopic values provides new insights into the provenance of first millennium BC glass artefacts. Most samples analysed in this project suggest an eastern Mediterranean origin although the exact location of their production centres(s) is still unknown. Although other production places cannot be fully excluded, indications are pointing to similar sources situated in the Levant as were used for the fabrication of later Roman raw glasses. Consequently, trading raw glasses or finished glass artefacts from the Levant to other places in the Mediterranean and beyond is very plausible. A minority of analysed samples tell a completely different story with the manifestation of more exotic isotopic values, indicating production centres located in the western Mediterranean and Europe, and even east of the Tigris and Euphrates rivers.

KEYNOTE PRESENTATION
39. Small Compositional Groups, Production Events and the Organisation of Production
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Materials analysis in archaeology has seen considerable success in determining the provenance of artefacts, the characterisation of technologies and how they change through time. However, production encompasses a good deal more; for example, how the people who made the artefacts were organised and their relationships to the consumers. Through the analytical identification of small groups of closely related materials, or batches, we can come much closer to understanding how artefacts were produced. However, attempts to do this using archaeometric methods have been undertaken only rarely. Using examples from a range of materials, including ceramics, glass and metals this paper addresses the identification of production batches and their interpretation. Many of the techniques used for provenance analysis depend upon high analytical sensitivity and accuracy; however, in batch identification the emphasis may be upon rapid techniques which allow the processing of many samples with high precision but lower levels of accuracy. Furthermore, close contextual and typological control is desirable. It is argued that this type of study offers a new way to bridge the purported “gap” between humanities- and science-based archaeologies; offers new but realistic analytical challenges; and the opportunity to develop new strategies for the sampling of archaeological assemblages.
40. Extending the Luminescence Dating Range to the Full Quaternary

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4. Centre for Nuclear Technologies, DTU Nuclear, Technical University of Denmark, Roskilde, Denmark.

In the field of archaeology there is a lack of generally-applicable dating techniques able to cover the full evolution of the genus Homo within the past 2.5 million years. Available methods either have a limited time range (OSL, radiocarbon) or are applicable only in very specific settings (U-Pb, 40Ar/39Ar, U-Th). As a consequence, key questions in the human evolution and dispersal are left unanswered.

Optically stimulated luminescence (OSL) dating is used extensively to determine the time of deposition and burial of Late Quaternary sediments due to the wide abundance of quartz on earth. Application of this method is usually limited to the past 150,000 years due to early saturation of the quartz fast-component blue OSL signal. One approach to extend the age range is to use violet light to directly measure deep traps in quartz (Jain, 2009). Over the past few years, we have characterized the dosimetric properties and investigated the applicability of the Violet Stimulated Luminescence (VSL) signal for dating Quaternary deposits (Ankjærgaard et al., 2013). Here we report on our latest insights.

To test the potential of the VSL signal on geological samples, we investigate two study sites of different ages. The first study comprises nine Middle to Late Pleistocene samples from a core in the south-central Netherlands previously dated using quartz OSL (Boxtel core; Schokker et al., 2005). Because dose rates are very low, a reliable quartz OSL chronology is available up to ~300,000 years; providing an excellent opportunity to test VSL dating for this ‘younger’ range.

The second study investigates a section in northern Israel exposing nine basalt flows (K-Ar dated 0.7 -1.5 million years; Mor and Danneels 1984) containing six layers of palaeosols bracketed by the basalt layers. New 40Ar/39Ar ages for the basalts provide excellent independent age control for the palaeosols. We will present the new 40Ar/39Ar-chronology, as well as the VSL ages. Based on our results for the Boxtel and the Israeli sites, we will discuss the feasibility of extending luminescence dating to cover the full Quaternary using OSL methods.

References

41. Recent advances in Geochronology and geochemistry applied to human fossil remains: maximizing the information with minimal damage

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Fossil remains are too valuable to be destroyed or damaged and therefore any alteration should be kept to a minimum. Recent advances in analytical capabilities of ESR technique and isotopic mapping allow new insight into the human journey, migration and diet. While ESR dating was previously destructive and untrustworthy, new ESR protocol offers a non-destructive and consistent approach that will generate a reliable chronology for modern human occurrences (Grùn et al., 2008a, Joannes-Boyau & Grün, 2011; Joannes-Boyau, 2013). The newly developed protocol using fossil fragments permits the extraction of unstable and interfering signals that allegedly were responsible for large dose underestimation.

Simultaneously, isotopic mapping using LA-ICP-MS was used to investigate a micro scale not only the U-uptake history crucial for ESR dating (Grûn et al., 2008b) but also to evaluate migration and diet patterns of early humans. The isotopic signature in fossil enamel has proven to shed light on environmental surrounding such as with Sr/Ca ratio (Aubert et al., 2013) or more recently the use of 8B distribution allowed scientists to look at breastfeeding time in Neanderthal (Austin et al., 2013). Possibilities appear to be endless, maximizing information for archaeologist while minimizing damages to the valuable samples.

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42. New Evidence with Radiocarbon for the Appearance of the Earliest Farmers in the Aegean

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The appearance of farming and stockbreeding is considered as a crowning event in the human evolution and history and quite rightly is sometimes called the “Neolithic Revolution”. Concerning Greece the issue of its appearance has a special significance not only because it completes an important early chapter of the history but because it is related with the spread of the farming-stockbreeding mode in Europe. The farming settlements in the European territory appear first in Greece and then to the rest of Europe and for this reason are of particular concern to research. It is claimed recently that the chronology of the Greek sites are some centuries younger from the sites in Northwest Anatolia. Thus, it is suggested that the Neolithic phase should have moved progressively in time by migration of people from NW Turkey to Greece, either via the Bosporus canal to Thrace and then to Greece, the Balkans and Europe or through the sea from the west coast of Turkey, crossing the Aegean to Thessaly and then to North Greece, the Balkans and Europe.
Here we present new radiocarbon evidence from early Neolithic sites in North Greece showing that the first human settlements in west Macedonia Greece and especially around the Yannitsa plain (then filled with sea extending the Thermaic Gulf island) were established in 6600/6500 BC. This is about 100 years earlier than NW Turkey (6500/6400 BC) and contemporaneous if not earlier than the West coast of Turkey (6600/6600 BC).

Based on this evidence the present model for the evolution and spreading of neolithisation in the Aegean should be revised by considering of a possible simultaneous development of the new knowledge, rather than by movement of populations around the Aegean, perhaps as a result of a rapid spread of the new knowledge, rather than by movement of populations.

43. Radiocarbon dating of old plasters and mortars. An overview of the last 5 years application of the “pure lime lumps’ technique

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The “lime lump technique” is a new approach for radiocarbon dating old lime-based mixtures such as mortars and plasters that has been applied over last years with interesting results (Fieni 2002; Gallo 2001; Pesce et al., 2009; Pesce et al., 2012). Authors of this contribution have been applying and researching this technique since 2008. To date, 30 samples from 10 different archaeological
sites have been dated. Overall, results show that 86% of the dated samples provided useful chronological data that was aligned with the archaeological framework while 14% of the samples gave results not aligned with the archaeological findings.

Furthermore, results demonstrate that even the radiocarbon dating of a single sample (i.e., a single lime lump) provides useful information. Compared to other techniques currently used for the radiocarbon dating of mortars and plasters where a single chronological data is obtained by dating several samples (up to 5), this technique is more convenient economically (allowing archaeologists to carry out more archeometric dating) and easier to apply.

The aim of this contribution is to highlight the main characteristics of this technique and provide an overview of all the cases where this technique has been applied including those where the results were not acceptable. Discussion will be focused on the limitations of the technique in its current form and the research that is still required to ‘deskill’ the sampling procedure therefore making its application even more interesting for the conservation industry.

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44. A New Approach for Combining Historical, Archaeological, and Scientific Chronologies
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The last decades have seen considerable advance in the use and application of radiocarbon dating and Bayesian modeling (i.e., combining radiocarbon determinations with other information, such as the sequence of samples derived from archaeological contexts) in the field of chronological research. In Bronze Age Eastern Mediterranean and Near Eastern archaeology (c. 3500-1200 BCE), different approaches to dealing with time and absolute chronology are in use. While historical chronologies dealing with kings and dynasties are derived from textual sources, the relative archaeological phases of the Levant, Cyprus and the Aegean are based on archaeological contexts and the development of material culture. Scientific (e.g., radiocarbon) dating provides a direct link between organic objects and the timeline. Major past projects like ARCANE (Associated Regional Chronologies of the Ancient Near East) or SCIMAP 2000 (Synchronisation of Civilizations in the Eastern Mediterranean in the Second Millennium BC) reviewed the material evidence for the relative chronological phases and aimed to synchronize different regions based on first appearance of certain key-wares. On the other hand, the Oxford-based project on “Radiocarbon Dating and the Egyptian Historical Chronology” combined over 200 new radiocarbon determinations with historical information, like the succession of kings and their respective reign lengths and the Dai-Thysse project on “Radiocarbon Dating the Bronze Age of the Levant” focused on acquiring radiocarbon sequences from key-sites in order to synchronize different regions on the basis of radiocarbon alone.

This talk presents preliminary work of the Chronological Investigations of the Near East and Mediterranean in Antiquity (CINEM) toward combining historical, archaeological, and scientific data in an online research environment using the Online Cultural and Historical Research Environment (OCHRE) of the University of Chicago.

45. More than meets the eye: Fiber Analysis and Manuscripts from the Silk Roads
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The core problem in case of paper analyses in objects of unknown origin is that we are lacking chronological references for material usage in particular regions that might enable us to interpret the results of material analyses in a wider context. Paper analysis helps to identify provenance and links between groups of objects with the same distinguishable features. By identifying fiber composition and studying variations in production methods, raw materials, and treatment of the paper surface, it is to some extent possible to determine time and place of production and understand the technologies involved in a regional and periodical perspective. However, to achieve higher precision of such estimations, it is necessary to collect more reference material which will allow to learn what type of paper was used, and where.

This study discusses possibilities and limitations of fibers analysis in the manuscripts from the Silk Roads. Within DFG-funded project at the University of Hamburg, I have created a typology based on systematic, codicological, and microscopic studies of collections found in Dunhuang and Turfan. Over the past three years I examined a total of 350 Chinese, Tibetan, and other manuscripts for their paper. These manuscripts were selected from the Dunhuang Collection in the British Library in London, the Bibliothèque Nationale de France in Paris, the Institute of Oriental Manuscripts in St. Petersburg and the Turfan collection in the Berlin Brandenburg Academy of Sciences (BBAW), and the Berlin State Library (BStL). Overlapping typologies of paper were used to classify a sample of manuscripts into coherent groups, and then relate them to different geographical regions and time periods. By using the technological study of paper combined with codicological and textual information, research aimed to explore possibilities for dating this material and fingerprinting their places of origin. The photographic and descriptive documentation produced for every sample will be highly practical source of information for the further forensic investigations aiming attribution and justification of art work is copied or forgery. The techniques and equipment remain the same whether one is engaged in the forensic examination of the object or conducting an investigation to aid art historians or paper conservators. However, the burden of proof required by these various disciplines is very different.

46. Improving lateral resolution of isotopic measurements of ancient glasses using spatially resolved ion beam microanalysis
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Isotopic and elemental analyses of archaeological glasses have proved a valuable tool in determining provenance1. Typically, isotopic measurements (e.g., 87Sr/86Sr) are performed by bulk methods, which average over heterogeneities, such as colorants added to the glass. To address this limitation and extract possible information on fine-scale mixing of base materials in the samples, we carried out in-situ measurements of 87Sr/86Sr and Sr concentration on ancient glasses utilizing the UCLA CAMECA ims1270 high-resolution ion microprobe. We used a 25nA O primary beam with a spot size of ~25 µm. Isotope ratios were determined by sequentially analyzing 40Ca2+, 85Rb+, 87Sr+, and 88Sr+ in the axial ETL electron multiplier at mass resolving power of ~6,000 with minor energy filtering (~20 eV). Our sample results were standardized to NIST 610 glass; Alder Creek sanidine was used as a secondary standard to ensure accuracy. The precision of the measurements varied between 0.05% and 0.1% (at 1 S.E.) depending on Sr concentrations. Sr concentrations were determined through a relative sensitivity factor (using 88Sr+/40Ca2+ on NIST 610) and then measuring Ca concentrations using our electron microprobe. Our results show that we can measure 87Sr/86Sr with sufficient precision to be of archeological interest while revealing intra-sample 87Sr/86Sr heterogeneity. Four of our five test samples yielded consistent and reasonable 87Sr/86Sr and Sr concentrations.
concentrations. The other glass shows evidence of mixing as 4 of the 5 analysis spots yield a linear array on a plot of 87Sr/86Sr vs 1/15 concentration. The fifth measurement spot contained an inclusion and yielded an anomalously high 87Sr/86Sr of 0.734. A distinct advantage of this in situ approach over bulk analysis is that it requires much smaller samples (+1 ng can be analyzed) allowing rare and precious artifacts to be isotopically characterized.

References

47. Testing the authenticity of the Sky Disc of Nebra

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Early in the year 2002 a sensational find was rescued from the antiquities market. It consisted of several bronze objects from clandestine excavations. They were reported to derive from a hoard in central Germany, including a bronze disc of about 32 cm diameter on which the night sky is depicted with gold intaglio. The hoard, recovered by police action, comprises two swords with gold decorated hilts, two flanged axes, a chisel and two arm spirals, all made of bronze. These accompanying finds date the hoard securely to the developed central European Early Bronze Age, and therefore around 1600 BC [1]. The find is so exceptional, because the “Sky Disc of Nebra” is the earliest astronomically identifiable representation of the night sky, which has considerable implications concerning archaeoastronomy, the history of religion and archaeology. The scientific investigations revolved around the question of authenticity, the provenance of the metals and their production technology. The presentation will concentrate on the question of authenticity, which was contested by the dealers who were taken to court for looting as well as by parts of the archaeological community. The hoard was analyzed by non-destructive and minimally invasive methods including XRF, PIXE, XRF with synchrotron radiation, General Area Detection Diffraction System (GADDS), neutron activation, MC-ICP-MS for lead isotope ratios, LA-QICP-MS, radioactivity measurements of 210Pb and, finally, tin isotope ratios [2]. Furthermore, the find location that was identified by police investigations was excavated and the soils analyzed mineralogically and chemically and compared with adhering soil on the disc. Experimental reconstructions of the production technology, the corrosion and the damages of the intaglio by the looters were used to derive indications of a modern production during the law suit [3]. Even archaeoastronomical measurements are consistent with a Bronze Age date of the Sky Disc [4], which is now beyond doubt.

References

48. Beyond the UNESCO Convention: the Case of the Troy Gold in the Penn Museum

C. Brian Rose

In 1966 the Penn Museum purchased a hoard of 24 pieces of gold jewelry of Early Bronze Age date. The jewelry's style and workmanship were similar to that of Early Bronze Age jewelry from both Troy in northwestern Turkey and Poliochni on the Greek island of Lemnos, but several pieces were so reminiscent of the gold jewelry found by Heinrich Schliemann at Troy in 1873 that the new Penn's assemblage became known as the “Troy Gold.” The acquisition of the Troy Gold prompted the Penn Museum curators to advocate the recovery of artifacts to scientific investigations for the acquisition of authenticities and, how professional ethics and the protection of cultural heritage intersect with issues of authenticity and conservation analysis more generally.

51. Pushing the Limits of Fatty Acid Stable Carbon Isotope Analysis in the Archaeological Record

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2. Department of Archaeology and Anthropology, University of Bristol, Bristol, United Kingdom.
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This talk reviews the history of the negotiations as well as the role of the UNESCO convention in the discussion, and offers suggestions for museums dealing with similar repatriation claims in the future.

49. Acquiring antiquities for museums: ethics, policy, and analysis

Timothy Potts

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This paper discusses the evolution over recent decades of U.S. museum practice and policy relating to the acquisition of antiquities, and how professional ethics and the protection of cultural heritage intersect with issues of authenticity and conservation analysis more generally.

50. Panel and open forum: forensic Science Investigations in art and archaeology

This panel and forum discussion will focus on the challenges and technological difficulties pertaining to forensic science investigations in art and Archaeology from the recovery of artifacts to scientific investigations including characterization, dating and provenance. Emphasis will be given to best practices and improved technologies that help identify objects and assign origin through chemical composition and trace element analyses; isotopic fingerprinting; or other types of analysis that can detect diagnostic markers for an accurate attribution.
be presented and interpreted in terms of the physiological, metabolic and environmental differences and similarities between the producers. The presentation will also consider the selection of appropriate reference materials for inclusion into databases for use in interpreting the results of analyses of archaeological fat residues.


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The insular environments of the Scottish North Atlantic Islands represented a challenging environmental niche for the archaeological populations inhabiting the islands, and careful management of animals by these prehistoric farmers would have been essential to survival. Until recently little has been understood about broad temporal trends in animal husbandry and wider economies in the islands, with previous research having focused on understanding discrete time periods, or processes undertaken at individual sites. The impact of different groups of settlers on the subsistence practices and strategies employed in the islands in different time periods is especially interesting to consider, and the proportion of cattle (Bos taurus) and horses (Equus caballus) present would have been important to survival. Until recently this has been difficult to study due to a lack of carbon and nitrogen isotope data from the islands.

53. Mobility and Diet in the Bronze Age West Eurasian Steppes: A Multi-Isotope Approach

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What was life like in the West Eurasian steppes during the Early Bronze Age? This question has been investigated within the wide-framed Topoi research cluster at the Free University Berlin. Two research projects, Prehistoric mobility and paleodiet in Western Eurasia (2008-2011) and Pastoralism on the Eurasian Steppes (2012- present), have focused on the reconstruction of mobility and economic patterns using isotopic (δ13C, δ15N) analyses. Several hundred samples were collected from micro regions between the Central Asian Altai Mountains, the West Eurasian steppe belt and the eastern European plains of Hungary and Bulgaria. The chronological focus has been on the 3rd millennium BC, where there is evidence for two cultural communities in the North Pontic and adjacent regions: the Yamnaya culture and the Catacomb culture. For these cultural entities most archaeologists cite i) a subsistence economy largely based on animal husbandry and ii) a multitude of grave monuments (kurgans) in comparison to the small number of known settlements as evidence for partly nomadic or pastoral ways of life. To fully understand contrasting patterns of movement we compared these cementary groups to samples from the same regions but dating to the preceding Eneolithic and the later Iron Age, a period for which archaeological and written sources indicate high mobility of the Scythian tribes. Using strontium and oxygen isotope analyses we were able to answer questions on the mobility of single individuals and small groups. Strong correlations between strontium and oxygen isotope ratios propose different points of origin or seasonal mobility for a number of individuals. However, the geological homogeneity of large parts of the steppes made it difficult to draw conclusions about small-scale seasonal mobility. The answer to the second key question regarding the diet and subsistence economy of populations from selected sites in the steppes and steppe-like region was approached by the application of carbon and nitrogen isotope analyses. Although the number of samples was small, there are obvious correlations between the results of different stable isotopes pointing to climatic and economic variations between single sites and regions. Hence, we present some of our key results, which have greatly improved our understanding of life in the West Eurasian steppes during the Eneolithic, the Early and the Middle Bronze Age.

54. Hapnoids as Biomarkers of Pulque in Mesoamerica

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Teotihuacan is considered one of the most important cities in Mesoamerica, with its influence manifested in various ways through the surviving material culture of the region. However, specific details of how the people lived remain obscure, since unlike the Mayas or Aztecs, they left no written records. The palaeobotanical and zooarchaeological work performed to date has shown that the diet of the Teotihuacanos was based largely on maize and beans; however, if not consumed in the correct proportions serious nutritional deficiencies occur. Thus, it has been speculated that the consumption of Pulque, a white alcoholic beverage produced from the fermented sap of several species of maguey plants, would have supplemented the low protein, low deficient diet of the Teotihuacanos. However, direct evidence of the production of pulque at Teotihuacan is currently lacking. One possible means of determining the production and consumption of pulque would be via absorbed organic residue analysis of pottery vessels. The identification of absorbed organic residues of alcoholic beverages in archaeological vessels is a major challenge because their main components are soluble in water and are not expected to preserve over archaeological time scales. However, in the case of pulque the complex fermentation involves the bacterium Zymomonas mobilis, that together with yeast is responsible for the alcohol production. In order to be able to resist ethanol stress, Z. mobilis has evolved a hydrophobic cell membrane containing high concentrations of long chain (≥1 d) w2 of hopanoids. These pentacyclic triterpenoids, biosynthesised by many prokaryotes, are extensively used as biomarkers in studies of bacteria in ancient sediments. Herein, we propose the use of hopanoids as biomarkers of absorbed organic residues from the Pre-Hispanic drink pulque.

Absorbed organic residues analysis was performed on >300 archaeological potsherds of different forms (olla, crater and amphora) from Teotihuacan. Lipid extracts were largely dominated by fatty acids and long-chain alkanols. However, a subset of vessels showed abietic acid derivatives as the main biomarkers, suggesting the sealing of these specific pots with coniferous resin. In addition, by carrying out GC/MS select ion monitoring experiments (m/z 219) only these resin-containing vessels were found to contain characteristic khanpe distributions. The detection of such bacteria/alkanoids pottery vessels is consistent with their use in the production and/or storage of pulque and offers a new means of identifying vessels used in the production of bacterially-fermented alcoholic beverages.
55. Transalpine mobility and culture transfer from the Urnfield Culture into Roman times: Isotopic mapping of a Central European Alpine passage

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Isotopic mapping has become an indispensable tool for the assessment of mobility and trade in the past. The research group “Transalpine Mobility and Culture Transfer” (www.for1670-transalpine.uni-muenchen.de) aims at solving one of the most prominent limiting factors inherent to this type of study, which is often considered too complex and expensive. Here, I present an approach allowing the detection of putative populations within the region of the Urnfield culture.

56. Changing Coastal Resource Use in the Bronze and Iron Ages at Ra’s al-Hadd, Oman

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Ra’s al-Hadd, on the eastern coast of Oman, was ideally situated in the Bronze and Iron Ages to capitalize on the mangrove environment as well as the marine resources of the Gulf of Arabia. The rich diversity of environmental evidence excavated from sites at Ra’s al-Hadd dating to the 3rd millennium BC and later, has revealed a complex response over time to seasonal availability of resources. During the intervening years, aDNA research has progressed through an over-ambitious phase in which anything seemed possible, a re-evaluation phase when nothing seemed possible and everything appeared to be modern contamination, and finally to a more sober and productive phase that can be traced back to the early 2000s. The growing maturity of aDNA research has been driven by an increasing understanding of the technical regimes needed to limit contamination of ancient samples with modern DNA and to recognize contamination when it occurs. Today, contamination is still a major issue with human remains, but it is no longer a serious problem with non-human material, at least when the work is done properly. The current productivity of aDNA research is also due to the introduction of new ‘next generation’ sequencing (NGS) techniques, which have largely replaced the previous methodology based on the polymerase chain reaction (PCR). With PCR it was only possible to obtain a few short sequences from an aDNA extract, but NGS provides many millions of sequences in a single experiment. NGS can therefore be used to sequence the entire genomes of extinct hominins or of prehistoric examples of Homo sapiens, or can be directed at individual genes and groups of genes of interest. Biomolecular palaeopathology has been reinvigorated by the ability to obtain complete sequences of pathogenic bacterial genomes from skeletons, and to examine oral microflora preserved in calculus. In many respects, the limit to the ambition of aDNA researchers now lies not with the questions being asked, but with the bioinformatics challenges inherent in handling and analyzing the millions of sequences that are now routinely obtained. The future trends are staggering in their possibilities. Sequencing a modern human genome is now so easy and cheap that it could be considered for an undergraduate lab class, and the techniques that make this possible are rapidly being superseded by even more powerful ones. In this paper I will attempt to map out the ways in which this revolution in aDNA research will provide new opportunities for biomolecular archaeology in the coming years.
Earth’s of the Aegean, mentioned extensively in Greek and Latin texts by Diocrotides, Pliny and Galen. Not all earths had medicinal applications and not all medicinal earths were of the same strength. We now know that earths did not simply consist of clay minerals but rather of a number of inorganic minerals as well, each contributing its own properties to the final product. In this paper we suggest that the study of medicinal clays and earths should be underpinned first, by field based geo-archaeological work (geological survey and sample collection) and laboratory analysis (chemical and mineralogical characterisation with XRF and XRD); secondly by subjecting components of these earths to microbiological testing against various pathogens. It is the latter testing that addresses head-on the issue of their potential medical use in antiquity.

We present the results of our ongoing research on the medicinal properties of earths and in particular Samian Earth, from the island of Samos in the W Aegean known in antiquity as a most effective salve against eye infections. The Dioscoridean or Galenic ‘mineral composition’ of Samian Earth had to be deduced from geo-archaeological fieldwork and a re-evaluation of the relevant texts. The results of the microbiological testing suggest that the relative rare boron mineral colemanite but also potentially boron-enriched smectites, both present on Samos, had a relative rare boron mineral colemanite but also potentially boron-enriched smectites, both present on Samos, had a

combined approach outlined above goes some way in shedding light into the ‘temperaments and actions’ of the Galenic pharmacopoeia; it also has the potential to introduce ‘new’ minerals-based antibacterial agents into modern pharmaceutical research.

59. Integration of advanced analytical techniques in the studies of the Dead Sea Scrolls

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For many years after the discovery of the Dead Sea Scrolls (DSS), text analysis and fragments attribution were the main concerns of the scholars dealing with them. The uncertain archaeological provenance of a large part of the collection added an additional difficulty to the formidable task of sorting thousands of fragments. After 60 years of scholar research dedicated to textual, paleographical, and codicological analysis, the questions of origin, archaeological provenance, and correct attribution of the fragments are still debated. Unfortunately, in the period 1948–2000 the material properties of the Scrolls received much less attention. Yet the works conducted in Leeds in the 60s and at the Getty Conservation Institute in the 90s are of defining importance for an integrative approach in the studies of the Dead Sea Scrolls proposed recently at the BAM.

Combined with the textual data, the analytical integrative approach developed for an accurate characterization of the highly inhomogeneous writing media of the Dead Sea Scrolls added another dimension to their studies and allowed us to resolve some of the discussions. Moreover, it provided new information on the production of ancient parchment toward the end of the Second Temple period, opening a new page in the historical study of technology. Within the frame of the Qumran project dedicated to developing a suitable methodology for the material studies of the DSS, we employed µ-XRF, 3D-XRF, SEM, µ-FTIR, FT-Raman, µ-Raman and hyper-spectral imaging techniques. The set under investigation included inscribed and non-inscribed DSS fragments, as well as mock-ups of goat parchment inscribed in our laboratory with the inks prepared according to ancient recipes. Archaeometric investigation of the scrolls necessarily embraced identification of the materials used in post-discovery treatments that included applications of oils and reinforcements with paper and various adhesives such as PVA, PIMMAD, and MC. With rare exceptions, the treatments performed on each Dead Sea scroll fragment are poorly documented. Therefore, reconstruction of the individual fragment history has to rely upon advanced analytical techniques to identify the treatments and their effects. Our approach will be illustrated by a reconstruction of the history of the Genesis Apocryphon (1QapGen) and the Temple scroll (11Qta).

60. Ethno-archaeology of Salt Supply during the Neolithic and Chalcolithic in the Romanian Carpathians

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The presence in Romania of more than 3000 salt springs, of Europe’s and perhaps the world’s oldest archaeological evidence for the production of recrystallized salt, the existence of large resilient areas with traditional practices of brine supplying, all plied in favour of this country as an ideal location for conducting ethnoarchaeological research on the salt water supplying.

This paper first presents the ethnological models generated by the intense research on the exploitation by the human communities, throughout the millennia, of the salt springs from the area between the Eastern Carpathians and the Prut River in south-eastern Romania. Proceeding from these ethnoarchaeological models, obtained from interdisciplinary inquiries and investigations, the resulting theoretic framework was applied to the Neolithic and Chalcolithic archaeological cultures found in this area. Because the supplying of salt suggested a radial pattern, the approach involved the delimiting of the supplying areas according to the distance to which the communities were found with respect to the location of the salt spring. Thus, a radius of up to 10 km was ascertained for the area with a high frequency of supplying, and a 10-30 km one for the one with a more reduced frequency, but with larger quantities involved. The most surprising phenomenon observed is that the selection by the human communities of a certain spring did not depend on its proximity, but on its specific output (discharge rate) and quality (chemical composition).

To understand the degradation of natural varnishes and recover the recipes used by the old masters various analytical techniques can be used. We focused our research on the use of GC-MS/MS with an ion trap device. It brings an incense, balm, religious symbolism, or varnishes. Those varnishes are made by dissolving the natural resin into alcohol, oil or turpentine spirit. Through time the reactions modifying their molecular composition. Those reactions also impact the aesthetic aspect of the artwork (crackling, yellowing, etc.).

To understand the degradation of natural varnishes and recover the recipes used by the old masters various analytical techniques can be used. We focused our research on the use of GC-MS/MS with an ion trap device. It brings information for a better restoration and conservation of artworks, and improves the identification criteria of old varnish.

The varnishes were made following ancient recipes coming from manuscripts and specialized literature. Diterpenic (sandarac, colophony, Manila copal) and triterpenic (mastic, dammar) resins were used in specific attention to the botanical origin. Once the varnishes elaborated, they were irradiated under artificial sunlight and analyzed.

61. Identification of Ancient Varnishes: Development of Adapted Methods in GC-MS(AMS)

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Resins were used since ancient times for different purposes: incense, balm, religious symbolism, or varnishes. Those varnishes are made by dissolving the natural resin into alcohol, oil or turpentine spirit. Through times the reactions modifying their molecular composition. Those reactions also impact the aesthetic aspect of the artwork (crackling, yellowing, etc.).

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before, during and after this artificial photodegradation. A gas chromatography coupled to an ion trap mass spectrometer was used to identify and characterize the chemical markers (abietanes, pimaranes, oleananes etc) thanks to comparison with commercial standards and the development of adapted fragmentation methods. By changing the ionization energy or choosing the right MS/MS parameters it is possible to have new information on the present molecules. The fragmentation of well chosen ions can separate different families of molecules otherwise very close as oleanane and ursane and help to their identification. Besides to focus on one ion increases the sensibility of the analysis, this can be very interesting when a sample with a low matter quantity is studied.

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4. Posgrado de Arqueología, Escuela Nacional de Antropología e Historia, México City, Mexico.

The Santo Domingo public square (Plaza de Santo Domingo) is located in Mexico City downtown. The history of its transformations begins in pre-Hispanic times and it is still being written. One of the objectives of our investigation was to determine the origin of this area as a public square, whether pre-Hispanic or colonial. For this purpose, we implemented two 80 m long ERT profiles in the middle of the square and one at the eastern side of the Church of Santo Domingo de Guzman. A Wenner-Schulmberger array was designed for the data acquisition. The results confirm the hypothesis that the Plaza de Santo Domingo was designed and constructed as a public square in colonial times, although the presence of a pre-Hispanic structure is also visible in the electric profiles. This structure is assumed to be part of the Northern Wall that surrounded the Mexico ceremonial compound. At the eastern side of the church, we could identify the foundations of the first Spanish chapel, running from East to West, and portions of the concrete deposits injected into the subsoil to stabilize the continuous subsidence of the building.

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4. 2D-ERT Geophysical Characterization of the Plaza of Santo Domingo, Mexico City.

Denise Argote-Espino², Pedro Paz-Arellano², Andrés Tejero-Andrade³ and Pedro López-García³

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65. Characterization of Structures at Sant’Ansano Excavation Site in Allerona, Italy using Portable Spectroscopy

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A new excavation site in the comune of Allerona, Italy (Umbria) was opened in summer 2014 by a research team from Saint Anselm College. This site, together with the excavations at Coriglia, Castel Viscardo and the Orvieto SW-Turkey and Magnetic Surveying by Spatial

66. Integrating Multi-Element Geochemical and Magnetic Surveying by Spatial Clustering: the Suburban Sagalassos Case, SW-Turkey

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Several studies have suggested that multi-element soil geochemical surveying holds potential as an archaeological survey method, complementing more common techniques such as magnetometry and fieldwalking. Despite this, only limited research has been carried out concerning the joint interpretation of these techniques.

In this study, we conducted a geochemical survey in an area where magnetometer data were difficult to interpret in archaeological terms. This research aims at investigating the possibilities and limitations of multi-element geochemical survey in facilitating the analysis of magnetometer data. The site under study comprises a suburban area of 1.5 ha, situated in the Roman to Byzantine city of Sagalassos (Taurus Mountains, SW-Turkey). For the geochemical survey, a total of 69 soil samples were collected in a regular grid with cell sizes of 20 x 20 m. After Aqua Regia extraction, 19 elements were measured by inductively coupled plasma optical emission spectrometry (ICP-OES), using a Varian 720-ES apparatus. The magnetic survey was performed with a Geometrics G-858 magnetometer in gradient mode, along 0.5 m spaced transects. To subdivide the magnetometer image into zones of similar magnetic response, spatial variability characteristics (variogram range and sill) and average values of sub-cells of 10 x 10 m were calculated. These data were analysed for patterns using a contiguity constrained spatial clustering algorithm.

The main difference with more standard clustering methods is that this method takes into account the spatial dimension of the dataset, resulting in clusters that are not only statistically, but also spatially homogeneous. The same algorithm was applied to the chemical dataset.

The advantage of this approach is that it allows one to understand the spatial dimension of the dataset, resulting in clusters that are not only statistically, but also spatially homogeneous. The same algorithm was applied to the chemical dataset.

The results of the geochemical surveys indicate the presence of archaeological features. The clusters identified in the geochemical surveys correspond to different periods of occupation, including earlyChristian and Byzantine periods. The magnetic survey results show consistent patterns across the excavation site, indicating the presence of a possible ancient road or trackway. The joint interpretation of the geochemical and magnetic data provides a more comprehensive understanding of the site's archaeological potential.
Scanning electron microscopy (SEM) and Raman microscopy have become routine tools in many analytical laboratories over the past few decades. The SEM provides the ability to image samples with extremely high magnification and is commonly combined with x-ray-based analyzers to study elemental information. The Raman microscope provides chemical and structural analysis, with very high specificity, on very small samples, and can reveal molecular distribution within samples. With these two instruments combined, the ability to perform high resolution imaging, carry out elemental analysis and probe the chemical and structural properties of a material can now be done quickly and easily on the same platform.

This presentation will show some examples where this combined tool has been employed in archaeometry, giving an insight into the power that these two instruments can provide in identifying elemental and chemical species at the same time.

68. SEM and Raman spectroscopy: a powerful analytical tool for archaeometry
Andrew King

SEM and Raman microscopy have been employed in archaeometry, giving structural properties of a material can now be done quickly and easily on the same platform. This project focuses on the chemical analysis of some samples of the production remains uncollected at Mes Aynak in order to identify the nature and technological parameters of the metallurgical activities taking place at the site and contributing to the understanding of their associated chaînes opératoires. The paper will present the results of SEM-EDS and lead isotope analyses of several fragments of slag collected from slagheaps covering an area of 100,000 square meters, containing an estimated 900,000 tons of metallurgical debris, and therefore representative of one of the largest industrial copper production sites. The initial results show that the technology employed revolved around exploitation of porphite and chalcopyrite from dolomitized marble host rock in a two-step matte smelting process. Interestingly, and at variance with the gradual progression in efficiency typically observed elsewhere, there seems to have been a sudden early shift in production processes away from tapped slags and towards non-tapping smelting on a much larger industrial scale in the later phases of the site.

References

70. Crucible or Furnace – A comparative study of silver production traditions in north and south China
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Before importing silver at a large scale from Japan and South America via Europeans in the 16th-17th century, China had a long history of domestic silver production. Since the second half of the first millennium BC, silver was gradually adopted in China as prestige material and its production culminated in the 11th-13th century AD. Silver in this period was used in various ways such as for awards, gifts-giving, paying tribute, and manufacturing artefacts. In addition, silver started to become one of the main currency metals in the early 11th century and was used in the taxation system. All of these made silver an important metal in both the Chinese empires, but little is known about its production. Our research shows that the production technology of silver varied significantly in different regions of China, as a result of local adaptive strategies to specific social-economic and environmental settings. At IS40, I would like to present data from two sites in north and south China. In the northern site Quyang, the production used cylindrical crucibles with a diameter of 7-8cm and a length of more than 15cm. Remains of crucible furnaces were identified as well. The slag adhering inside the furnace indicates coal instead of charcoal was used as the fuel to provide heat for metallurgical reactions inside the crucible. On the other hand, in the southern site of Minshan, tap slag and furnace fragments identified in the field suggest that the metallurgical reactions happened directly in the furnace. Both sites date roughly to the same period and the main reason for their adoption of two totally different technologies might be their various environmental conditions. After thousands of years of deforestation, the relative arid north China had been short of wood for charcoal making while semi-tropical south China was still richly timbered. Previous research has shown that the shift of fuel source from charcoal to coal in iron smelting industry of north China occurred during the early Song period (11th century). Interestingly, the northern silver smelters adopted the new fuel with a delicately designed process. A coal fired furnace was used to provide heat and high quality crucibles were employed to contain metallurgical reactions, protecting the metals inside from being contaminated by impurities in the coal.

71. Iron and the Khmer Empire, Cambodia (9th to 15th c.): first study on the sourcing and dating of iron construction materials of Angkor
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The Angkorian Khmer Empire required substantial quantities of resources materials to construct their immense masonry temples and earthen hydraulic infrastructure, supply armies and trade with foreign nations. Investigation into the industrial processes that enabled these feats will therefore generate new and dynamic insights into multiple aspects of Khmer society. A key commodity in this process is iron, a metal with dynamic material and cultural applications that has been utilized over a century of academic writing on the Khmer Empire. The work presented here represents the first investigation of a wider research study that aims to evaluate the role of iron (supply, production, trade) to shed light on the Angkorian exchange system and its subsequent impact within the historic events and processes that saw the Khmer exert political influence over mainland Southeast Asia. For the last 10 years, our team investigated the significant physical and chemical properties and features of iron objects, in particular those linked to microscopic slag Inclusions (Sl) embedded within artefacts, to provide crucial information on the iron-making processes, technology and more recently provenance and absolute dating to provide a renewed vision of trade flows, supply and employment of iron in specific historical, chronological and socio-economic contexts. These innovative methodologies based on an integrated interdisciplinary approach were applied and adapted to the medieval Khmer context. Using macroscopic and microscopic compositional (major and trace elements) investigation (IEMB, LA-ICP-MS, ICP-MS) on a specific set of ores, slag samples and architectural cramps and tools from three temples within Angkor, we examined the geochemical variability of potential sources of Si and of cramps using an ad-hoc statistical treatment of multivariate compositional observations.
This investigation provides the first evidence for the geographical origin of iron production and products used within Angkor. In addition, application of an innovative radiocarbon dating approach to the crampons establishes the first absolute dates for the construction sequence of the Angkor monuments. The combined provenance and chronological study provides the first reconstruction of iron procurement during the Angkorian period and suggests a temporal shift in the iron supply for Angkor’s temples from the late 10th c. to the late 12th c. More significantly, this shift seems to support the hypothesis that the Angkorian centre of PKKS (Bakan) was built to enable communication with Phnom Dek and the iron produced there for the Khmer elite. Finally, the results indicate that at least five other yet to be identified iron sources were exploited during this period. This pattern strongly indicates that the Angkorian Khmer relied on a broader trade network to obtain this important resource for their massive program of territorial and cultural expansion between the 11th to 13th centuries.

72. Archaeometallurgy of Metal Finds from the Medieval “Royal” Burials of Durbi Takusheyi, Northern Nigeria

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Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds located between the modern towns of Katsina and Daura in northern Nigeria.

73. Outside the gates - Metalworking around medieval and post medieval Copenhagen

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Recent excavations, in connection with the construction of the Copenhagen metro, has yielded large amounts of slag and other remains of metalworking especially from Kongens Nytorv and Rådhuspladsen (Town hall square). These sites were in the medieval and renaissance period areas just outside the Eastern and Western gate of the City. The atrium is dated to a period spanning from the 14th to the 17th century.

A large number of analyses of slag, hammerscale and other types of material show that in the earliest period, primary smelting of imported bloom iron was predominant. Only very few traces of secondary smelting or other types of metalworking was found. The bars or billets made from the iron were probably traded on to blacksmiths within the city or to tradesmen passing in or out the gates on their way to or from the markets.

Analyses of iron objects showed that iron produced within present Denmark never played a significant role in the iron economy of the city.

Over time, the metal work performed became more diverse. At least one workshop still preformed primary smelting while secondary smelting was probably done in another smithy. In addition there is evidence of copper alloy casting and at Kongens Nytorv even of iron casting. One find indicated that noble metals were, at least occasionally, assayed or refined at Rådhuspladsen.

Around 1500 AD the primary smiting ceases, as it is also known from slag finds from other medieval Danish towns, probably due to the significant decline in local iron production based on bog iron ore.

74. Copper production at El Coyote Honduras: The first evidence for copper smelting in Central America

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Excavations at El Coyote, in the lower Cacaulapa river drainage of northwest Honduras, revealed the first evidence of copper smelting in southeastern Mesoamerica. Within the southern portion of this Late Classic and Early Postclassic center a full extractive copper production site has been uncovered. This includes an ore processing area, a smelting center, a bimetal for the sorting of copper prills from crushed slag, as well as multiple slag heaps used for disposal of used furnace fragments and discarded slag. Archaeometallurgical investigations of the remains focus on establishing the metallurgical processes undertaken on the site. Samples from each stage of the process were investigated using light microscopy, scanning electron microscopy and Raman spectroscopy to characterize the process. A potential connection to the Blackstonian Hoard of copper bells is explored.

The importance of this site cannot be overemphasized as there are no other copper smelting sites currently identified in Central America.

75. Goldsmiths or Wax Sculptors? Individual Skill and Social Agency in Muiscan metalwork (Colombia, AD 600-1800)

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Traditional approaches to Pre-Columbian goldwork are dominated by manufacture studies that focus on the technical sophistication of individual objects, and/or on chemical analyses that seek to determine authenticity or metal provenance. More technologically interesting, these studies yield relatively little information about the societies who made and used those artefacts - at best, archaemetallurgical studies present gross generalisations. Only a closer integration of technical and contextual data will reveal more subtle aspects of the agency, craft organisation, metal value systems or community interaction in specific settings, as revealed in patterns in the manufacture and consumption of metalwork. This paper introduces the main findings of a large-scale contextual study of the votive metalwork produced by the Muiscas – a Chibcha-speaking community that inhabited the Eastern highlands of present-day Colombia for at least one millennium before the Europeans arrived. The research has included hundreds of objects and involved analyses by XRF, metallurgy, SEM and LA-ICP-MS, while striving to consider the context where each artefact was found, and the other objects it appeared associated to. Of potential relevance for archaemetallurgical studies in other areas, we highlight the importance of our study for our understanding of the adoption of lost-wax casting as a metallurgical innovation, as well as some challenges to the ways in which we tend to search for structure in datasets of chemical data. Our work has allowed the identification of individual artisans (and, in one case, an apprentice) based on subtle aspects of the choice of materials (as seen through chemical analyses) and techniques (as seen under the microscope) employed for the modelling and casting of our objects or tunjos using the lost-wax technique. These are informative of individual dexterity, personal preferences and learning
traditions within the broader social customs that strongly constrained the technical and iconographic aspects of Musica votive metalwork. Based on our dataset, we argue that the choice of alloys in some votive offerings reveals an explicit search for a diverse spectrum of compositions - as opposed to the simple correlations between object types and chemical clusters that we often hope to find in our datasets. We further contend that the manufacturing process of votive goldwork was culturally more important than the appearance of the finished products themselves, and that the wax employed for the modelling of objects to be cast by the lost-wax technique was potentially more important than the goldwork itself. These findings also shed new light on the renowned raft of El Dorado. We will bring up relevant ethnographic data about the value of bees and wax that broadly support our claim, and discuss the extent to which our findings should trigger a review of old assumptions elsewhere.

76. Micro-invasive and non-invasive techniques applied to Italian Renaissance Terracotta Sculptures: Provenance and chronological issues of Della Robbia Collections in Portugal

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A group of Italian glazed terracotta sculptures, attributed to the della Robbia workshop of Florence are displayed in various Portuguese museums and private collectors, and was analyzed in the framework of an FCT funded project (PTDC/HS/IEC/116742/2010) and a CHARISMA project at BNC (BBR-345). They include a variety of objects for private use (devotional images, altarpieces) and decorative (big medallions mainly for outdoor walls decorations). The exploratory plastic and iconographic analyses enable us to assign the group of sculptures to a period from the end of the 15th to the first quarter of the 16th century, which coincides with the peak of success of Della Robbia workshop, mainly due at the time to the work of Luca’s nephew and chief artist Andrea and his children. In the research project, interdisciplinary methods were applied to the Robbiana sculptures found in Portugal aiming concrete answers to a number of questions that have puzzled art historians for a long time, like fine adjustments to the chronology, determining the nature of raw material, inquiring into their authenticity and rectifying the artistic attribution of the sculptures.

In this work the main goals are to address the question of the homogenity of “Portuguese” Della Robbia sculptures by looking at the chemical and mineralogical composition of the ceramic body, and the chemical composition of glazes, in order to obtain more information on the way in which the objects were manufactured, and also contribute to solve chronological issues. Materials were analyzed using a variety of analytical techniques such as INAA, PIGA, PIXE and XRD.

Results from the glazes showed in some cases a subdivision of the sculptures according to their shape in the medallions, featuring fruits, figurines and background blue. The ceramic body analyses on the other hand suggested in general a common origin for the clay raw materials - carboniferous rock of marine origin (negative Ce anomaly) - marly clays, and firing temperatures around 900°C with the main mineralogical association: gehlenite > diopside > quartz > calcite and traces of feldspars. Within some sculptures we have detected adjacent samples with negative Eu and positive Eu anomalies. Nevertheless, a common raw material is suggested, as according with literature regarding geological context of Central Italy, the anomaly initially existing in the source area rocks was modified during the sedimentary and/or diagenesis processes, in which sediments with heterogeneous Eu anomaly size were admixed and present in the same quarry.

The archaeometrical data on a set of 35 glass beads coming from a necropolis, two and a half centuries after the end of the 15th century, situated near the modern city of Sarno (Napoli), are reported in this work. The glass samples are dated from the 9th to 6th century BC.

The chemical analyses were obtained by Electron Microprobe (EMPA), for major and minor elements, and by LA-ICPMS for trace elements. The chemical data indicate that both natron and plant ash glass are present in the sample set. The natron glass beads are mainly copper blue and turquoise, cobalt blue and iron black. The cobalt blue samples show very high Al2O3 (~6.60%) and MgO (~4%) levels associated to trace elements such as Ni and Zn, that indicate the use of cobaltiferous alums as source of colorant [1]. Furthermore they exhibit a very low amount of CaO (1.3-3%), K2O and P2O5 (0.2-0.6% and 0.03% respectively). The question about what kind of fluxing agent was used to produce these glass has been object of great debate. Gratuze and Picon [2] and Reade et al. [3] understood the differences between the 2nd millennium BC cobalt blue glass and the 1st millennium BC ones. The latest contain low amount of K2O (~0.5%) and P2O5 (~0.15%) as the earlier, but show also low levels of CaO (3-4%). These chemical characteristic strongly suggested the use of natron. The Sarno cobalt blue glasses were hence probably produced with natron and the high amount of MgO can be related to the use of cobaltiferous alums. The iron black samples exhibit similar chemical characteristics as regards CaO, K2O and P2O5, consistent with the use of natron, but also observed for coeval black glass from France [2] and Italy [4]. Moreover these beads are rich in FeO (10-14%), responsible for the black coloration. The majority of the plant ash samples are colorless and an high antimony levels are found (Sb2O3 ~ 0.4%). The trace elements analysis show that the plant ash and the natron samples (excluding the cobalt black) are characterized by a high Sr concentration, suggesting the use of a coastal sand as vitrifying raw material [5]. The natron cobalt blue and iron black samples exhibit the lowest amounts of Sr (~75 ppm), that could indicate the use of a limestone-bearing sand as vitrifying. There is no chronological distinction among the samples: the presence of natron glass and plant ash glass overlap each other in a span of time from the 8th to the 6th century BC.

References


78. Boron Isotopic Composition of Roman Natron Glasses to Provenance the Flux Raw Material

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2. Department of Analytical Chemistry, Ghent University, Ghent, Belgium.
3. Centre for Archaeological and Forensic Analysis, Cranfield University, Shrivenham, UK.
4. School of Archaeology & Ancient History, University of Leicester, Leicester, UK.

Provenancing the raw materials of natron glasses has gained tremendous importance these last years. This growing importance is due to the recent developments in analytical (geo)chemistry which use several isotope systems for obtaining reliable information. The silica source can be provenanced using Hg isotopes in combination with trace elements (Degryse and Schneider, 2008), the lime source can be revealed by the use of Sr isotopes (Wedepohl and Baumann, 2000), while (de)colorants can be provenanced using Si isotopes (Lobo, et al., 2013). However, no means for provenancing the natron flux existed. Since B largely comes into the glass via the flux, B isotopes are targeted to prove the natron flux. Several Greco-Roman glasses, natron from Egypt, Libya and Greece and sand from the Mediterranean were analyzed for their B isotopic composition and the corresponding results will be presented. The silica source has an influence on the B isotopic composition, complicating the
picture, but in general, it will lower the 1818 of the glass compared to the natron sources studied. The high melting temperatures showed no significant influence on the B isotopic composition.

It can be concluded that Greco-Roman natron glasses show a rather homogenous 1818. The Wadi Natrun salts analysed, perfectly fit a model in which the 1818 of the glasses is somewhat lower compared to the natron source due to the input of low 1818 of the sand. The samples from Lake Piroklimin in Greece show too low 1818 values to be used in glass making according to this model.

References


79. Iron Age Glass from Myanmar: Addressing Provenance Issues with Trace Element and Isotopic Compositions

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2. Centre National de la Recherche Scientifique, UMR 7055 “Prehistoire et Technologie”, Nanterre, France.

Glass appears in Southeast Asia at the début of the Iron Age, around the middle of the 1st millennium BC. Variations in Southeast Asian glass type distributions were found to be excellent markers of changes in cultural and economic interactions but are based on limited material from Thailand, Cambodia and Vietnam. Other regions, in particular Myanmar’s pivotal position with India, have remained largely unexplored, making it difficult to draw a global picture for Southeast Asia during this transitional period. The Mission Archéologique Française au Myanmar has conducted excavations of Iron Age cemeteries located in Upper Myanmar since 2001, throwing new light on social interaction networks around the Bay of Bengal. The cemeteries yielded grave goods including glass, mostly in the forms of beads. An in depth study of this material including typological description, elemental (using laser ablation – inductively coupled plasma - mass spectrometry) and isotopic analysis has recently started. Results currently available indicate the presence of two major glass types. Some glass beads have a potash composition. Three sub-groups, all present in Upper Myanmar, were identified for that type of glass even if no clear production zone has yet been established for any of them. Potash glass distribution covers a very large area encompassing South Asia, China and Southeast Asia. The other glass artifacts have mineral - high alumina (m-Na-Al) composition. Among the sub-groups of that type of glass, only the m-Na-Al 3 glass type appears in our study. This type of glass was also identified at sites located in northeastern part of India and it is hypothesised that it was produced in this region. If the compositions of the glasses do not support the possibility of a local glass production, the singularity of some bead types would suggest that glass beads were maybe manufactured in the lead. Strontium and neodymium isotope ratios were measured on a small subsample of glass artefacts. It is the first step toward building a database of isotopic data, accompanied by elemental data for glass in South and Southeast Asia to address provenance issues that elemental analysis cannot resolve alone.

80. Non-invasive techniques applied to the characterization of art nouveau glasses

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Current implication of the application of non-invasive and portable techniques to the characterization of glass is well known. However, despite the large number of publications on medieval glass, few studies have been performed on early modern glass. Since the opportunities to sample or to move the work of art out of the conservation location are very limited, the application of non invasive and portable techniques appears to be the best way to perform an in-depth characterization of the chroomophores and raw materials even though the complexity of interpreting the results and the lack of reference data need a preliminary phase of testing on standard and reference samples.

In this study a collection of colorant and opalescent glasses from the first half of the 20th century and some standard samples of cobalt and cadmium glasses produced ad hoc at the Vicarte Research Unit were analysed using both traditional (XRF, SEM-EDS, XRD and UV-Vis-NIR) and portable and non-invasive techniques (XRF, FORS).

The standard samples consist of 21 glasses different base compositions (soda-lime, potash and mixed alkalis) and different cobalt levels. For each cobalt glass different amounts of cobalt (0.5, 0.75 and 1% wt) were added to each base composition (9 samples). Also, yellow to orange and ruby red colorations were obtained by modulating the cadmium/sulphide and cadmium/selenium ratios.

The cobalt glass absorption spectra detected by FORS are usually characterized by three sub-peaks located around 530 nm, 590 nm and 650 nm due to the cobalt tetrahedral coordination. A change in the base composition of the glass could, however, affect the three-peak position due to a change in the ligand field strength.

The influence on the FORS spectra of a different base composition and amount of soda present in the glasses (detected by SEM-EDS and XRF) was studied. For glasses with soda content under 15% (some soda-lime samples and mixed base glasses), the resolution of the three-peak absorption band of cobalt is poor. The band appears to be broad, unsymmetrical, and centered around 550 nm even though the characteristic triplet was detected when the amount of soda increased to between 15% and 29%. A shift of about 10 nm in the position of the peaks can be observed in all glasses with a potash base.

The study of glasses colored by CdS and Se is still in progress, and the results will be available soon.
Glass technology and glass provenance represent major archaeometric issues, far beyond the abundance of glass objects in the archaeological excavation. In the field of glass technology, the focus has mainly been on colouring agents, being X-ray diffraction, scanning electron microscope, electron microprobe and bulk chemical analyses the most effective and widespread analytical techniques. Compositional analyses and isotope determinations have been used for provenance issues, often trying to overestimate the effectiveness of one over the other, while remaining both undeniably useful.

The archaeometric literature includes a vast number of discrimination diagrams in which almost every compositional variable has been plotted one against another to obtain some chemical distinction. However, an important yet serious problem is clearly determining the properties of these diagrams and their ability to contribute to interpretation making. In order to provide some practical guidelines, the use of major glass diagrams has been revised. Firstly, the use of several diagrams for intentionally coloured glasses have been discussed, particularly with regard to data processing. Secondly, a comprehensive review of available data is used for selecting suitable diagrams for data interpretation and publication.

A special focus has been placed on naturally coloured glasses from the Mediterranean basin. In this latter case, in fact, it has been possible to provide a set of diagrams able to discriminate the Levantine glasses (Syrio-Palestinian coast) from those of reliable Egyptian origin, based on a few major elements contents. Lastly, the mutual influence of Fe2+/Fe3+ and Fe2O3:MnO ratios has been reassessed, based on both literature and XAS data.

82. Glass and Diagrams: a Review (Roman and Medieval glasses from the Mediterranean area)

Gliozzo, E.1

1. Department of Physics, Earth and Environmental Sciences, University of Siena, Italy.

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STONE, PLASTER and PIGMENTS

83. Multi-Analytical Investigation on Greco-Roman Wall Paintings: The Case of Tuna El-Gabal Funerary Houses, Upper Egypt

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A multi analytical study has been undertaken into wall paintings from Tuna el-Gabal funerary houses in El-Minia, Upper Egypt. Tuna el-Gabal is a large site functioned as the necropolis for the ancient Egyptian town of Khnum or Hermopolis. It comprises various remains of Ptolemaic and Roman chapels of which some are in the pure classical style, while others represent a mixture of Pharaonic-Greek style, both of which are covered with wall paintings. In the funerary house under study, the usual wall decorations depicting scenes of daily life or of offering bearers are not found. Instead, geometrical and floral ornaments are executed.

The technical investigation of the materials and techniques employed for wall painting of these types of ancient Egyptian funerary houses in Tuna el-Gabal, have not yet been undertaken. In the present study, ground and paint layers as well as paint media were examined using: Fourier transform infrared spectroscopy (FTIR), Optical microscopy (OM), Scanning electron microscopy coupled with energy dispersive X-ray spectroscopy (SEM-EDS), X-ray powder diffraction (XRD) and Raman microscopy in order to characterize materials and techniques employed. Our findings, concerning one of these houses, are discussed and compared with the other findings of previous studies from the same period. Pigments like red and yellow ochre, amorphous carbon, calcium carbonate and calcium sulphate are used in the wall paintings. The green paint comprised a mixture of blue and yellow pigments. Mud bricks were the main substrate on which these types of plaster were used to cover both the walls and the columns.

84. Analysis of Colored Archaeological Fibers from Taira, north of Chile

Tomás Ávila1, Marcela Sepúlveda2, Patricio De Souza1, Celine Paris1 and Ludovic Bellot-Gurlet1

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3. Programa de Doctorado en Arqueología Universidad Católica del Norte- Universidad de Tarapacá, Arica, Chile.
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The site A-16 is located on Taira, Antofagasta Region in the north of Chile. In the sector 2 of this site a funerary context was excavated. The body of a newborn was found at 90 cm under the surface of the site and due to the burial characteristics, it’s highly probable that it corresponds to the early Formative period (1200 - 100 B.C.). Colored fibers were studied using a multi analytical approach that allows using a minimal amount of sample and obtaining complementary information that allows determining some of the most important features of the textiles.

The characterization of the materials from this burial site allows understanding the clothing and dyeing technologies for this particular period in this region as well as to implement a methodology for the study of successive funerary contexts. The techniques utilized are optical microscopy (OM), infrared spectroscopy (IR) and Raman spectroscopy (RS). Sample preparation for OM consists in the dispersion of a few fibers in a drop of ultrapure water. Fibers are then observed using an Olympus BX51 polarizing microscope. The IR spectra were obtained using a Perkin Elmer 380 and FTIR. Optical microscopy (OM), Scanning electron microscopy (SEM) and Raman microscopy in order to characterize materials and techniques employed. Our findings, concerning one of these houses, are discussed and compared with the other findings of previous studies from the same period. Pigments like red and yellow ochre, amorphous carbon, calcium carbonate and calcium sulphate are used in the wall paintings. The green paint comprised a mixture of blue and yellow pigments. Mud bricks were the main substrate on which these types of plaster were used to cover both the walls and the columns.

85. Investigation study using of Laser-Induced Breakdown Spectroscopy (LIBS) on analysis of Historical Embroideries

Harby E. Ahmed1,2, Yuan Liu1, Matthieu Baudelet3, Martin Richardson4

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2) Department of Conservation, The College of Archaeology, Cairo University, Egypt.

Embroideries were one of the most sumptuous kinds of textiles produced in the world. In the present work, we studied the use of laser induced breakdown spectroscopy (LIBS) and other methods to Egyptian historical textiles analysis. The textile object was shown in cases no 124/3 in the museum of the Faculty of Applied Arts, Helwan University, Egypt.

The current research project focuses on the use of LIBS in the field of historical textiles conservation, especially the; investigation of metal threads embedded in antique samples. The chemical information was studied as a function of laser energy and irradiation regime and the number of laser shots used for the analysis. In parallel, the laser induced damages during the analysis was measured. A Q-switched Nd:YAG laser (Brilliant, Quantel) operating at its second harmonic wavelength (532 nm) at 10 Hz repetition rate with a 5 ns pulse duration FWHM was used in this study. The light emitted from the plasma plume was collimated by a lens (25 mm diameter with focal length 38 mm) and then focused into a UV transmitting optical fiber by a second lens (25 mm in diameter with focal length 60nm). The spectrometer (Acton 2300 Acton 2306i, Princeton Instruments) was equipped with an ICCD camera (Pi-MAX2, Princeton Instruments) providing a pixel resolution up to 0.04 nm/pixel. Different numbers of LIBS shots were studied. Different laser pulse energy values such as 10, 20 and 30 mJ were studied. The morphology of the surface of metal threads was investigated before and after LIBS analysis. Furthermore elements composition was confirmed of the metal fibers by Scanning Electron Microscope (SEM) with energy dispersive X-ray analyzer (EDX) – ULTRA 55, ZEISS).

According to our results, LIBS for the analysis metal threads has key features which make it an attractive analytical technique by its simple implementation, the speed of analysis, the simple preparation of samples and the ability to achieve high spatial resolution nearly non-invasively.

References
and X-ray diffraction analysis were carried out. Moreover, in particular, to investigate petrographic and mineralogical features of some samples were collected from the masonry walls of houses, thermae, tabernae and warehouses. In particular, remains of the ancient Roman city of Baiae and Portus Iulius are submerged after bradyseism events, started in the IVth century AD. Several architectural structures are still preserved into the submerged environment, such as buildings, streets, arches, and belong to Planalto tradition, which are common in the Itararé-Taquara farmers and ceramists of Jê linguistic family, from 4,000 to 500 years BP. Rock art of this site is one of the most important and representative materials of the ancient material culture, in order to contribute to the history of the late Classical and Hellenistic painting, as they preserve the decorated cist tombs, the stone sarcophagi or even the painted decoration of the tombs, combining archaeological and archeometrical research has begun. The aim of the research is to examine the techniques and materials used and trace the different artistic trends and the reciprocal influences in the ancient world.

Standard analytical methodology for the study of these stratified works of art has been applied in order to reveal the basic components and suggest the painting techniques used for the realisation of the wall paintings. As yet, Optical and Polarised Light Microscopy, μ-XRF, XRD, SEM-EDS and FTIR have been applied in more than 100 samples, collected from fragments already detached from the wall surface, either found on the interior of the tombs or in the storage rooms of the Archaeological Service concerned. Twenty-two monuments, on which no previous analysis had been conducted, were selected, and an effort was made to include all tombs types and represent as more regions as possible. They vary in terms of decoration themes and are located in archaeological sites near seven major cities of Macedonia such as Thessaloniki, Amphipolis and Markopoulo.

This poster presentation will focus on the results concerning the inorganic materials comprising the pigments and the mortars used. Regarding the pigments, the preliminary results cover almost the entire palette of the ancient Macedonian painter. Ferrous compounds provide the majority of the reds, the yellows and the browns but there are more rare materials such as cinnabar or orpiment, used mainly to emphasise the details of the decoration. Mixed with yellow ochre or a ferrous red creates a rich brown, which is one of the most used in ancient wall painting. Lead white is present in the samples. All these e can be mixed with carbon black or calcite for the darker or lighter hues. Lead white is observed, although much less often than the usual white of calcite.

Reference
**NARIA** (New Archaeological Research Network for Integrating Approaches to ancient material studies) ITN (Initial Training Network) Project 2014-2017

This interdisciplinary project aims to provide young researchers with the means and analytical skills to conduct research on ancient material culture, in order to contribute to the history and archaeology of the Eastern Mediterranean basin.

POSTER ABSTRACTS

**86. Archeological materials of the submerged site of Baia (Naples, Italy): production technology of mortars and bricks**

Aloise Piergiorgio, Buffolo Silvestro Antonio, La Russa Mauro Francesco, Belfiore Cristina Maria, Barca Donatella, Gneo Michele Cricci

The present study belongs to the framework of the Italian National research project called “COMAS” (Planned Conservation, in situ, of underwater archaeological artefacts).

This work aims to evaluate the features of archaeological bricks and mortars taken from the archaeological area of Baia, (Naples, Italy), an important site, where the remains of the ancient Roman city of Baiae and Portus lulius are submerged after bradyseism events, started from 15th century AD. Several architectural structures are still preserved into the submerged environment, such as: luxurious marble villas, imperial buildings, private houses, thermae, tabernae and warehouses. In particular, some samples were collected from the masonry walls belonging to a building of the underwater area called Villa a Prostro.

Amultianalytical approach has been applied to analyse thirty archaeological samples in order to define: mineralogical and chemical composition, textural features, raw material and firing temperature.

In particular, to investigate petrographic and mineralogical features, observation under polarizing microscope (POM) and X-ray diffraction analysis were carried out. Moreover, morphological and microchemical SEM-EDS analysis have been performed to evaluate some specific technological features of the analysed samples.

The study revealed two different production technologies of bricks, since they show two different tempers. In addition, two types of mortars were found, one of them characterized by the presence of cooccipesto and marble fragments.

**87. Rock Art at Morro Azul caves in Paraná State, Brazil: an in situ XRF and Raman study**


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Until recently, the pictograph fragments were analysed by using destructive chemical methods or taking samples for laboratory to more refined methodologies, destructive or non-destructive ones. In this study are presented the results of using a portable Raman and EDXRF system to the characterization of rock art pigments at Morro Azul Caves in Brazil. Morro Azul archaeological site is the biggest set of rock art paintings actually known in South Brazil, located in Ventania municipality, Paraná State, Brazil. They are over sandstones and diamictites of Itararé Group, since they show two different tempers. In

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**88. An Analytical Study of the Inorganic Materials Used in the Funerary Wall Paintings of Ancient Macedonia**

Lydia Avlonitou


The funerary monuments in the area of ancient Macedonia (Northern Greece), namely the famous Macedonian tombs, the decorated cist tombs, the stone sarcophagi or even the humble pit tombs, form a remarkable source of evidence on late Classical and Hellenistic painting, as they preserve compositions executed in the techniques formulated at the end of the 5th and in the 4th cent. B.C. In the framework of the interdisciplinary European project NARIA ITN, an integrating approach to the study of the painted decoration of the tombs, combining archaeological and archeometrical research has begun. Focused on the vegetal and geometric motifs, the aim of the research is to determine the techniques and materials used and trace the different artistic trends and the reciprocal influences in the ancient world.

Standard analytical methodology for the study of these stratified works of art has been applied in order to reveal the basic components and suggest the painting techniques used for the realisation of the wall paintings. As yet, Optical and Polarised Light Microscopy, μ-XRF, XRD, SEM-EDS and FTIR have been applied in more than 100 samples, collected from fragments already detached from the wall surface, either found on the interior of the tombs or in the storage rooms of the Archaeological Service concerned. Twenty-two monuments, on which no previous analysis has been conducted, were selected, and an effort was made to include all tombs types and represent as more regions as possible. They vary in terms of decoration themes and are located in archaeological sites near seven major cities of Macedonia such as Thessaloniki, Amphipolis and Markopoulo.

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89. A multi-disciplinary approach for studying Michelangelo’s drawings

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3. Casa Buonarroti, Firenze, Italy.
4. Several drawings by Michelangelo Buonarroti (collection of Casa Buonarroti in Florence, Italy) were examined in-situ by non-invasive analytical techniques such as Multispectral Reflectography (MSR), Fourier Transform Infrared Spectroscopy (FTIRS), and X-Ray Fluorescence (XRF). The restricted material palette and the materials’ low concentrations present in drawings make the biochemical survey challenging. Multispectral reflectography is a well-established technique for the non-invasive inspection of canvas and easel paintings. Especially in combination with other analytical methods it can provide information on the spatial distribution of constituents across the entire examined area. The technique was used to support historical information and to perform non-invasive sampling of materials. For MSR, a scanning instrument with a single spot, for respectively elemental and molecular analyses, was used to collect 30 measurements of reflectance in three minutes. For XRF, scanning was performed to collect 10 samples from different areas on the canvas. The results were reported on a geometric survey allowing for an accurate visual examination at different scales in order to identify and map the distribution and composition of dark washes and highlights. The multi-disciplinary approach provided some key elements for gaining a further insight into Michelangelo’s creative process by recognizing several types of inks (iron-gall, carbon-based, red ochre) and their distribution, and assuming the method of use of materials. For example lead white had several functions such as enhancing some pentimenti, outlining particular areas, and preparing the paper before drawing.

90. Features of a Roman Clay Plaster (Brixia, Lombardy, Italy)

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A particular kind of plaster containing clay was identified in a Roman republican sanctuary (first century BC, first half) unearthed in 1992 near the Flavian Capitoline of Brixia (today Brescia, Lombardy). The examination of different samples by different analytical methods (X-ray diffraction, Optical microscopy, Scanning electron microscopy, Infrared Spectroscopy) showed that this plaster sample (US 592), situated near the vault of the Sanctuary of Brixia is probably connected preparing the paper before drawing. For example lead white had several functions such as enhancing some pentimenti, outlining particular areas, and preparing the paper before drawing. The plaster examined in the Sanctuary of Brixia is probably connected to the use of creta in vault rendering (De Arch. 7.3.3): in this case the clay could act as a powdered marble. Other clay-based plasters were found in some archaeological sites of Lombardy (Calvainate Bedriacum, domus Labirinto - Scavo sud, Saggio Beta 96; Milan, domus via Correnti 24 - US 219), but they were related to Eave in wall construction as reported by Vitruvius (De Arch. 7.3.11).

91. Influence of synthesis conditions on growth of Egyptian Blue

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Egyptian Blue (EB) was found as early as in the fourth dynasty. It spread to the Aegean and Mesopotamian areas as early as the third millennium BC and was used throughout the Greek and Roman periods until the ninth century AD. Pompeian blue is similar in chemical composition and in optical properties to the ancient EB, but it is purer and finer. The secret of its manufacture was lost between 200-700 AD. Its principal component iscalcium-copper silicate crystals (i.e. cuprorivite, CaCuSi4O10) which is blue in colour. However, the crystals can vary in colour from deep blue to faint, depending on whether EB contain glass phase, silica phase (quartz, cristobalite, tridymite) and copper oxide as impurities. The synthesis of this pigment “caeruleum”, described by Vitruvius in De Architettura in the first century BC, was performed by heating at 830-1050 °C. A mixture constituted by siliceous sand (angular quartz pebbles or rounded quartz sand), lime (limestone, calcium carbonate) copper compounds (malachite, cuprite, copper) and a flux (natron, plant ash). The mixture constitutes EB shows a wide variety of possible sources of materials and temperature of formation. As regards preparation of EB, the quality of EB remains open. The different types of materials used to produce EB may have a specific archaeometric meaning. In the context described here, and in the light of the potential archaeometric implications, the present work aimed at determining the influence of various synthesis variables (T, t, materials) on the preparation and features of grown EB. Several runs were carried out at temperatures between 800 and 1050 °C and with reaction times ranging from 10 to 72 hours. Samples were all examined under a binocular microscope (20 x), by X-ray Powder Diffraction (XRPD), scanning electron microscopy with energy-dispersive spectrometry (SEM-EDS), and their color were studied by Konica Minolta Spectrophotometer combined with standard illumination D65, including the specular component (measuring area: 8 mm). EB growth seems to be closely related to the starting materials used. On the whole, the best synthesis conditions for the EB (i.e. cuprorivite) occur at 900 °C for reaction times of 24 hours.

92. Petroarchaeology and Architectural Stratigraphic Research of the Visconteo Castle in Locarno, Switzerland

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Main goal of the research is the assessment of the role played by the architectural and scientific studies to support the knowledge of modification occurred during the centuries on the main facade and the courtyard of the Visconteo Castle in Locarno, Switzerland. The research on the renders was initially conducted throughout the available historic documentation and accurate visual examination at different scales in order to understand the technical characteristics of the surfaces and to establish a possible relative chronology of the diverse phases related with the modification of the castle. The results were reported on a geometric survey allowing for the detection of different renders grouped in the different categories. The visual examination allowed to make hypothesis on
the relative chronology of the renders related with the modification occurred on the monuments during the centuries based on formal, stylistic, textual and functional characteristics.

The compositional and technical differences are associated with their specific function: the 15th c. renders exhibit a symbolic and decorative function on large areas; later renders are the result of limited restoration works with no formal requirements. The last restoration works carried out by Berta during the early of the 20th c. are aimed at the reconstruction of the missing parts.

A research program was carried out by means of PLM integrated with SEM/EDS in order to understand possible differences between the different renders. Binder aggregate (b/a) ratio was determined through weight before and after binder dissolution of the samples and the grading curve by dry sieving.

All the collected samples corresponding to different chronological phases exhibit similar compositional characteristics. Alg time was used as binder and aggregates are represented by silicious sands coming mainly from the weathering of gneiss rocks; minor differences - in trace - are related with the presence of grain of different types (serpentinites, amphibolites, schists).

The samples corresponding to the last restoration works carried out by Berta during early 20th c. are completely different from the previous ones as it is composed of Mg-lime and calcitic fragments (marmorino). In this case b/a ratio was determined comparing the sample with mortars of known design.

The proportion of the mixes allowed to group the samples in different types corresponding to various b/a ratio and to compare it with the hypothesis of the chronological phases.

In conclusion, the scientific research was not able to support the macroscopic differences of the renders as the composition of the components (binder and aggregates) is very similar even if macroscopic differences were clearly identified. Finally, we should be aware that the scientific research can, in some cases, help to support the visual identification. Groups of renders, the provenance of the sands and grains of different types (serpentinites, amphibolites, schists) are related with the presence of grain of different types (serpentinites, amphibolites, schists).

93. Use-wear Evidence and Functional Information on Lithic Tools at Wulanmulun site, Inner Mongolia, China

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4. The Wulanmulun site is located in the north side of Wulanmulun River, Ordos City of Inner Mongolia, with an age of 50-60 ka. About 4200 stone artifacts, 3400 fossils and loads of hominid use of fire are uncovered. This is another important discovery of prehistoric culture in Ordos area beyond the Salawusu site and Shuidonggou site. The objective of this study is to explore tool function and human behavior in Wulanmulun site during Middle to Late Pleistocene. We have selected stone artifacts discovered from Locality 1 of Wulanmulun site in 2010 for use-wear analysis. Because raw materials of Wulanmulun artifacts are quartzites, which appear to be in a variety of poor-quality and rough surface, we therefore employ the low-power technique. In the first stage’s analysis, we have pick out 283 specimens, accounting for 20% of the artifacts unearthed in 2010, including flakes, scrapers, knives, arrowheads, notches and denticulates.

The analytic results suggest that 134 specimens retain use-wear, accounting for 47.3% in the observed samples. Many stone artifacts display used wear, and several show hafting wear. The tools motion is dominated by slicing and cutting/sawing, and the mainly contact material is animal substances. It is suggested that animal substances might be utilized in Wulanmulun site, since lots of animal bone fragments with obvious cutting traces were found in the site. As well as the burnt bones and use of fire, flesh processing therefore might be one of the main use-tasks at Locality 1 of Wulanmulun site.

94. Characterization of Natural and Artificial Stone Materials from S. Niccolò Archaeological Complex in Montieri (Tuscany, Italy)

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S. Niccolò archaeological site is situated on the northeast side of Montieri Hill (Southern Tuscany), in an ancient mining district. Ruins of the medieval ecclesiastical complex were discovered during recent excavations and consists of: a peculiar church, characterized by six apses; an annexe to the church; a productive area; a central place, interpreted as porticoed cloister; a great number of tombs. This archaeometric study is aimed to deepen the knowledge of the historical site through the characterization of natural and artificial (mortars, plasters and bricks) building material rests. The petrographic analysis was performed on the thin sections by polarized light Optical Microscopy. Mineralogical and chemical composition was determined by XRPD and XRF, respectively. Textural and chemical micro-analysis were carried out by SEM-EDS.

Preliminary petrographic study indicates that quartziferous-feldspathic-micaeous sandstone was utilized for the foundation walls of the complex, while the outer walls are mainly constituted by marly limestone and calcareous tufa ashes. A petrographic, mineralogical and chemical study allowed us to distinguish various typologies of mortars, characterized by different aggregate and binder as well as by variable aggregate/binder ratios. The various aggregates are constituted of minerals and lithic fragments. The most common minerals found were quartz, plagioclase, muscovite and calcite; sandstone, limestone, shale, quartzite, and phyllite were the most widespread lithic fragments. Shards of glasses, coal, metallic slags and crushed ceramic fragments (cocciopesto) were also identified. In the majority of samples the binder is weakly hydrated and it shows a moderate hydraulicity in the samples containing slags or cocciopesto. The archaeological and microscopic data suggest a development of the site in different successive phases. The church was built during the most ancient one. The mortars sampled from all the six apses of the church belong to an unique typology, so that it can be ascribed to a single building phase. The fragments of metallic slags were observed in the mortar’s aggregate of the annexe, of the productive area and in the complex entrances, but they are lacking in the church.

The use of slags as constituent of mortar’s aggregate could be due to an evolution of building technology, with respect to the church, when probably the metallic activity have not yet started. These preliminary results represent the starting point for the future provenance study of the raw materials, in order to plan compatible products for restoration of the archaeological heritage.

95. The use of hunte in the antiquity. A review with respect to ongoing studies in the archeological site of Hierapolis in Phrygia (Turkey)

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Hunte, CalMg(CO3)4, described and firstly identified as a separate mineral species in 1953 by Faust, is known to occur mainly: 1) by weathering process of magnesite, dolomite, develope deposits (Faust 1953) or simply in dolomites (Skinner 1958), or in serpentized dolomites (Golovanov 1959); 2) as a product of precipitation in caves as a component of “Montmilch” which is deposited from water that has seeped through Mg-rich rocks (Baron 1957), or associated with aragonite, calcite, hydromagnesite and dolomite, probably as an alteration product of hydromagnesite (Tosbiiil 1960); 3) as early diageneric products of Mg-rich solutions in pore waters of supratidalitevaporitic environment (Kinsman...
676) or in salt lake deposits by diagenetic transformation of calcite, aragonite, dolomite and hydromagnesite (Irion & Muller 1968). Several studies have shown that huntite mineral was already used before Greek and Roman Periods. On the basis of the results of the work of Barbieri et al. (1974), related to a discovery of 10 Kg of a white substance in a wooden box in a shipwreck in the Gulf of Prochio (Elba Island, Italy) the huntite was known and traded in the III and IV centuries A.D. Its properties, such as the extreme fineness and with colour, together with the fact that it forms a good, dense coating material, suggest that it has been used as a pigment or as a cosmetic. Furthermore, a possible medicinal use may also be considered, on account of the study of Riederer et al. (1974), first discovered the use of huntite as pigment on Ancient Egyptian artefacts at the Museum of Egyptian of Art in Munich. The white pigment was found on two bowls and several sherds dated back at1600 BC and later identified as huntite. For many years it was thought that huntite was a very rare and prestigious pigment in Egyptian art and may have been restricted in use to specific social or religious groups (Ambers 2004). However, it has now been identified in an increasing number of contexts (Heywood 2001, Middleton & Humphrey 2001) and it seems likely that its apparent limited distribution may have owed more to the ability to identify the pigment than to its actual pattern of use. Heywood (2001) carried out an extensive study of Ancient Egyptian, painted artefacts in the collections of the Metropolitan Museum of Art in order to determine the actual use of huntite. The results showed that huntite was used for common objects as well as for those produced for royalty. Huntite continues to appear frequently during the Late, Ptolemaic, and Roman Periods. The huntite mineral was originally used as a restoration material, like adhesive, sealant, anti-corrosion. In this contribution the authors will present a critical analysis of the literature and the research results about the previous hypothesis and some new data about restoration measures and materials that were part of the ancient technological know-how. The use of huntite in Hierapolis is also very interesting because, according bibliography, it is not present in the valley of the Çirkuş River (ancient Lykos), where the ancient city lies. But the main quarrying district of this diDistrict in south-western Turkey is located in the Acipayam area (Denizli Province), about 60 km south-east of Hierapolis (Seki et al. 2013); these huntite mines are on the plateau crossed by the ancient main road between Hierapolis itself and the ancient coastal cities of Pamphylia (such as Antalya, Perge, Aspendos, Side), from where the huntite mineral could be exported in the Mediterranean Basin. This research activity has been co-founded by the Ministry of Education, Universities and Research in the framework of the FIRB project “Marmora Phrygiae”. References


96. Mobile Hyper-spectral imaging for the non-invasive study of a mining paint from the Belves Castle (France, 15th C)

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The paintings (15th century), situated in the last floor of a medieval house (Belves Castle), today transformed into attic, represent an important example among the civil pictorial production of the end of the Middle Ages in France, by the iconography and the aesthetic qualities. The theme is the “Nine brave knights”, group of legendary and historical heroes, carriers of the chivalrous virtues for the old aristocracy of the late Middle Ages [1]. The painting was made on the wall of the medieval “false-blue” pigments for which the perception of certain grey pigments seems bluish [2]. Measures of colors, physico-chemical analyses (SEM/EDS, Raman) and spectro imaging were led to characterize these pigments. Spectro-imagery associates reflectance spectra with each pixel of the image and treat the signal received in various wavelengths. The characteristics of the spectral signal in VIS range (UV fluorescence) or NIR, are used to get an identification and localization (mapping) of the components (binders, pigments) [3] [4]. The specificity of the used equipment (SPECIM) is its mobility which allows it to be used in situ analyses. A methodological development of the technique as well as preliminary tests on reference pigments, allowed to validate the analytical parameters and to establish a database of spectral references. An ACP analysis gives a spectral signature of these paintings and the mapping of the pigments highlight the original paintings and the previous restorations.

References


Keywords: Hyper spectral imaging, pigments, mural paintings.

97. Non-Destructive Analysis of Green Stone Royal Burial Offerings from the Maya Site of Palenque, Mexico

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Mesopotamian cultures used more than a dozen varieties of green and blue minerals with four main uses: funerary, ornamental, ritual and utilitarian. For this, multiple stone-minerals were used, including serpentine, quartz, amazonite, turquoise and jadeite. Due to its hardness, durability and beauty, jadeite was considered one of the...
most valuable of these green stones. The scarcity of this mineral made it exclusive for the elite classes and they used jadeite in many different forms and ornaments, as is demonstrated in the sumptuous funerary objects and royal burials found in various buildings in the city of Palenque. Palenque is considered one of the most important Mayan cities known. Its splendor is demonstrated via its architectural achievements and the many burial offerings from several royal tombs in Palenque from the Classic Period (400-700 A.D.). More than one hundred pieces were studied by a combination of non-destructive in situ techniques, namely colorimetry, X-ray fluorescence (XRF), Raman and Infrared Spectroscopies (FTIR).

Although many of the pieces have been historically considered jadeite, our study revealed a wider variety of minerals, including jadeite, olivine, amphibole, green quartz, among others. Mineral identification was achieved primarily by FTIR and confirmed by Raman while elemental composition information obtained via XRF can be related to possible mineral sources in Mesoamerica. Main results and the chronological and material comparisons between several royal tombs are presented.

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98. Surface analysis and materials characterization for the study of biodeterioration and weathering effects on Gaogouli’s Stone Cultural Heritage

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Gaogouli’s Stone cultural heritage provides a habitat for an array of microorganisms, many of which have been demonstrated to have a deleterious effect in the appearance and/or structural integrity of stone masonry. It is essential to understand the composition and structure of stone-dwelling microbial communities if successful stone conservation strategies are to be applied. Several methods for stone cultural heritage and surface analysis such as scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDX), conventional X-ray diffraction (XRD) have been used for assessing weathering and biodeterioration effects on Gaogouli’s Stone cultural heritage. The results show that the biological effect is extremely serious, which includes the plant and the microorganism, especially the lichen and the fungus. Biological effect has badly changed the original condition of these Stone cultural heritage, the biological secretion created by these living creature also can destroy the stone. In order to prevent and control the serious biological weathering, focusing on the lichen and the fungus from different position on the surface of these Stone. Lichens, mosses, and liverworts are easily identified using visual observations in the field and in the laboratory through microscopic diagnostic methods. The microbial investigations carried out were mainly based on classical cultivation studies.

Twenty samples were taken from the outer surfaces of stone monuments of the Gaogouli’s Stone cultural heritage. Biofilms developing on mineral substrates were analysed in situ scanning electron microscopy and classical cultivation studies. Analyses revealed complex fungal communities, which include Penicillium cyclopium, Curvularia lunata, Penicillium implicatum, Phymocytos, the lichen is Xanthoparmelia mexicana (Geyen) Hale. The paper also covers the protection methods of Gaogouli’s Stone cultural heritage. To identify the most suitable biocide treatment, different products were evaluated in situ. MEIDI was a compound invented by the Northwest University, which show the most effectiveness in our experiment test. The results show that MEIDI is a better agent for preventing biodeterioration than other tested conventional biocides, both in mortars slabs and in situ studies. After five years of treatments application shows that lichens and other microorganisms disappear from the places where MEIDI was applied.

99. Contextualizing Bronze Age Obsidian Use at the ‘Ritual Spring’ of Mitza Pidigli (Sardinia)

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This study focuses on obsidian consumption at the ‘ritual spring’ of Mitza Pidigli in west-central Sardinia, Italy. The site dates to late Nuragic I to Nuragic III phases of the Bronze Age (c. 1350-850 B.C.) and is found just east of a contemporaneous residential village. Mitza Pidigli consists of a natural spring surrounded by an oval-shaped construction of basalt blocks approximately 15 x 6 meters in size, a common construction type found throughout the island hypothesized to be related to a range of ritual activities. While recent years have seen a surge of archaeological literature on the subject of obsidian exchange networks and lithic reduction sequences at contemporaneous residential sites throughout the island, there has been no consideration of obsidian use in other archaeological contexts, a research bias that this presentation aims in part to redress. In total, 801 chipped stone artifacts were recovered from Mitza Pidigli, of which approximately 78% was obsidian and the remaining material black/gray ryholites. For this study, 142 obsidian artifacts from the site were analyzed non-destructively at the McMaster Archaeological XRF Laboratory (MAX Lab) using a Thermo Scientific ARL Quant’X EDSXR spectrometer to determine their geological origins. The samples were run under two analytical conditions to generate data (in ppm) for the elements iron (Fe), zinc (Zn), rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), niobium (Nb), and barium (Ba); elements already shown to be successful in distinguishing between the various West Mediterranean sources and subsources. In addition, each artifact was analyzed techno-typologically to allow for the reconstruction of the entire chain of events leading up to an artifact’s discard. The sourcing results show that obsidians from all four Sardinian subsources are represented at the site, although most come from just one outcrop; this pattern is similar to other Nuragic sites on the island. The typological analysis indicated that the artifacts were physically knapping obsidian near the well to create expedient knife tools and non-prismatic blades. While differences do exist between the reduction sequences seen at Mitza Pidigli and those from contemporaneous residential sites, these disparities are not significant. These results therefore have important implications in interpreting the social, economic, and symbolic function of Mitza Pidigli and in understanding the role of obsidian use outside of domestic contexts.
carbonate and other bio-mineral features like the phosphate bands of apatite, which are main indicators of bone or dentine. The ability to distinguish between the different carbonate phases by Raman spectroscopy is another advantage of this method, since most mollusks and stony corals are of aragonite, while Corallium rubrum always consists of calcite. Unfortunately, some shells like Spondylus show the same Raman features (pigments plus calcite) as C. rubrum. This is why an additional microscopic investigation of the surface structures is important, e.g. to search for the very rare venuccia structures of red corals. After this first step, a success rate of already 90 % of identified materials can be reached only using microscopic and Raman spectroscopic analyses.

For the remaining cases we suggest a complementary examination using XRF and XRD to distinguish between coral and mollusks, which is the most difficult case together with the differentiation between bone and ivory. This multi-stage approach enables a fast identification of bio-minerals with a success rate of almost 98 %. We analyzed numerous fibulae, helmets, daggers or necklaces from Celtic tombs and several princely seats.

101. Soft X-ray Absorption Spectroscopy of Sulfur in Lapis Lazuli

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Since antiquity, lapis lazuli has been highly valued across many cultures for its bright blue color. While the most well-known source of lapis lazuli is Afghanistan, there are other sources, including sites in Tajikistan, Russia, Canada, and Chile. Because of the significance of lapis lazuli, there has long been interest in understanding the color variations of the mineral and determining the geographic origin of lapis lazuli, whether used as the processed pigment ultramarine in painted works of art (e.g., paintings and manuscripts) or the raw stone in cultural heritage objects (e.g., jewelry and inlaid decorations). Naturally occurring lapis lazuli contains the blue mineral lazurite along with other minerals, such as calcite, pyrite, diopside, and sodalite, among others. Work in our laboratory identified characteristic fluorescence from the minerals associated with lazurite that showed a distinct variability with geographic origin.1 Expanding on our previous work, this study focuses on the lazurite component of lapis lazuli. Lazurite has been broadly defined as (Na,Ca)Ba4Al6Si6O24(SO4,5,Cl)2, a member of a larger aluminosilicate-sodalite group of minerals in which the sulfur species are trapped in an aluminosilicate cage.2 We are investigating the sulfur speciation within the aluminosilicate cage of lazurite—using a diverse sample set of both lapis lazuli and ultramarines pigments from many origins including Afghanistan, Russia, and Chile—as a potential means for identifying a geological fingerprint.3 Sulfur x-ray absorption near edge structure (XANES) spectroscopy was performed on the samples using the newly developed soft X-ray Beamline (14-3) at the Stanford Synchrotron Radiation Lightsource (SSRL). The data gathered allow sulfate, polysulfide, and thiosulfate species, and their distributions within a sample, to be characterized, which facilitates comparisons of these species between geologically diverse sources. As a whole, our work not only contributes to a deeper understanding of lapis lazuli but also illustrates the potential of soft X-ray analysis for cultural heritage research.

References

102. Identification of provenance markers in Lapis Lazuli: a study on rocks and artworks

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Lapis lazuli is a blue semi-precious stone used for more than 7000 years for carving decorative objects and jewels. The high value of lapis lazuli as a raw material was related to the very few quarries in which it can be found. Despite the Afghan mines are nowadays widely considered the only quarries in ancient times, some archaeologists report that the exploitation of other quarries could have been equally well-founded.1 An exhaustive provenance study on lapis lazuli is still lacking and it could shed light to many questions regarding the old trade routes. This ongoing research is based on a multi-technique approach and divided in two phases. The first phase consisted of an extensive X-ray chemical characterization of rocks from known provenances to identify peculiar markers of the various quarries. We studied a total of 46 rocks samples coming from different sources: 19 from Afghanistan (Badakhshan), 4 from Tajikistan, 13 from Lake Balaikai area, and 10 from Chile (Ovalle). Markers were searched by means of microscopic techniques[2,3], such as optical microscope, Cathodoluminescence, Raman spectroscopy, Scanning Electron Microscopy (SEM-EDX), Ion Beam Analysis (IBA) and µX-ray-Fluorescence. We looked for the presence/absence of mineral phases, peculiar luminescence features and trace elements composition of minerals themselves[5]. The second phase of the work was the development of a non-invasive protocol based exclusively on IBA techniques (mainly micro-PIXE: Proton Induced X-ray Emission and micro-IL: Ionoluminescence) and µX-ray-Fluorescence that are techniques suitable on artworks. In this way we was able to carry out some preliminary measurements on valuable pieces of collections belonging to different museums: the Museum of Natural History of Firenze (“Collezione Mediche di pietre lavorate”) [4], the Egyptian Museum of Firenze (New Kingdom amulets and pendants) and the Regional Museum of Natural Science of Turin (some polished items of the 19th century “Collezioni Sabauda”). The first results demonstrated the applicability of our approach, and allowed to suggest the origin of the raw material used for precious objects or archaeological findings. These achievements encourage to increase the experiments on artworks and also to improve the statistics on rocks samples.

References

103. Towards portable X-ray spectroscopic imaging of Palaeolithic cave art. Insights into used pigments and wall taphonomy in three Palaeolithic key cave sites

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Palaeolithic cave art has taken a more and more prominent place in our cultural heritage. Its preservation is one of the major issues and involves necessarily a better understanding of the cave environments and of their evolution. However, the on-site geo-physics-chemical study of archaeological record stays difficult and the conservation of its integrity imposes restrictions. Taking benefits of recent analytical developments in the X-ray field, new perspectives of acquiring statistically relevant data for archaeochemical interpretation directly in the field are provided by the implementation of portable and non-invasive characterization methods. It allows the improvement of archaeological and physico-chemical knowledge about the pigments used, the evaluation of the state of wall decorated surfaces over time and a better assessment of the relationship between pigment and wall.
support. For these purposes, complementary self-built portable spectrometers (X-ray fluorescence in one and two dimensional mode, X-ray diffraction) are combined to perform qualitative and quantitative characterization of the pigments and cave walls as well as for chemical imaging on a decimetre scale. By using this combination of portable instruments the feasibility of analysis under very difficult conditions specific to the cave environments (humidity, temperature, difficulty access to the caves and to the decorated panels) was shown. Special spectrum evaluation procedures have been developed to take into account the heterogeneity of the cave walls in order to gain reliable data for chemical characterisation. The efficiency of the analytical procedure developed, has been demonstrated for three major cave sites featuring Paleolithic art: Font-de-Gaume and Rouffignac cave in Dordogne (France) and La Gárma in Cantabria (Spain). A large assortment of colours can be observed in these caves (red, black, yellow and purple), associated to different mineral phases (iron and/or manganese oxides, charcoal and mixtures). Their detailed characterization provides an improved comprehension of the pictorial techniques used. Furthermore, it allows a better comparison between representations found in the same cave, giving more detailed insights into their pictorial homogeneity and the different execution phases of its figures. As an example, the results obtained at Rouffignac cave showed that heterogeneous mixtures of manganese oxides have been employed to design the Great Ceiling figures whereas a unique pigment mixture has been used for the drawing of the Ten Pigments – a mixture of Cinnabar (HgS) and Zinc White (ZnO2) – caused significant S concentrations to occur in the cupola walls or capillarity, bringing pollutants such as those microbial species responsible for the formation of gypsum-sulphurous crusts. This fact, coupled with those aspects. Dampness percolating from outside, due to cracks in the cupola walls or capillarity, brought pollutants such as zinc and other metals), favoured colonization of a first-generation microorganism. During the course of research project “Conservation and Restoration of the peripheral monuments of the archaeological site of Knossos (“High Priest’s House”, “Royal Villa”, “Royal Tomb”), funded by the European Union, implemented from June 2011 to date and carried out by 23rd Ephorate of Prehistoric and Classical Antiquities, conservation applications are taking place on the “High Priest’s House”, which is located south of the Palace of Knossos. The restoration took place during the winter period of 2012 – 2013 and the need for collocation of the route of the rain water became compelling. This need became a necessity since the state of preservation of gypsum-sulphurous crusts in the west part of the monument was critical. As a result of the restoration applications, a part of the stone drain covered by the first of the three steps leading to the adyton came to light. The Investigation of the Excavated Duct in the “High Priest’s House”, a Peripheral Monument of the Palace of Knossos.

105. New Evidence About the Use of Ophionites in the Minoan Architecture.

Grammatikakis Ioannis1, Anagnostaki Georgia1.


During the course of research project “Conservation and Restoration of the peripheral monuments of the archaeological site of Knossos (“High Priest’s House”, “Royal Villa”, “Royal Tomb”), funded by the European Union, implemented from June 2011 to date and carried out by 23rd Ephorate of Prehistoric and Classical Antiquities, conservation applications are taking place on the “High Priest’s House”, which is located south of the Palace of Knossos. The restoration took place during the winter period of 2012 – 2013 and the need for collocation of the route of the rain water became compelling. This need became a necessity since the state of preservation of gypsum-sulphurous crusts in the west part of the monument was critical. As a result of the restoration applications, a part of the stone drain covered by the first of the three steps leading to the adyton came to light. The position of this stone drain was designated by Sir Arthur Evans in his 1906 work The Palace of Minos. A preliminary results of the investigation for the determination of the material of the drain revealed the presence of Christolite a characteristic mineral of the family of Ophionites. Although the use of this type of stone is limited in Minoan architecture, this is the only case where it is used for making a drain. The analytical techniques used in order to specify the mineralogical phases of the stone were X-Ray Diffraction (XRD), Differential Thermal Analysis (DTA), Thermogravimetric analysis (TGA) and Scanning Electron Microscopy (SEM-EDS). The combination of the results from the analytical methods with the archaeological and geological bibliography in regards to the Minoan quarries as well as the ophionite - bearing melange on the Island of Crete, excluded several outcrops. Further analysis of samples from most of the ophionite outcrops that are related to Minoan quarrying and comparison with the sample from the drain indicates two specific positions.

106. Archaeometric Characterization and First Distribution Study of a Spanish Marble Used in Antiquity: The Marble from O Incio

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During the last decades, the characterization and study marble use in Roman Spain has leapt forward yet some areas, such as the northwestern territories, remained quite obscure as they still lack significant work. Thus, we addressed the study of this region with the aim of not only to gather data to determine which marbles reached an area as far apart from the Mediterranean as Gallaecia but to do so from an interdisciplinary perspective to enable a chronological sequence of the present as well to understand of the trade routes and mechanisms of the economy and society that produced or enjoyed these objects. The work presented here is part of an ongoing project and stems from the fact that a significant number of a first marble objects assemblage did not match the features...
of the main well-known Classical marbles but seemed to have been produced with a local stone known as O Incio marble which had not been yet characterized. Therefore, we focused on sampling of the quarries near the small village of O Incio to identify and adequately characterize the different occurring marble varieties as the first and basic step to correctly differentiate from other Spanish or even Mediterranean marbles. Petrography, cathodoluminescence CL and, in some cases, IRIS for C-O isotopic determination were applied and enabled to distinguish at least three significant varieties: a) a poorly crystaline banded fine-grained marble or marble limestone, with fine white and gray bands of varying tone or shade (it is the most abundant variety), b) a fine-grained limestone, with orange veins and occasional centimetric gray bands, and c) a greyish "marble", which in fact is a gray, crystalline limestone with gray sheets of different tones. Furthermore, eight out of the nineteen objects analyzed so far turned out to match these varieties; their distribution in through the territory gives a first glimpse of this marble diffusion, which to this point reaches as far as 130km from the outcrop.

The high presence of O Incio marble in the archaeological context and its wide chronology (between 2nd and 7th centuries AD) confirms a long life of this marble extraction and use, which in some cases may be related to its slight resemblance to other, more prized marbles (i.e. grey, banded marbles from the Eastern Mediterranean or banded varieties of Estremoz). The archaeometric characterization provides the basic essence upon which pursue further research.

**107. Microbiological Deterioration and its Relation in Identification of Reinforcement Material Utilization in Gypsum mortar.**

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Gypsum plasters as decorative material in the architectural buildings are a legacy of the building techniques of our ancestors. These coatings, frequently gifted with a high artistic value, are part of the historical building heritage of each country that needs to be well known and preserved.

In order to reinforce and consistence of gypsum plaster, it was sometimes used animals' hair or straw, linen fibers. They were added to the gypsum plasters only at the time of application. These organic materials are considered the main cause of microbiological deterioration of the mortar. The aim of this work is to define the organic material that used to reinforce the gypsum mortar in the dome of Prince Gashwih in Al Mahala Al Kaura, Egypt. by using different analysts, XRF to estimate the components of reinforcement material after burning compared with common fiber used as reinforcement material like linen, hay, and investigations, LMK-SEMI to determine the species of fungi and bacteria that caused microbiological deterioration. Many swabs were taken from infected areas. They were isolated, purified and identified to explain and emphasize the relationship between the kind of reinforcement material and infection with restricted species of fungi and bacteria. Data showed that sugar cane bagasse fibers were the reinforcement material used in the studied gypsum mortar. Aspergillus niger, Aspergillus fumigatus, Trichoderma viride, Alternaria alternata, Botryodiplodia sp., Penicillium sp., were the detection fungi and Xanthomonasaalineaeus bacteria.

**108. Characterisation of ochre pigments from Jawoyn rock art paintings of Arnhem Land, Australia.**

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During 2006 remote rock art sites of the Jawoyn people in the Northern Territory of Australia were rediscovered during an aerial survey of the Arnhem Land plateau. More than 4000 rock art sites have been rediscovered, including the spectacular Nawarla Gabarnmang site, which dates back 45000 years making it one of the earliest human occupation sites in Australia [1,2]. The art at the sites depicts a history of the culture of the Jawoyn people, contain paintings of different generations and illustrate an array of pigment types. In 2010 an international team of archaeologists were invited to document these extraordinary sites. The current project is a study of rock art at one of the Jawoyn sites being documented known as ‘Little Barra’. The site contains a range of pigment types, with ochre colours ranging from red to yellow and with white and black pigments also being observed. Ochre is an important component of paint used in traditional, as well as modern, Australian indigenous art. This mineral-based material is mined from particular sites and is coloured by iron oxides. The source material was extensively traded across Australia in the past and it has been established that the chemical composition of ochres is dependent on the source [3,4]. A series of small specimens have been collected from the Little Barra site, with most comprised of paint on a sandstone substrate.

A multi-analytical experimental approach has been conducted to understand the composition of the paints used at the Little Barra site. The paint specimens have been categorised based on colour data and microscopic examination. X-ray fluorescence techniques are also used to determine compositional information about the elemental composition of the pigments. Raman spectroscopy has been employed to identify the molecular structure of the inorganic pigment components. Infrared spectroscopy is being employed to complement the Raman data, providing information about the nature of both inorganic and organic components in the paint specimens. An in-depth understanding of the chemistry of the pigments is combined with archaeological information to build a clearer picture of the social practices of the Jawoyn people.

**References**

the basal structure of lacquer film already were elected and different size particles were used to paint different lacquer plaster layer by ancient craftsmen. The research results demonstrated valuable information about Chinese ancient technology and also give important knowledge on present-day lacquer manufacture, also supplied important reference data to copy, identify and protect them.

110. First Results of a Systematic Study on the Use of Binding Media for Late Medieval and Early Modern Wall Paintings in the Low Countries

Karin Keutenery, Anna Lluveras-Tenorio, Anna Bergmans, Peter Vandenabeele, Bernard Delmottena and Maria Perla Colombini

The results that will be presented, are part of a broader interdisciplinary research project, in which techniques of mediaeval and Renaissance wall paintings in the Low Countries are being identified. This paper presents the first results of binding media analysis carried out on a group of approximately 25 samples taken from a small group of wall paintings sites in the Low Countries, differing both geographically and in time. Characterisation of the binding media is mainly based on optical microscopy and imaging techniques. Hitherto little is known about which specific binding media have been used. Late mediaeval and early modern wall paintings in the Low Countries mainly are executed using a secco painting technique. It has been established that hyperspectral imaging can be used in several diverse areas of research and analysis. Areas such as forensics, art identification, color matching, conservation, & other related areas. There is, in fact, a very close relationship between these areas; such as comparison of pigments, inks, glues, mixing compounds, and color matching; to name a few. The idea here is to not only compare the inputs and outputs to other known methodologies, but to also build a related database to help in restoring ancient artifacts to their original glory. This task has a mix of inputs which are a mixture of known(s) and unknown(s). There may be some original paint and/ or past restoration material and in other cases is based on historical accounts. The methodology is to begin with quality normalized hyperspectral (We have used a NASA award-winning system from Phillips, LLC, known curves based on due diligence, compare the processed data sets to other methods and several wave ranges, and prepare for future work in age process & measurement. Several techniques will be used ranging from Principal Component Analysis Statistical Analysis, Unmixing techniques, spectral classifiers, library comparisons, and other spectral statistical imaging analysis techniques. The software being used is PhLiumina Imaging Software and ENVI analysis software. Pigments will be that of Chinese Red, Chinese Blue, Gold Gilded materials, and base coat mixtures. The data will be based on samples from cultural heritage sites in the People’s Republic of China. Past techniques used on master paintings from Europe and from past work on artifacts and forensic based materials. The conclusions are that Hyperspectral imaging can be used to discern differences in paint pigments and that libraries can be established to help in matching paints for purposes of conservation & restoration efforts worldwide.

112. Investigation of an Unusual Composite Material Found in a Larnax with Cremated Bones in Royal Tomb II at Vergina


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The past few decades, research on geochemical characterization of obsidian archaeological artifacts and geological samples from the greater American Southwest has been extensive, primarily for provenance purposes (Shackley, 1995; Ambrose et al 2001; Eerkens and Rosenthal, 2004; Ericson et al., 2004; Eerkens et al., 2008). Using different analytical techniques, such as neutron activation analysis (NAA), inductively coupled plasma mass spectrometry (ICP-MS), and laboratory and handheld X-ray fluorescence (LabXRF and JXR), the elemental fingerprint of obsidian artifacts can be established and correlated to known geological sources. This paper presents preliminary results for the geochemical characterization of an obsidian artifact from the Fowler Museum Collection (UCLA) using a Handheld X-ray Fluorescence Spectrometer.
assemblage from the Fowler Museum collections consisting of one hundred fifty-six obsidian samples from various sites in California. The assemblage was analyzed with a Bruker handheld XRF to determine the number of groups with different geochemical signatures. Data were compared to geological and reference samples from known California, Arizona, and Eastern Oregon sources in an attempt to assign individual groups to specific obsidian sources. Using elements bivariate plots and multivariate statistics, and beside several outliers, six distinct obsidian groups were identified based primarily on the concentration of iron (Fe) and some trace elements, in particular strontium (Sr), yttrium (Y), zirconium (Zr) and Niobium (Nb). Although obsidian source attribution remains challenging for such a diverse assemblage, one artifact group could be confidently assigned to the Obsidian Butte source in San Diego County while a large number of samples from obsidian-rich northern California sites cluster well with sources located within the Coso volcanic mountain range in central-eastern California. Finally, the results for these groups are discussed in terms of artifacts spatial and temporal distribution which provide useful insight on procurement patterns for this material in California.

References


114. Metal Leaf Decorations in Post-Byzantine Devotional Panel Paintings from Greece.

George Mastrotheodorou1, Konstantinos G. Bletsis2 and Yiannis Bassiakos3


Metal-leaf decoration plays an essential role in the context of Eastern Orthodox rococo iconography. Church’s devotional panel paintings (‘icons’). A common feature of these paintings is the covering of their background by gold or other metal leaves in order to enhance the ‘spirituality’ of the depicted scenes/persons. In many icons, the highlights of the clothing and other details are executed in metallic-leaf based materials as well. Two are the main traditional techniques by which a metal leaf is attached to a solid surface: by using a water-based gluing agent (‘water gliding’) or by employing drying oil based mordants (‘mordant gliding’). In order to investigate the techniques and materials (focusing on metal leaves) employed in the decoration of post-Byzantine icons, tiny samples from ten artifacts were subjected to examination. All ten icons are dated between the 15th and 18th century AD (post-Byzantine period) and are exhibited in the Zante Ecclesiastical Museum (Zante island, west Greece). Analytical techniques employed include X-ray fluorescence analysis (XRF), optical microscopy (OM) and scanning electron microscopy coupled with energy dispersive X-ray analysis (SEM-EDX). Results indicate the use of metal leaves as well as metal powders. In most of the cases high purity gold-based alloys were used while the use of silver alloys is rather restricted. Of special interest is the thickness of the gold foil which in many cases was found to be well below 1 micron. Both gluing techniques are employed; backgrounds are embellished by using exclusively the ‘water gliding’ technique while the highlights are made by employing various versions of the ‘mordant gliding’ method.

115. Archaeometric Methods Applied to the Conservation and Study of the Site Named ‘Altar of Mictlantecuhtli’. A proposal

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The conservation of the site named ‘Altar of Mictlantecuhtli’, a product of the Cultures of the Gulf of Mexico, presents a challenge to restoration, since it is of mixed construction (earthen architecture, wall painting and sculpture), all of which are integrated by materials of differing types (clay, lime and sand plaster layers, pigments and, most likely, binders of organic origin) which were combined to express a religious, ideological and cultural ideology. The site suffers from significant deterioration which puts the pictorial discourse at risk, since there have been losses due to humidity and salt formation. Additionally, some conservation materials applied in previous interventions present deterioration which increases the loss of material. The application of archaeological methods to this site will provide important information in order to select the appropriate methods, materials and processes for its conservation, guaranteeing its permanence and possibilities for its study. For example, through the use of techniques of electromagentic prospection it is possible to identify the presence and concentration of water in the subsoil, the type of foundation and the possible identification of construction phases. Through the chemical and mineralogical characterization of the clays, along with the application of fluorescence studies, X-ray diffraction and scanning electron microscopy, it is possible to characterize the materials and manufacture techniques of the earthen and lime plasters and the paint layers. In order to evaluate the degradation conditions of the polyurethane foam applied in 1974 as a support for the Mictlantecuhtli, it is appropriate to take a series of radiographs. Additionally, it is necessary to identify the polymer film applied on the paint layer in order to evaluate the viability of its removal and replacement with a fixative which will be compatible with the original material. The application of these techniques will provide important data which will be interpreted from an interdisciplinary perspective, with the goal of describing its manufacture, understand its condition and to elaborate an appropriate treatment proposal.

116. Geochemistry of Jadeitites to Link Maya Artifacts and Geologic Sources in Guatemala

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The only known jadeite source region in Central America lies along the Motagua Fault in Guatemala, divided by the Motagua Fault into two source regions. Jadeitite from north of the Motagua Fault Zone (MFZ) differs petrologically from that south of the MFZ; this section petrography further reveals three populations of differing mineralogy south of the MFZ. However, petrologic diversity of jadeitites within each source region makes the identification of artifact provenance difficult using current methods. The present study contributes geochemical characterization using LA-ICP-MS and stable isotopes, paired with traditional petrologic studies, to address the problem of discriminating jade sources near the MFZ that may improve the resolution of provenance determination over that possible with mineralogy alone. The utility of this approach is evaluated with jade debitage from Cancuén, the southernmost Classic Maya site on the Pasión River, north of the MFZ. Preliminary oxygen isotope data demonstrates potential for systematic differentiability between northern and southern jadeitites by approximately 0.5-4% with a window of overlap between 8.6-9.1%, while 0180 values of the Cancuén samples span both groups. LA-ICP-MS chemical characterization of major mineral groups in artifacts from this site will compare to results of a previous publication which demonstrated that these artifacts examined as homogenous materials
lack sufficient bulk chemical characteristics to consider it an advantageous sourcing method. This study revisits the same assemblage, focusing on characterization of major minerals such as jadeite, olivine, and albite, highlighting potential systematic geochemical variability among mineral phases. The exhibited isotopic difference between northern and southern geologic samples may be further distinguished by major mineral geochemistry. Since the Carcuel workshop may represent a link between the Matagwa source areas and jade-artifact consumers who lived farther north, this work holds promise for tracing the economy of jade in Classic Maya society.

117. Illuminated Manuscripts from Turfan
Tracing back Silk Road Glamour by Analysis of Pigments

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In the beginning of the 20th century a great variety of manuscripts were brought from the oasis of Turfan to Berlin by Grünwedel and Le Coq. These documents reflect altogether a close relationship in the manufacture of Syrian, Tibetan and Uighur manuscripts. The use of arsenic clarifies special implementations of the mineral pigment. Trace elements in gold are responsible for the source of the metal. As it is applied on paper in different ways, experience and knowledge of its chemical properties is indicated. Even if the material of coloration is not always identical, the selected fragments can be distinguished from others by special preparation characteristics. The criteria indicate altogether a close relationship in the manufacture of Tocharic, Sogdian and Manichaean manuscripts and a provenance or influence from Western and Indian tradition [1] [2].

References
[2] The research is funded by the DFG. The selection of manuscripts was done by courtesy of the Berlin-Brandenburg Akademie der Wissenschaften, the Berlin State Library and the Berlin State Museums, Museum of Asia.

118. Obsidian Economy In Neolithic Corsica: Insights From The Phase III Level Of Renaghju

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The project "Statues-menhirs, Menhirs et Mégalithisme en Corse" aims to shed light on the 'megalithic phenomenon' on Corse Island (western Mediterranean). We determined the provenance of obsidians from the Neolithic site of Renaghju (Sartène, southern Corsica; D’Anna et al., 2001). Obsidian is the main raw material of its lithic industry. The hundreds samples (622) of Renaghju phase I occupation (6th millennium BC) were sourced previously by their visual appearance and/or their elemental composition by PIXE and SEM-EDS (first results in Bressy et al., 2008). We bring provenance data on the phase III obsidians (5th millennium BC). The elemental composition of more than hundred artefacts was determined by SEM-EDS, LA-ICP-MS, EDXRF and PIXE, with some samples analysed by more than one of these methods. As for almost the entire assemblage of the phase I, all obsidians were found to come from the three main sources of the nearby island of Sardinia, although with various relative abundances, resulting in implications for the local and regional obsidian economy.

"project coordinated by one of us (AD) at LAMEPEA (University of Aix-Marseille/CNRS, France)

References

119. Importations of Highly Priced Products to Inland Eastern Iberia during the Roman Republican Period (2nd and 1st centuries BC): the Case of Egyptian Blue Pigment through its Archaeometric Study

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Some materials, like some pigments, gems or beads, are rarely found in most of the archaeological excavations. This usually suggests that they were goods of great value and their trade would be controlled and well defined. In the excavations carried out in La Cababeta (Zaragoza, Spain), an important number of highly prized objects and materials have been found, especially Egyptian blue beads. The study of these products can highlight some significant trade connections between the Mediterranean and the Tarraconensis area (Roman eastern Iberia). La Cababeta is an archaeological site, probably the ancient Castra Aelia, founded in the 2nd century BC in the middle Ebro valley and destroyed in the 1st century BC during the Sertorian wars. The city was built probably to receive an important amount of Italic people, with a Roman urban model. Part of the excavated area highlighted several large rectangular places corresponding to some big-dimensioned rooms, probably a kind of an Italic immigrant corporation, probably dedicated to trade. The materials studied in the current work were found in this
120. Catching Neolithic Humans Red-Handed: the Procurement of Colouring Materials in N. W. Mediterranean Neolithic

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Materials procurement studies provide key data for determining territories, mobility systems and socio-cultural relationships. The transition to sedentary agricultural societies created new paintings associated with a considerable increase in the complexity of exchange networks: varied goods diffused in considerable quantities and distances. In the N.W. Mediterranean area, previous research showed high variability in diffusion modalities according to materials (obsidian, flints, clastic rocks) and cultural groups (Impressa, Cardial or Chassey cultures).

This observation calls to integrate data from a greater number of materials. Despite their technical and symbolic value, colouring materials (“ochre”, bauxite, cinnabar), naturally abundant in the Mediterranean Franco-Italian area, has received scant attention; very few is thus known on the ways of their procurement and on their geological and geographic origins.

With this purpose, the study of colouring materials from both archaeological sites and putative sources was undertaken in the Liguro-Provençal area. Geological surveys allowed the establishment of a reference collection of a wide range of raw colouring materials. Their petrological nature has been determined by a combination of complementary imaging, elementary and structural techniques (petrography, SEM-EDS, X-ray diffraction).

In addition, two archaeological series were investigated by the same analytical approach: those of Pendimoun (Castellar, France), a rock shelter site occupied by Impressa and Cardial series (Early Neolithic: 5750-5200 cal. BCE) and those of the open-air site of Giribaldi (Nice, France) that belongs to Pre-Chassey and formative stages of Chassey culture (Middle Neolithic: 4700-4050 cal. BCE). The results compared to the frame of reference highlight two contrasting economic systems: one based on the procurement of local resources (Pendimoun) and the second one that shows a more complex acquisition network (Giribaldi).

At Pendimoun, the colouring materials imported are varied and heterogeneous, but widespread in the rock-shelter itself or in the close environment (less than 5 km). These results have to be considered in the context of an occupation assigned to specific functions (agriculture, pottery, sheep pen).

At Giribaldi, colouring materials assemblage consists of close geological materials (weathered glaucony) but also of two types of exogenous rocks, 70 90 and 60 70 km away (bauxite and ferruginous psammitic sandstone). This Middle Neolithic settlement is known to be well inserted in complex exchange networks including western Provence (flint), French and Italian Alps (quartz, clastic rocks), Liguria (clastic rocks) and Lipari island (obsidian). The presence of these three types of colouring materials all along the occupation, underlines the permanence of their exploitation, which gives evidence of stability of exchange networks and durability of relationships and technical practices.

121. Provenance study of marbles used as covering slabs in the archaeological submerged site of Baia (Naples, Italy): the case of the “Villa con ingresso a protiro”

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This paper is focused on an archaeometric study of marbles taken from the submerged archaeological site of Baia (Naples). The marine area includes the ruins of the ancient Roman city whose structures range from luxurious maritime villas and imperial buildings with private themae and tabernae, to more simple and modest houses. The work was carried out on fifty marble fragments of covering slabs, belonging to several pavements of the monumental villa, called Villa con ingresso a protiro, in order to establish the provenance of raw materials. Minero-petrographic and geochemical techniques were used to identify the marble sources. In particular, X-ray diffractometry and polarized optical microscopy analyses were performed in order to study textural features, such as maximum grain size of crystals (MGS), typical fabrics and grain boundary shapes (GBS). In addition, carbon and oxygen stable isotope ratios, and a detailed study of trace elements, using the inductively-coupled plasma mass spectrometry (ICP-MS) technique, were carried to define the provenance area of marble samples.

Results were compared with existing databases of white marbles commonly used in classical antiquity, especially in the Mediterranean basin.

Analytical data show that a variety of precious marbles was used in the ancient roman city of Baia, confirming the importance of the archaeological submerged site.

122. Material Analysis on 17th century Armenian Wall Painting in New Julfa-Isfahan

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Historical sources refer to some Armenian houses and churches from 17th century in New Julfa-Isfahan have been decorated with both oriental and European art works and wall paintings as well. Armenian merchants in Safavid era, generally, are one of the main channels for bringing European art styles, in particular, paintings to Iran society from c. 1600 AD onward.

In the other hand we know that in the majority of Islamic countries, the art of painting had been restricted to non-figural designs, at least in the public places, and strictly limited to small-scale illustrations of manuscripts. By contrast, in Safavid era, specially in Armenian buildings and Safavid palaces in Isfahan, Iran witnessed the development of large-scale figural painting. However, these paintings have been perceived in the past as an offshoot of European mural and easel paintings.

As a research result till now, Armenian illuminators have left no written document of how they prepared their pigments. But fortunately by recent scientific analyses it is possible to observe which pigments have been used by artists. In this case we could differentiate the Armenian palette from that used by Islamic artists. Based on some literature review, Armenian palette in 1200 to 1348, have been recognized as six pigments but usually in their manuscripts. These six pigments are: gold, white lead, vermilion, orpiment, ultramarine, and red lake but some of these pigments were not common pigments in Iran and just with more studies and analyses on Armenian wall paintings’ material and pigments we can get more information about 17th century Armenian wall paintings in Iran. For this reason the aim of this study will accomplish by Micro Raman spectroscopy, XRF (X-ray florescence), XRD (X-ray diffraction) and FTIR (Fourier transform infrared spectroscopy) analyses.

Keywords: Armenian wall painting, pigments, European style, Safavid era, New Julfa, Isfahan.
123. Elemental and Isotopic Variability in Mogollon-Datil Province Obsidian, Western New Mexico

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The Mogollon-Datil Volcanic Province (MDVP) in western New Mexico has been a subject of geological and geoarchaeological research for over three decades. Geologically, the province contains some of the largest caldera collapse events on Earth during the Tertiary Period, particularly in the 20 Ma time frame. These major events incorporated significant areas of crust over tens of thousands of km^3 and the rhyolite glass produced from these events are consequently similar in elemental composition even though the five major sources are isolated over a 100 linear km radius, and crossing a number of cultural territorial boundaries in the late prehistoric period.

The obsidian sources are also archaeologically significant in that they were used throughout the chronology from Paleoindian through Historic times (ca. 13,000 ka to ~A.D. 1600), and transported throughout the North American Southwest. Recent large scale National Science Funded research projects including these sources have demonstrated extensive prehistoric human migration throughout the North American Southwest, particularly during the Late Classic Period (ca.A.D. 1250-1350), and the need to discriminate between these sources are crucial to archaeological interpretation. The elemental composition using mainly laboratory x-ray fluorescence spectrometry (XRF) is similar among these sources, and the number of cultural territories throughout prehistory is so extensive that extreme care in source assignment is required. Recently some portable instrumentation (PXRF) has been found wanting in the source discrimination of these elementially similar sources. In order to better understand the compositional and geological chronology, an isotope study presents a segment of my doctoral thesis project which integrates the archaeological, mineralogical, and chemical data of pigments to reach a more full interpretation of the significance of colourants from the Anatolian Neolithic excavation Catalhöyük in Turkey. The range of mineral colourants includes common minerals such as iron oxides and carbon-based blacks and the rare materials azurite and cinnabar. This poster is motivated by the strong interest in one of the earliest known occurrences of azurite as a mineral pigment for body adornment and paintings. Until now, no further investigation or analysis has been published on this early use of azurite since the reporting of its presence in the Prehistoric palette in the “Conservation of Wall Paintings” in 1984 by Mora et al. The four samples from the excavation are from different locations over the 21 hectare area dated ~6,500 cal B.C. in the middle levels of the 1,400 year occupation of the site. Findings from an approach of complementary techniques including microscopy and instrumental analysis are reported here. This approach utilizes PXRF, FTIR, SEM, XRF, and XRD, to provide data beyond pigment characterization; this includes identification of accessory minerals of quartz and dolomite the detection of trace elements including of iron. Findings of this study contribute evidence towards the interpretation of the significance of colourants from the Prehistoric Palette in the “Conservation of Wall Paintings”.

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124. Investigations of Blue in the Prehistoric Palette: Analysis of Azurite from Neolithic Catalhaöyük, Turkey

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The samples collected prior to 2008 were analyzed using a Bruker III-V portable X-ray fluorescence spectrometer, while the recent finds were analyzed with the Bruker III-SD model. Some of the obsidian artifacts were re-analyzed to double-check on the comparability of the two instruments, while several other lithic pieces first recorded as obsidian were re-tested and reconfirmed that they were flint. All artifacts were analyzed non-destructively, with filters and voltage/amperage settings chosen to provide quantitative results for trace elements Rb, Sr, Y, Zr, and Nb which have been successful in differentiating all Mediterranean obsidian sources and subsources. Analyses were for 120 seconds (180 seconds for older instrument). Many geological source samples were tested with this same instrument, so all source assignments for the 85 archaeological samples are assured. For the obsidian artifacts, 75 were assigned to Lipari, an Aeolian island north of Sicily, about 350 km to the south. It appears that all of the Lipari obsidian artifacts came specifically from the Gabbro Sorge subsource, although one artifact may have been from Canneto Dentro. Ten obsidian artifacts were identified as coming from Pantelleria, an island off the Tyrrhenian Sea about 250 km to the west, and from a single subsource. The movement of obsidian from these sources to the Tavoliere may be used to address the socioeconomic systems involved during the Neolithic. Our data also will be compared with other obsidian studies done in central-southern Italy, the Adriatic islands, and the Dalmatian coast of Croatia. These combined data provide a broad understanding of Neolithic trade and exchange of obsidian and potential parallel movement of other materials, including the introduction of domesticated plants and animals to this region.

125. Non-Destructive pXRF Sourcing of Neolithic Obsidian Artifacts from the Tavoliere, Italy

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A surface survey of prehistoric archaeological sites in the Tavoliere plain of southeastern Italy was conducted in 2012 and 2013, recovering 24 obsidian artifacts along with stone tools, awls and arrowheads/points. For the obsidian artifacts, 75 were assigned to Lipari, an Aeolian island north of Sicily, about 350 km to the south. It appears that all of the Lipari obsidian artifacts came specifically from the Gabbro Sorge subsource, although one artifact may have been from Canneto Dentro. Ten obsidian artifacts were identified as coming from Pantelleria, an island off the Tyrrhenian Sea about 250 km to the west, and from a single subsouce. The movement of obsidian from these sources to the Tavoliere may be used to address the socioeconomic systems involved during the Neolithic. Our data also will be compared with other obsidian studies done in central-southern Italy, the Adriatic islands, and the Dalmatian coast of Croatia. These combined data provide a broad understanding of Neolithic trade and exchange of obsidian and potential parallel movement of other materials, including the introduction of domesticated plants and animals to this region.
voltage and amperage settings for other obsidian research projects, providing quantitative data for elements including Fe, Re, Sr, Y, Zr, and Hb. Along with visual assessment of the obsidian artifacts, which include both black-grey and green color types, we attempt to identify the number of different obsidian sources that must have been utilized in this region of Ethiopia. The two closest known sources of obsidian are in Soddo Wolayta, which is about 60 km north from the Borada highlands. Other sources in northern and more eastern Ethiopia are at Balchit, nearly 380 km to the north, and across rift lakes in Sidama about 150 km northeast of the Borada highlands. Obsidian has also been found to use in ethnographic contexts and at paleoarchaeological sites about 100 km south in the Konso region. While some claims have been made about local obsidian sources, none less than 60 km away have been identified, suggesting that there may have been trade with other ethnic groups. Our scientific analyses of obsidian artifacts thus provides important information about the socioeconomic practices of the caste system in Ethiopia.

127. Marble Sculptures in Algeria: From Local Sources or Elsewhere?

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As presented at the 39th ISA in 2012, a detailed survey and scientific sampling of nine Algerian and four Tunisian marble sources was conducted from 2005 to 2008, followed by color examination and isotopic, maximum grain size, and other analytical methods to add significantly to the database for Mediterranean marble sources used in ancient times. Since then we have also analyzed many marble sculptures and architectural units from sites and museums, and for the presence of magnesium to identify potentially as dolomitic marble and thus assign to the Cape Vathy source on Thasos. A Bruker III-SD X-ray fluorescence spectrometer was used to test for the presence of magnesium, on solid and powder samples, and compare directly with geological samples from Thasos. Nearly 85 percent of the samples tested are indeed dolomitic and mostly conform with the previously made visually-based assignments. The long-distance movement of marble from Thasos to Algeria adds to our understanding of the Roman economy.


References


128. Analysis of Paintings in the Prehistoric Genovese Cave (Levanzo, Egadi Islands, Sicily)

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Engraved and painted animal and anthropomorphic figures were discovered in 1949 in the Grotta del Genovese on Levanzo, one of the Egadi islands west of Sicily. The engravings are thought to date back to the upper Paleolithic (ca. 10,000 BC), and the black painted figures to the Late Neolithic-Chalcolithic (ca. 3500 BC) based on comparison with finds in other Sicilian caves (e.g. Addaura). A selection of the approximately 100 red, black, and white painted figures were analyzed, as well as unpainted areas for comparison. To identify the colorings used, non-destructive analyses were performed using a Bruker III-SD portable X-ray fluorescence spectrometer. The settings chosen were 40 kV and 1.5:A, with no filter, and analyses were done for 30 seconds. Since X-rays may penetrate into the lithic material below the paint, and the painted surface is of irregular thickness, visual assessment of peak heights in the analysis graphs were used to put the analyzed spots into a few separate groups. Two analyses of the red painted figure have extremely high iron (Fe) peaks, but no extra manganese (Mn) or mercury (Hg), so we interpret the red as coming from ocher. The other “outliers” are a white spot which is very high in calcium (Ca) and strontium (Sr). All of the other analyzed areas - plain rock and black paint - are relatively similar, but with some differences in Fe, as well as other major elements like K, Ca, Ti. Much of this variation is likely due to the varying depths of carbonized black paint on the surface, but in certain cases there might also be some iron-based mineral mixed with the carbon ash. We plan to do some radiocarbon and perhaps other dating methods in the near future.

129. Weathering mechanism on the whitening jades of Neolithic China

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Abstract: Most ancient jades are excavated ones, and weathering effects have suffered after having been buried for a long period of time. We often describe the weathering characteristic by the coloration because it is obvious, for example, whitening, bronzing, reddening, yellowing, blackening, green and so on. According to current researches, most colorations were caused by transitional ions except for the whitening. General speaking, whitening is the most severe weather that caused macroscopic changes in density, hardness, and transparency, and microscopic changes in structure and elemental composition. For example, whitening jades excavated from some significant Neolithic archaeological sites in southern China (Songze site in Shanghai Municipal, Liangshu site in Zhejiang Province, Berynyangying site in Jiangsu Province, Lingjiatang site and Xuejiaotang site in Anhui Province), showed alterations such as hardness, density and transparency decreased, and loss of structural integrity.

We have found a very special weathering phenomenon existed in the above whitening jades, that is “denser outside, looser inside”. It can not be explained by the ordinary weathering mechanism because it often carried on from the surface to the inner which would cause the opposite phenomenon of “looser outside, denser inside”. Two typical nephrite jades from Lingshu culture in Zhejiang Province and Huangjidian culture in Jiangsu Province respectively were selected for this study, which were analyzed by several methods such as XRD, FTIR, Raman, PIXE, XPS and FE-SEM. The results showed that these jades had experienced two stages. The first is the dissolving or hydrolyzing stage. After these jades were buried, they dissolved and hydrolyzed. Then more intergranular pores formed. Relatively speaking, the outside was weather more severe than the inside, so the fibrous crystals of the outside would change to be granular, whereas the crystal of the inside is still fibrous. The second is the penetrating and cementing stage. We found the outside has more content of Si, Fe and Al than the inside, which showed that some unmovable colloidal materials from the surrounding, especially soils, would penetrate and deposit in the outside, and it may be the reason for the formation of special structure of “denser outside, looser inside”. In the study, we found silica from the surrounding is more important to the surface characteristics, and further found the luster of ancient jade is not the original luster but formed after they were buried, which is greatly related to silica penetrating and cementing.

130. Technology of the Nubian Wall-Painting: A Reconstruction of the Past through the Painting Materials and Techniques

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131. Preliminary Results of Petrographic Analysis of Halafo and Ubaid Sherds from Tell Ziyadeh, Syria
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This abstract presents the preliminary results of a project focused on the fifth millennium B.C. Halafo and Ubaid period ceramics excavated at Tell Ziyadeh, a site located in the Khabur River basin of northern Syria. While Tell Ziyadeh is primarily an Ubaid and post-Ubaid site, more than 50 painted Halafo sherds were found out of context in the basal layers of the site, suggesting that there once was a small Halafo settlement, most of which has disappeared, possibly as a result of flooding. Although in general, radiocarbon dating suggests that there was some overlap between the Halaf and Ubaid societies, in the Khabur region it is commonly accepted that the late Ubaid was intrusive and not a development out of the earlier cultures. The study of ceramic manufacturing techniques through macroscopic and microscopic analyses has the potential to help us understand the relationship between Halaf and Ubaid period occupations by focusing on the practice and process of making ceramic vessels.

From the collection of sherds from Tell Ziyadeh, currently housed in the Department of Anthropology at Yale University, a representative number of both Halaf and Ubaid painted sherds were selected for petrographic analysis carefully considering the variation in vessel type, macroscopically visible paste variation, and vessel wall thickness. Although much petrographic research has focused on sourcing ceramics, based on the nature of the site and the style of ceramics, this project was carried out under the traditional assumption that the Halaf and Ubaid painted pottery from Tell Ziyadeh were manufactured locally, until proven otherwise. Therefore, emphasis was placed on microstructural analysis by carrying out a thorough observation of all aspects of the sherds in order to understand their variability for future fabric classification, as well as to better understand the manufacturing technology. The results have provided a baseline understanding for the Halaf and Ubaid cultures at Tell Ziyadeh. There seem to be no drastic changes observed in the materials that were used in the pottery manufacture between the two periods. The manufacturing techniques did not show a major difference as well, other than the unexpected frequent use of chalk temper in the Halaf period and the unexpected lack of chalk temper in the Ubaid periods. Furthermore, the soft paste and the non-vitrified paint of the Ubaid painted pottery at Tell Ziyadeh, may indicate regional differences in Ubaid pottery that a further study could explore.

132. Analysis of archaeological pottery from Maranhão (Brazil) by six atomic and nuclear analytical methods
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This work deals with ceramic fragments from the Sambaquis of “Panaquitara” and “Rabo de Porco” located in the São Luiz city area, at Brazilian northeast. Ancient civilizations that inhabited that territory were characterized as fishing, hunters and ceramics populations. Dates obtained by termoluminescence ranged from 5730 to 127 BP. The studied samples were ninety five representative portions of ceramic suggest that different atmospheres catchers, hunters and collectors populations. Sixteen elements were measured by termoluminescence from 5730 to 127 BP. The studied samples were ninety five representative pottery fragments selected of stratigraphic levels from the surface to 180 cm deep for both Sambaquis. The atomic and nuclear analytical methods employed were EDFRX, PIXE, Mössbauer and Raman Spectroscopy, XRD and Computed Radiography. Sixteen elements were measured with good statistics in the different ceramic samples through EDFRX and PIXE analysis: Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Cu, Zn, Rb, Sr, Y and Zr. Bivariate plots and convex sides in relation to the ceramic paste of the fragments. The elements Ti, Mn, Fe and Zn are present in the fragments with larger amounts at concave and convex sides, compared to the ceramic paste, indicating a surface treatment (engobe) with an enrichment of these elements. Mössbauer spectra from outer and inner portions of ceramic suggest that different atmosphere prevailed during the firing of the studied samples. QS for Fe3+ species, of the archaeological samples, in the refining curve meets the firing curve of the clay at 800 - 900 °C. With the portable Raman spectrometer, it was identified the presence of Wollastonite, suggesting that the firing temperature reached 950 °C. The presence of Albite indicates firing temperatures below 950 °C. This indicates a range for the maximum burning temperature from 900 to 1000 °C, which is in agreement with the obtained results. The XRD diffractograms from Panaquitara exhibit quartz, feldspars and layer silicates. Rabo de Porco samples show additionally mica and amphiboles suggesting a manufacturing process different from that employed in Panaquitara samples. The internal structure of the ceramic fragments observed by Computed Radiography revealed the presence of various sizes and types of anti-plastics in the sherds.

133. A Study of Bronze Age Pottery from Al-Khidir Site, Kuwait: Chemical and Petrographic Characterization
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Dilmun sites on Falika Island (Kuwait) speak to the role of Kuwait as a participant in a larger trade network of the 2nd millennium BC that had socio-economic relations and connections with other territories in the region; Mesopotamia, the Indus plateau, and the Indus Valley. As a natural shelter in the northeastern part of Kuwait, Al-Khidir is one of the Dilmun Bronze Age sites that was discovered recently by the Kuwait-Slovak Archaeological Mission (2004-2009) and revealed three distinct Early-to-Middle Dilmun occupation horizons.
Dilmun ceramic artifacts were analyzed by means of stylistic analysis to build a chronology for the ceramics and cultural affiliation. The aim of this paper is to present research based on chemical and petrographic analysis of early Dilmun - 2nd millennium ceramic sherds from Al-Khid by using a non-destructive portable X-ray fluorescence spectrometer (pXRF) and petrographic thin section anal. pXRF data of Mesopotamian and Dilmun ceramic artifacts from Failaka Island (Kuwait) and Barbar temple (Bahrain) are also considered to present chemical recipes of Mesopotamia and Bahrain mainland. The significance of this research project is to establish a benchmark using pXRF and petrographic analyses to construct a database for chemical components and mineralogical composition of Dilmun pottery and possibly fingerprint production centers as well as trade and exchange in the Bronze Age. The preliminarily results demonstrate the ability of pXRF to discriminate between and within sites. It also shows that there is a significant variation within pottery at Al-Khid. Interestingly, using Mesopotamian pottery as a reference is helpful to fingerprint nonlocal greenish ceramic sherds at Al-Khid. The pXRF results are confirmed by petrographic analysis that shows two distinct groups of Bronze Age ceramics representing Dilmun Barbar pottery and gray-to-green Mesopotamian pottery. Despite no separation between Failaka Island and Bahrain pottery sherds, a noticeable variation in term of petrographic sub-groups within Dilmun ceramic sherds suggest unstandardized choices of raw materials and probably a presence of independent professional craft specialists. The study results would encourage in the future integrating quantitative and qualitative analyses to yield clear information about variation in choice and manipulation of raw materials within the Dilmun realm, and also to emphasize the variety of factors that affect the grouping of pottery.

134. A Chemical Characterization of Dilmun Pottery from Bronze Age Sites (tell F3) in Kuwait and (NE Temple) Bahrain Using Non-Destructive XRF analysis

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Dilmun is the name of a political and cultural entity identified by Sumerians in the late third millennium B.C. It was mentioned to refer to Dilmun agents to transship raw materials and finished products back and forth along local sea routes from southern Mesopotamia to their trading partner. The Early Dilmun period, around 2050 BC, had witnessed a dramatic change and social development in its main center, modern-day Bahrain, in the Arabian Gulf and its adjacent regions. Unlike during the 3rd millennium BC, Dilmun would dominate the Mesopotamian trade network in the 2nd millennium BC by expanding to the north, including Failaka Island in Kuwait. On the southwestern corner of Failaka Island, tell F3, also known as a Dilmun Town, was founded along other occupational settlements (e.g. F4, F5, and F6) on the island that points importance for Dilmun authority as a trading colony or transit point. The northern part is the oldest tell of tell F3, which dates back to 1850 BC. The emergence of this residential or large complex is further evidence of Dilmun cultural expansion, which is characterized by the presence of Dilmun-type seals, red-edged Barbar ware, and burial mounds. The ridged Barbar pottery was the most dominant as a distinct local production of Dilmun. The mass production of this type of pottery suggests the standardized nature of this pottery had shifted from a household level in the later 3rd millennium BC to a professional level. In order to examine the level of standardized production recipes used for Barbar ware, this research project aims to construct a chemical database of Dilmun Barbar ceramic sherds from tell F3 in Failaka Island, Kuwait, and Barbar ceramic samples from Bahrain as well, using a non-destructive portable X-ray fluorescence spectrometer (pXRF). The trace element data obtained from pXRF are subjected to multivariate classification procedures to examine their common provenance and address a circulation of nonlocal pottery and trade and exchange as well in the Gulf’s Bronze Age. The preliminarily results demonstrate the invaluable contribution of pXRF to constructing a database for chemical components of ceramic pottery wares and the instrument’s ability to discriminate between and within site collections.
137. Characterization of Byzantine Primary Glass Furnaces

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After decades of research, it still remains difficult to determine the primary provenance of Roman glass. To do this, a complete geochemical characterisation of raw glass from any identified primary production centre and of any potentially suitable sand raw materials is required. In this study, we provide trace elemental and Sr, Nd and Sr isotope data for 15 samples of raw natron glass from a single tank furnace in Apollonia (6th-7th century A.D.) and 8 glass samples from two tank furnaces in Bet Eli‘ezer (6th-8th century A.D.). This data provides information about the geochemical homogeneity within a single batch of raw glass and about the differences and/or similarities between different tank furnaces from a single site. In earlier work, major elemental compositions have been analysed using SEM-EDXA. These data already showed significant variation in SiO2, Na2O and CaO concentrations in glass from a single tank furnace. This reflects poor mixing of the glass batch and a failure to eliminate heterogeneities during the melting process.

The isotopic composition of Sr, Nd and B was measured via MC-ICP-MS after separation from the sample solutions using sequential extraction procedures. The Sr isotopic signatures of the analysed glasses are very homogeneous and lie close to the present day seawater value (87Sr/86Sr between 0.70902 and 0.70919). This indicates that the main source of lime was Holocene seashell. Also the 87Sr/86Sr ratios and pattern are very similar for all glasses analysed in this study. However, absolute trace element concentration can vary substantially within a single tank furnace. This indicates that the raw materials were poorly mixed before firing and that convective currents within the molten glass were insufficient to homogenise the batch. The concentration of trace elements commonly associated with decolouring can be attributed to background concentrations in the sand raw materials. This indicates that there was no recycling of glass cullet at this stage of the production process.

138. Geochemical Heterogeneity of Sand Deposits and its Implications for the Provenance Determination of Roman Glass

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In the Roman period, the majority of the glass was of the natron type. This type of glass was produced by melting three components (i.e., quartz sand, lime and natron) at temperatures of about 1100°C. During this period the raw materials are completely molten, mixed and homogenised, and their original crystallographical and mineralogical features are lost. Only some chemical characteristics are preserved, which can be useful to provenance ancient glass. To determine the provenance of archaeological glass artefacts, suitable sand raw materials have to be accurately characterised. In this respect, also information about the possible variation in geochemical properties within a silica source is vital to account for potential (partial) overlap of different sources. Variations in the geochemical characteristics of a sand deposit can occur due to a heterogenous distribution of different mineral phases caused by for example different local hydraulic conditions. In this study, the variation in mineralogical and geochemical properties of present-day beach sand is studied. To do this a sand deposit is chosen in the Basilicata Region (SE Italy). Beach sands in this area are mostly derived from Pliocene-Pleistocene sedimentary rock and are potentially suitable for natron glass production. Over a distance of 600 m along the coastline, sand is systematically sampled. The major elemental composition of all sand samples is determined via ICP-OES. L.O.I. measurements are carried out to determine the amount of volatile elements. The isotopic composition of Sr and Nd is determined via MC-ICP-MS after sequential extraction from the sample matrix. The results are compared to the mineralogical composition of the sand and discussed in relation to Roman glass production.
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144. Investigating the Firing Protocol of Athenian Pottery Production: A Raman and colorimetric study of replicates and original samples

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The ceramics produced in ancient Athens from the 6th through the 4th centuries BCE, also known as Attic pottery, are considered one of the great technological achievements of the ancient world. Although a basic understanding of their production has been developed, details regarding the painting and firing schemes employed are still not completely understood[1,2]. The iconic black and red figure pottery (with figures painted directly with black gloss or left in reserve, respectively) were painted with a refined illitic stage on the chemical and physical characteristics of the firing conditions used to create these vessels, based on archaeological ceramic shreds found in Costa Rica belong to this application. The iconic black and red fire figure pottery (with figures painted directly with black gloss or left in reserve, respectively) were painted with a refined Fe-rich clay and then subjected to a three-stage firing cycle of oxidation-reduction-oxidation. The painted areas turned from red (due to the presence of Fe3+ compounds: hematite and magnetite) to black (Fe2+ iron compounds: magnetite, hercynite) gloss depending on the conditions of each stage. As part of an ongoing study[3,4] into the materials and firing conditions used to create these vessels, based on chemical and morphological studies of sherds from the collection of the J. Paul Getty Museum, the work presented here evaluates the effect of the temperature of each firing stage on the chemical and physical characteristics of the black gloss. Replicate samples are painted with refined illitic clay and then fired with the three-stage firing protocol with strict control of temperature, oxygen fugacity, humidity and duration. The resulting gloss is analyzed using Raman spectroscopy, which allows the relative amount of magnetite (black) and hematite (red) in the gloss to be characterized. Spectro-colorimetry is used to precisely measure the color of the black gloss. Results indicate that the temperatures of both oxidative stages and the first and third stages are important for controlling the color and mineralogical phases in the glosses produced. The correlation between the Raman response and the color measurement of given conditions was used to propose a predictive scheme for the result of the firing process. Since the materials and firing conditions of the replicates are precisely known, these results can serve as a means of calibrating the measurements made on original sherds. The predictive scheme was thus used to infer the firing conditions of original Athenian black and red glosses from the Getty collection.

References

145. Characterization of Costa Rican Archaeological Ceramics from the Formative Period: Preliminary Electrochemical Studies

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Studies of archaeological materials may render valuable information regarding culture, technological processes and history of the past native societies offering invaluable information for conservation and/or restoration of these materials[1]. The Costa Rican Formative Period (2000 to 300 b.c.) represents the transition from nomad to semi-sedentary societies coinciding with the beginning of agriculture in the Costa Rican territory. The oldest archaeological decoration found in Costa Rica belong to this period; however, their study have not been as extensive as that for pieces from other periods. There is not enough information about the technological processes implemented during this archaeological period, and it is vital to understand the behavior of the different ceramic complexes. This study aims to acquire more detailed information related to the chemical composition of the pottery specimens utilizing electrochemical techniques [2].

Electrochemical measurements were implemented to characterize samples of archaeological pottery. All measurements were carried out in an Autolab PGSTAT128N, using cyclic voltammetry (CV) and square wave voltammetry (SWV) as methods of analysis. Modified electrodes were prepared using a conductor glass electrode (ITO) as support and a suspension of the archaeological sherd powder in 0.1M HCl. The suspension was sonicated (10 minutes) and applied over the conductive glass. Experiments were performed at room temperature in acetate buffer as supporting electrolyte (pH= 4.72, 1.0 mol/L). All the potentials were referenced versus an Ag/AgCl (3 mol/L) reference electrode; a Pt-wire was used as auxiliary electrode. SW experiments were performed under the following experimental conditions: amplitude (25 mV), step potential (4 mV), and frequency (10 Hz).

The characterization of the archaeological samples consisted in determining the ratio of Fe2+/Fe3+. This ratio indicates the use of oxidative or reductive conditions in the kiln during the pottery manufacture. Experimental conditions were initially optimized using synthetic magnetite (prepared in the laboratory). CV experiments shown to be unproductive because the signals were ill-defined and weak; therefore, SWV was selected as the analysis technique. Figure 1 presents several consecutive anodic SWV runs (SWV) with a magnetite sample for a magnetic signal showing the oxidative or reductive process in the glass. The intensity of the signal decreases with the number of runs indicating the dissolution of the material. Magnetite was used also as a reference material to compare with the archaeological pottery samples. Figure 2 shows consecutive anodic SWV for a ceramic sample from the Chaparrón site. The signal at 0.290 V can be assigned to the Fe2+/Fe3+ pair; whereas, the signals at -0.300 V and 0.198 V may be related to the presence of hydrated hematite in the sample. The intensity of the signals decreases with the number of runs as well. Quantification of the Fe2+/Fe3+ ratio was accomplished by performing consecutive SWV runs and determining the total electrochemical charge related with the observed signals.

146. The Glass Road: Using Quantitative Analysis of Islamic Glass at Merv, Turkmenistan for Boundary Material Mapping of the Silk Road

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Located at the confluence of all three major land routes of the Silk Road trade network, the site of Merv, Turkmenistan displays a wealth of artefacts with influences from many disparate cultural groups (Williams 2002). However, this same diversity can make it difficult to accurately attribute the origin of the artefacts as either local or obtained through trade. The sociological concept of boundary material, one that is plastic enough to comply with local constraints, yet strong enough across sites (Star and Gresemer 1989), can assist in mapping the flow of cultural materials and technologies along such a complex trade network by providing a more relative framework, which allows better comparison of quantitative analyses between multiple sites. This research focuses on glass as the boundary material for mapping and comparing technology and artefacts at Merv, as well as within the wider Central Asian region. Geographical logic, archaeological and historical research indicate that the glass recovered from the Late Islamic or Early Mongol Sultan Kala area of Merv should conform to Brill’s Central Asian compositional typology (Brill 2012), a plant-ash based glass with higher percentages of K2O (3.7%) fitting well within the typical Central Asian typology constraints, yet still retain a common identity across sites.

Quantification of the K2O and Fe2O3 ratio was accomplished by performing quantitative SWV runs and determining the total electrochemical charge related with the observed signals.
with recently excavated contextual evidence of primary glassmaking, coloured glass residue on furnace bricks and chunks of glass slabs. Although the Central Asian elemental composition of these artefacts is relatively standard, high levels of variation in technique and colour suggest an advanced level of technical knowledge from multiple glassmaking/working traditions. Therefore, this combination indicates the use of Central Asian source material with an outside technological influence. Comparison with trends from other geographical regions, through the lens of glass as a boundary material, secures better placement of the Merv artefacts within the larger technological landscape.

References

147. Archaeometric Comparison between the Early and Late Sasanian Period Ceramics at the Archaeological Site of Qizlar Qal’eh (North-Eastern Iran)
Maria Daghmehchi1, Jebrael Nokandeh2, [affiliations]

148. Copper and Antimony isotopic analysis via multi-collector ICP-mass spectrometry for provenancing ancient glass
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The origin of the materials used for glass production and the trade of glass in antiquity are currently very active topics of research. Ancient glass was produced using three main components, (i) a silica source in the form of sand or pure quartz, (ii) a stabiliser, mostly lime, added with the silica source or as a separate constituent, and (iii) a flux, in the form of plant ashes or mineral soda, to lower the silica melting point. Also colourants and decolourants were used in the glass production process. In particular, Cu was used from the late Bronze age in Egypt and Mesopotamia to produce blue colours. Sb on the other hand, was widely used as an opacifier in glass (50 content > 1 %) from the late Bronze Age onwards. Calcium antimonite (white) and lead antimonate (yellow) are also commonly found, while Sb has also been used for blue glasses to achieve opaque turquoise. Additionally, Sb is known as a decolourant (~0.5 % Sb) from the Greco-Roman period onward. Major, minor and trace elements have been used to provenance the raw materials of ancient glass making, as some elements proved to be directly related to mineral raw materials in the silica source, colourants or flux. Isotopic analysis of Sr and Nd has also allowed to distinguish different raw material sources, and also the use of O isotopic analysis in this context has been reported in literature. However, little work has been done regarding colourants or decolourant agents.

In the present work, the use of Cu and Sb isotopic analysis for provenancing purposes will be shown. Suitable protocols for digestion and isolation for both Sb and Cu have been optimized and validated, relying on the use of both an in-house multi-element standard and NIST SRM 610 glass reference material. The methods for Sb and Cu isotopic analysis were subsequently applied to a series of Mesopotamia, Egyptian, Georgian, Turkish and European glasses from different periods. Results obtained show that the isotopic composition of Cu, expressed as 66Cu/64Cu varies from -1.9 to -0.2‰, thus covering a range of approximately 2 ‰, whereas the isotopic composition of Sb shows a 10-fold lower range of variation, of approximately 0.5 ‰ only. The use of Cu isotopic ratios for identifying the raw material used in the glass manufacturing is complicated by the fact that Cu oxides and sulfides ores from within the same deposits can exhibit different 66Cu/64Cu values. For Sb on the other hand, oxides are far less common, and the main natural source of Sb is in the form of sulfides. Therefore, a series of Sb sulfides, mostly stibnite, from different Mediterranean and other European areas have been studied with the aim of obtaining information on the origin of Sb in glass.
This paper examines the origin and distribution of these stove tiles using X-ray fluorescence (XRF). The composition of bodies and glazes of more than 150 samples of these tiles were investigated using an Olympus Delta handheld XRF (µXRF) analyzer and an Edax Eagle III micro XRF (µXRF) spectrometer. The samples were selected based on archaeological, historical and stylistic arguments. These tiles were then compared to over 50 samples of confirmed local origin such as raw clay sources, mistres and other pottery waste. Simple bivariate plots, cluster analysis and principal component analysis (PCA) distinguished several chemically differentiated groups. Preliminary results point to a local production for a large part of the redware tiles. There are however outliers and exceptions, for example, a small group of tiles which seems to link between ceramics and local raw materials, especially in the case of recipients for funerary purposes. Ceramic production at Perdigões site was complex and local production of domestic wares related with quartzodiorite derived clays, diorites and associated gabbros, and in some cases also Tertiary clays, as well as the existence of pottery, mostly funerary, and also foreign raw materials. Mineral phases indicate low firing practices, around 600°C. These results confirm previous conclusions about the organization of the site, and support the hypothesis of the Perdigões necropolis use by distant communities. Besides a consistent occupation of the site with the resource to the same type of raw materials, appears to occur from Neolithic to Chalcolithic.

This study in the application of geological survey and ceramic compositional studies became very useful on tracing the provenance of ceramics in a diachronic and utilization point of view, as well as on probing manufacture practices, particularly firing range temperatures.

150. Home and Hearth: A Multidisciplinary Investigation of Stove Tiles in Post-Medieval Flanders (Belgium)

Peter Vandenabeele2, Laszlo Vincze3

and the Netherlands. Furthermore, the majority of the sites yielding stove tiles were discovered in Flanders. These Flemish tiles seem to use a different iconographic context of elite housing. During the last decennium several have played an important role in the material and social practices, particularly firing range temperatures.

In this decennium several studies involving provenance issues may be done, to obtain representativeness of geological contexts, so far a fact clearly reflected by its name. Our physicochemical and structural analyses show that this terminology has to be reassessed. This issue shows us the complexity of the technical system of the ceramic manufacturing and the socio-cultural interactions process during the Late Mochica and Transitional periods at SJM.


Joanna Dunster1, Andrew Shortland1 and Kelly Domoney1

and also foreign raw materials. Mineral phases indicate low firing practices, around 600°C. These results confirm previous conclusions about the organization of the site, and support the hypothesis of the Perdigões necropolis use by distant communities. Besides a consistent occupation of the site with the resource to the same type of raw materials, appears to occur from Neolithic to Chalcolithic.

The foundation for tracing provenance of ancient ceramics is the regional geology. Besides regional geologic maps, the more appropriate lithological variation, which is necessary for a robust provenance study of ceramic materials, requires geological survey. So, field work, mapping and analysis of clay-rich materials potentially used as raw materials must be detailed identified and studied, even not recognized at an usual geological map scale (in Portugal 1:50000 and 1:250000). In the framework of the construction of the Alqueva Dam, Alentejo (South of Portugal), several archaeological sites were studied in an interdisciplinary approach and subsurface field work was performed in order to obtain representativeness of geological contexts, so further studies involving provenance issues may be done, even in locations already submerged. Most of the samples correspond to clay materials derived by the weathering of the diverse regional lithologies, and some from sedimentary deposits.

In this provenance study a large set of prehistoric ceramics from Perdigões archaeological site (Reguengos de Monsaraz, Alentejo) were chosen and compared with regional geological samples. We report the results of an instrumental neutron activation analysis (INAA), and an X-ray diffraction study undertaken on both ceramics and clayey samples. The results demonstrate local production of Neolithic and Chalcolithic pottery from Perdigões, establishing cases of significant correlation with specific clay materials, along with the connection between ceramics and local raw materials, especially in the case of recipients for funerary purposes. Ceramic production at Perdigões site was complex and local production of domestic wares related with quartzodiorite derived clays, diorites and associated gabbros, and in some cases also Tertiary clays, as well as the existence of pottery, mostly funerary, and also foreign raw materials. Mineral phases indicate low firing practices, around 600°C. These results confirm previous conclusions about the organization of the site, and support the hypothesis of the Perdigões necropolis use by distant communities. Besides a consistent occupation of the site with the resource to the same type of raw materials, appears to occur from Neolithic to Chalcolithic.

This paper defines a set of compositional traits for the types produced by the twenty factories for which data found to be groups corresponding to distinct recipes. However, the products of Caughley and contemporary Worcester, Vauxhall and Bovey Tracey, Derby and some experimental phosphatic Worcester, Longton Hall and West Par's, Cookworthy's Plymouth and Bristol manufactories, and Pomona cannot be reliably distinguished.

Due to industrial secrecy and the complexities of creating a product which would survive high-temperature firing, a range of paste recipes were employed by dozens of manufactories. This has resulted in an array of porcelains which vary in their elemental composition and mineralogy. Traditionally, connoisseurship techniques have been used to unite an object, on the basis of its form and decorative features, with a factory and period of origin. For the past twenty years, scanning Electron Microscope and spectrometric microprobe analyses have been carried out to characterise the products of individual manufactories by the major and minor elemental composition of their paste (Tite and Bimson, 1991; Owen, 1997; Owen and Barila, 1997; Owen, 1998; Ramirez Gomila, 2003; Ramirez and Ramirez, 2007), and to distinguish them from their contemporaries by applying discriminating factors (Owen and Sando, 1998; Owen et al, 1998; Bimson and Freestone, 2002; Owen and Sando, 2003).

This study presents a meta-analysis of data from previous work, and tests some multi-elemental systems for discriminating between manufactories. Within the traditional compositional categories of paste-types – magnesian, phosphatic, frit, and hard-paste – there were found to be groups corresponding to distinct recipes. This is found to be effective for the paste, based on the limited amount of data available, and ten of the paste-types produced by the twenty factories for which data were available can be distinguished using systems of between two and four elements. However, the major and minor elemental composition of the glaze was found to be unsuitable for establishing the provenance of an unknown object, as intra-factory variation was found to be as great and often greater than inter-factory variation. This paper defines a set of compositional traits for the products of some factories, in order that data from unprovenanced porcelain objects may be compared, and their factory and period of origin may be proposed. However, the products of Caughley and contemporary Worcester, Vauxhall and Bovey Tracey, Derby and some experimental phosphatic Worcester, Longton Hall and West Par's, Cookworthy's Plymouth and Bristol manufactories, and Pomona cannot be reliably distinguished.

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152. ASSESSING THE USE OF ELEMENTAL COMPOSITIONAL DATA FOR PROVENANCE AND DATING BRITISH SOFT-PASTE PORCELAIN FROM 1740–1820

Owen and Sandon, 2003).

Due to industrial secrecy and the complexities of creating a product which would survive high-temperature firing, a range of paste recipes were employed by dozens of manufactories. This has resulted in an array of porcelains which vary in their elemental composition and mineralogy. Traditionally, connoisseurship techniques have been used to unite an object, on the basis of its form and decorative features, with a factory and period of origin. For the past twenty years, scanning Electron Microscope and spectrometric microprobe analyses have been carried out to characterise the products of individual manufactories by the major and minor elemental composition of their paste (Tite and Bimson, 1991; Owen, 1997; Owen and Barila, 1997; Owen, 1998; Ramirez Gomila, 2003; Ramirez and Ramirez, 2007), and to distinguish them from their contemporaries by applying discriminating factors (Owen and Sando, 1998; Owen et al, 1998; Bimson and Freestone, 2002; Owen and Sando, 2003).

This study presents a meta-analysis of data from previous work, and tests some multi-elemental systems for discriminating between manufactories. Within the traditional compositional categories of paste-types – magnesian, phosphatic, frit, and hard-paste – there were found to be groups corresponding to distinct recipes. However, the products of Caughley and contemporary Worcester, Vauxhall and Bovey Tracey, Derby and some experimental phosphatic Worcester, Longton Hall and West Par's, Cookworthy's Plymouth and Bristol manufactories, and Pomona cannot be reliably distinguished.
153. Archaeometrical characterization of red opaque glasses
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Red opaque glass is produced by crystals of metallic copper dispersed in the glass matrix (Weyl, 1951; Freestone, 1987; Brill & Cahill, 1988; Brun & Pernot, 1992). This means that strongly reducing conditions or a reducing agent must have been adopted to achieve complete reduction of copper, both in the case where copper was added in the form of a metal or as alloy scraps, to prevent the development of a blue transparent glass as a consequence of copper oxidation. The presence of lead and tin is believed to be necessary for the formation of the red colorant. Lead could have prevented the copper from oxidizing by helping to achieve reducing conditions (Ahmed & Ashour, 1981), since it has the ability to form stable complexes with copper. This study focuses on 38 glass fragments, all dated 1st to 4th century AD, which were excavated in Sagalassos, and four in Cyprus, and are dated to the 1st century AD (Brems et al., 2013). The results show that red opaque glasses were produced in different geographical areas. Six samples excavated in different regions described by Pliny the Elder, and some others from the regions described by Dio Cassius, were dated about 1325-1188 cal. BC. Among the beads, 25 are glasses, one is metallic and 29 are made of a resinous material. The conservation of this last material is exceptional in this area and for this period. However the conservation state of these beads is quite poor and the external macroscopic aspect does not allow an unambiguous identification, moreover for resins which could have several origins. The identification of these organic substances therefore requires an analytical characterization procedure.

References

154. The archaeological site of Luni: first archaeometrical results on the glass findings
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The Roman colony of Luni (Luna) was founded on the left bank of the Magra river in 177 AD at the end of a fierce battle. The town was known as the capital of the Apuan Alps, and it was a major center of trade and commerce during the Roman period. The conservation of this last material is exceptional in this area and for this period. However the conservation state of these beads is quite poor and the external macroscopic aspect does not allow an unambiguous identification, moreover for resins which could have several origins. The identification of these organic substances therefore requires an analytical characterization procedure.

References

From the Bronze Age to the Iron Age

155. Raman and infrared spectroscopies for the identification and provenance of resinous beads from Middle Bronze age Corisca. Insights of a Mycenaean influence?
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During the excavations of the Campu Stefano site in southwestern Corsica island (France) a set of beads clustered in a Middle Bronze Age level was unearthed. This level could be dated to the Corisca Middle Bronze age at about 1325-1188 cal. BC. Among the beads, 25 are glasses, one is metallic and 29 are made of a resinous material. The conservation of this last material is exceptional in this area and for this period. However the conservation state of these beads is quite poor and the external macroscopic aspect does not allow an unambiguous identification, moreover for resins which could have several origins. The identification of these organic substances therefore requires an analytical characterization procedure. In order to respect the integrity of the very fragile resinous beads, the first retention of samples was adopted. This sample set has involved Raman and infrared spectroscopies. Raman analyses are performed with a near infrared excitation at 1064nm (FT-Raman) in order to avoid the fluorescence commonly encountered with organic substances. The collection of the Raman diffusion does not require any sampling or sample preparation and analyses are achieved directly on the artefacts and thanks to the use of a microscope the analyzed areas are carefully selected. Infrared analyses are performed with a micro-ATR (attenuated Total Reflection) configuration by contact with the sample without any preparation. To avoid damages to the whole beads by the ATR crystal's contact, some micro-samples detached from surfaces and present in the storage bags are selected for the ATR-Raman analyses. The spectroscopic signatures obtained underline a chemistry corresponding to resins for all the analyzed beads. Because of their specific chemistry and diagenesis each fossil resin presents some specific vibrational features especially for their IR spectra. The various degradation state of the analyzed artefacts leads to some variability of their spectra, underlying their evolution through ageing. But the obtained signatures still allow an unambiguous identification of amber and more specifically of Baltic amber. The geographic origin of the raw organic substances used

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156. The Technology of Late Bronze Age/Early Iron Age Glass in the Mediterranean: Analytical Studies of Vitreous Materials from Lofkënd

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Dating to the 5th-4th c. BC, the mainland Southeast Asian Bronze-Iron Age transition is at first appearance quite disconnected from the epochal socio-cultural developments seen almost 1000 years earlier in Western and Southern Eurasia. Indeed, what is remarkable with Southeast Asia is not the timing of its transition but rather the rate of cultural change and the implied capacity of Southeast Asian populations to rapidly adopt and modify foreign social practices to suit their needs. A large body of evidence, and subsequent academic opinion, points to a regional Neolithic-Bronze Age transition in the late or terminal 2nd millennium BC, and this after a proposed Mesolithic-Neolithic transition only at the beginning of the 2nd millennium BC. It can thus be argued that the passage of only two millennia saw some mainland Southeast Asian populations evolve from a hunter-gatherer lifestyle to full state formation by the early centuries AD.

As with many Eurasian culture areas, the Southeast Asian Bronze-Iron Age transition relates to the major economic, political and social changes that accompany or are in some way catalysed by ferrous metallurgy, rather than the mere appearance of iron in archaeological contexts. With 1st millennium BC Southeast Asian iron production, exchange and consumption still practically unresearched, a major source of data for this critical period is the changing pattern of copper/bronz/lead production, exchange and consumption for the same period. Continuing from Pigott’s and Natapintu’s “Thailand Archaeometallurgy Project” of the 1980s and 1990s, research over the last decade has provided morphological, technological, elemental and isotopic datasets for all the known regional copper production centres and around 500 metal artefacts. These studies have not only added precision to models for the origin of the Southeast Asian Bronze Age but provide for a relatively detailed account of changing metallurgical behaviour over the course of the 1st millennium BC, with the 5th-4th c. BC Iron-Age transition being the marked break point. At this juncture copper-base metal consumption appears to leap, probably reflecting a heightened concern with social display and status at the period when long-distance exchange networks facilitate the transmission of novel foreign practices. This rocketing demand is reflected in the import of typological and geochemical ‘exotics’, more intensive supply from the local production centres, and with evidence for extensive circulation, re-use and potentially monetisation. Thus contemporary metallurgical behaviours seem to mirror the increasing socio-political complexity of some Southeast Asian groups at this critical proto-state period.

158. Beads Culture of Early Myanmar, Doorway to Southeast Asia

Terence Tan

The Late Prehistoric society of the Samon predates the ancient Pyu civilisation by about 500 years. Samon sites were scattered from Hanlin to Pyinmana in Myanmar, but the principle concentration was based in Samon Valley. It is an area around present-day Pyawbwe, Yamethin and Tharzi along the Samon River which flows northwards into the Myit Nge River which in turn runs into the Ayeyarwaddy. Geographically, Samon Valley is situated right at the crossroad from east to west, and north to south. It is referred to as ‘The Doorway to Southeast Asia’. Samon beads are generally made of both organic and non-organic materials. The beauty of the Samon beads is in their varied forms, patterns, iconography and production techniques which involve human milk with ancient alchemy. The mystery lies in what form of superstitious or mystical role the beads played in the Samon culture; another mystery is the mobility of the beads that spread to the faraway lands and into the society of various races, adding to the formation of their unique culture.

By analysing the forms and production techniques of the beads, one could see the transition from pre-Buddhist belief to the growing strength of Buddhism. This paper focuses on the transitions as noted through ornaments, especially beads and their forms, materials, production techniques and iconology, and the change from Bronze-Iron Age (circa 700 BC - 300 AD) to the Pyu Period (200 BC - 900 AD). It is unfortunate to have lost the technologies of those days, the genius of the ancient people. However, what remains could still be observed in the north at Hwa-hoe-rye village where similar chemical compounds to those used by the ancient people on today’s puntuk beads made of fossilised wood.

Metals and Metallographic Ceramics.

159. Persian Crucible Steel Production: Chāhak Tradition

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Crucible steel has fascinated modern scientists for over a century, but the study of its production is a fairly new field of research. Publications so far focus on archaeological sites from Central Asia (9th-12th centuries CE), India and Sri Lanka (mostly 17th century CE onwards). However, the development and spread of crucible steel making is yet to be re-constructed to its full extent. It has been long suspected that the origins of this sophisticated technology potentially stem from Persia, modern day Iran, but no archaeological evidence for this has been published so far. A number of historical manuscripts provide some original data on this technology and relate it to several production centres in Persia. This research reports initial results of the archaeometallurgical study of historical and archaeological data of an on-going project on Persian crucible steel production, based on the medieval site of Chāhak in Central Iran.

A visual reconstruction of crucible fragments reveals some distinctive features of Chāhak crucibles that had not been viewed elsewhere. However, some similarities with Ierv and Ahktshet crucibles are explicit. Microstructure and elemental composition of different crucible fragments and slags were determined with metallographic optical microscope and SEM-EDX, providing information on the fabric of the crucibles, the slag composition and the metal which was produced by this process. This study attempts to open a new chapter in the study of crucible steel production by introducing the Chāhak process, offering a comparison to production at other Central Asian traditions which may pave the way to track and study the origins of crucible steel production in the broader context of Central and Western Asia.
160. Tracking Technological Change in High Resolution: an XRF Study of Iron Age Copper Smelting in the Southern Levant

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The copper ore districts of the Arabah Valley in southern Israel and Jordan were exploited intensively during the early Iron Age (late 12th – 9th centuries BCE), ushering in the first industrial revolution in the southern Levant. Recently, a number of the smelting sites associated with this industry were excavated, and an unprecedented collection of stratified slag samples became available for analytical research. In order to track technological variations in time and space we analyzed the averaged chemical composition of approximately 100 slag samples from 11 distinct stratified contexts. The results were complemented by XRD, SEM and petrographic analyses done on selected slag samples.

Initial results indicated that only by pulverizing the bulk of a slag sample can a reliable average of the chemical composition be achieved; hence we crushed all samples into grains of several tens of microns (using a Jaw Crusher and a Vibratory Disc Mill), leaving about a third of the original sample as a control. Each sample was measured 3 times by pXRF (Bruker TRACeR) using standard calibration methods. Plotted by context, the results revealed distinct patterns, providing significant insights on rationality in technological practices and the evolution of smelting technology through time.

The results demonstrate that while in the northern Arabah manganese ore was the main fluxing agent, it was iron ore in the south. However, this difference stems directly from the geological setting: all other technological variables are undistinguishable, indicating that one production system (representing integral social organization) operated in the entire region throughout the 300+ years of activity in the early Iron Age. Two of these variables were efficiency and standardization, estimated by us using Cu content as a proxy. The substantial sample size and accompanying 100+ high resolution 14C dates allowed reconstructing a detailed picture of changes through time: a gradual improvement of efficiency and the appearance of highly standardized technological practices (indicated by the appearance of a new slag type, presenting less the 0.5 wt.-% Cu and a minimal standard deviation). These finds from the turn of the 1st millennium BCE are in the background of crucial social developments in the broader area of the southern Levant, in particular the formation of local complex polities such as ancient Israel and Edom. Originating from the area of the Arabah, the formation of the latter is reflected in the technological practices of copper production, as better control over smelting processes, standardization and centralization of production indicate more complex social organization. Moreover, the constant search for improving production necessitated the occasional use of some of the social processes that in turn are reflected in the technological record. As these semi-nomadic societies left very little archaeologically-visible material culture behind, the technological record is a crucial component in tracking associated social processes.

161. Experimental and Analytical Investigation of Black Bronze Alloys

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Black bronze is an alloy used as a decorative element on metal artefacts from the Late Bronze Age Mediterranean through to modern China and Japan. It seems to have been reserved for objects of high status, and is essentially an alloy of copper containing a few percent gold or silver, sometimes along with other metals such as tin, arsenic and lead. The surface patina was black with a dark bluish tint and was produced by treatment of the alloy with complex solutions made of inorganic salts. It is purported to have been very stable, resistant to wear, and in some cases able to regenerate by handling. However, no systematic study has been made of the properties of the patinas and their dependence on alloy composition.

We have produced a series of replica coupons of black bronze with controlled contents of 5%, 10% and 15% Cu and Ag and Au and treated them with solutions mimicking those used in restoration methods today. The resulting coatings are examined with metallographic microscopy, scanning electron microscopy, X-ray fluorescence, Raman spectroscopy and x-ray diffraction. Colour and appearance are determined by reflectance spectrophotometry and colorimetry. The quality of the patina and its durability are tested using controlled abrasion experiments. The results are allowing the development of an understanding of the relationship between the production technologies, alloy composition and physical-chemical characteristics of the patinas. Ultimately this will allow us to understand what, if anything, is special about these particular alloys and why they were chosen, as well as to objectively evaluate the claims that have been made for them in the literature. In addition, the research will also lead to reference data for the study of archaeological objects and to methodological protocols of interest to archaeologists, curators and conservators who work with material from a range of cultures.

162. An Unusual Example of Gold Cloisonné from Central Anatolia

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An unusual gold object was unearthed from the Kaman-Kaleköy excavation in 2010 dating to 1800 BCE, the Assyrian Colony Period in Central Anatolia. Preliminary examination of the disfigured object suggests a lion rearing on its hind legs. The gold is 0.5 mm thick, weighs 104 grams, is hammered into a sheet and cut to form the figure. Two rows of hollow tubes, perhaps originally at each end of the object, resemble threading holes found on Egyptian gold pieces for stringing onto the body (e.g. gold plaque [C67] no. 585s) from King Tutankhamen’s tomb. Two rows of tubular stringing holes, the empty cloisons, and the unchased gold surface suggest an unfinished ornament, perhaps an arm band, bracelet, or belt. This unfinished cloisonné object may be the result of trade between the Assyrian Colony in Central Anatolia and the capital of the Old Assyrian Kingdom, representing one of the earliest examples of cloisonné in Anatolia where it is claimed “cloisonné inlay was not known until the 1st millennium BC.” Several examples of gold cloisonné jewelry from Ashur, Urk, Georgia, and Byblos pre-date the Kaman object.

The metal was analyzed with portable XRF in eleven points and found to range in composition from 87.26% to 95.79% gold, 1.98% to 10.5% silver, and 1.55% to 3.31% copper. The majority of the point analyses indicate a type I alloy of AuCuG homogeneous solid solution (<10% silver). One point analysis reveals a Type II alloy of higher silver content, perhaps solder or a harder alloy for attachment to the body. The figure may be divided into 3 alloy groups based on the compositional analysis: gold sheet, gold foil, and stringing tubes. The alloy composition approximates that of a Sumerian necklace from Ur (Early Dynastic Period) and an Egyptian necklace EA 14693 (18th Dynasty) in the British Museum.

One major goal of the project was to discover the method(s) and material(s) of manufacture. Insufficient silver or copper to support the use of hard solder or colloidial solder may suggest autogenous fusing for the attachment of cell walls and stringing tubes. Evidence of partial melting on both sides of the joined cell walls in some areas supports this theory. However, this could be the result of overheating during soldering. Fusion bonding has been found on Sumerian gold objects from the Tomb of Queen Puabi in the Royal Cemetery of Ur that pre-date the Kaman object. Plotting the alloy composition range on the ternary liquidus chart of the gold-silver-copper phase diagram reveals a maximum divergence in melting temperature of approximately 50 degrees. The evidence to support or dispute soldering and fusion bonding is examined using the melting points derived from the liquidus chart.

163. Analytical Study of Andean Precolumbian Metallurgy by Energy Dispersive X-Ray Fluorescence

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On the basis of a detailed elemental quantitative analysis by energy dispersive x-ray fluorescence (EDXRF) of metal objects belonging to the Sipán (AD 0 – 700) and Sipán (AD 700 – 1000) cultures, the aim of this study is to judge the contribution of the Andes to the Metal Production of the Sipán society. Several objects belonging to the Middle and Late Sipán periods were selected and the metal contents were determined using X-ray fluorescence spectrometry. The study demonstrates that the metal content of the Sipán objects is similar to that of other Pre-Columbian metallurgical sites in the Andean region, indicating a similar technological tradition. The results suggest that the Andes played a significant role in the development of metallurgy in the Sipán culture.
900 - 1375) cultures belonging to the Royal Tombs and Sican Museums respectively, an attempt is made to compare the metallurgical processes used in their manufacture. A program based on the fundamental parameters model and developed in this Laboratory, was used for the quantitative analysis by EDXRF. This program allows the detection of surface layers several microns in thickness. Usually a two layer model for the surface of the object is sufficient to interpret the experimental data. However, one can take advantage of the emission of M-characteristic X-rays of heavy metals like gold in order to detect very thin, say one micron thick surface layers. In this case a three layer model can be invoked to interpret the experimental data. An evaluation of the effects of the restoration techniques on the surface structure of the objects is attempted also.

An evaluation of the effects of the restoration techniques on the surface structure of the objects is attempted also.

164. Copper Supply During the Third Millennium BC (Late Neolith and Bell Beaker) from the Pyrénées to the Western Alps

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This communication concerns the third millennium BC copper metallurgy from the Pyrénées to the Western Alps. It focuses specifically on the Late Neolithic and Bell Beaker period by studying collections from various archaeological sites. Using a representative data set characterized by elemental and lead isotope analyses, the goal is to differentiate the Late Neolithic copper supply from the Bell Beaker one. It is assumed that the geographic origin of the copper mirrors the social and economic networks. In particular, it is aimed at tracing the source of the Bell Beaker copper and bringing new elements for a better understanding of the origin of this phenomenon, which is a highly debated question since more than a century. In the study area, three geographic zones are observed:

- The South of France is represented by artifacts from Le Vignaud at Langlade (Gardi), Castelnaudary (Aude), and the Grotte du Rhinocéros 4 (Hérault).
- The Saline Valley is exemplified by a set of artifacts coming from museum collections.
- The Northwestern Alpine fringe is illustrated by the Bains des Dames site at Saint-Blaise (Switzerland).

The elemental and lead isotopic compositions display complex patterns of variation that reflect multiple copper supplies. For the Late Neolithic, a specific mining center highlighted by a characteristic fingerprint seems particularly active. It is compatible with the Cabrières mining district (Hérault, France) that is active at the same time. This signature is found in the South of France collections as well as at the Saint-Blaise/Bains des Dames site (Switzerland), thus indicating a vast circulation network. In all likelihood, the Rhône-Saléne corridor played a key role in the establishment of the cultural components of the Late Neolithic groups. Later, during the Bell Beaker period, a profound change in copper supply is evidenced. A part of the data shows radiogenic Pb/Pb ratios possibly referring to Asturias in northern Spain. If it were to be ascertained, this provenance would reinforce the influence of the Iberian Peninsula for the Bell Beaker components in Western Europe as already shown by the ornamented ceramic, human DNA, and non-metric dental traits.

165. Low Tin Bronze Corrosion by Hydrosulfide (HS-) and Sulfide (S2-) Ions

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Polished contemporary quaternary bronze coupons, nominally Cu93.8Sn5.2Pb0.2Zn0.5 and compositionally similar to bronzes used in some ancient artifacts (low Sn bronzes), were exposed to aqueous hydrogen sulfide (H2S) solutions to simulate environments containing sulfate-reducing bacteria such as anaerobic waterlogged soils. Sulfate reducing bacteria obtain energy by oxidizing various organic compounds, hydrocarbons and/or molecular hydrogen while reducing dissolved sulfate, sulfite, thiosulfate or elemental sulfur to H2S. In water, H2S forms weakly acidic solutions containing the hydrosulfidic ion, H2S (aq), and the sulfide ion, S2 (aq), both of which can react with metal surfaces to generate a range of metal sulfides. The H2S(aq)-exposed bronze surfaces were analyzed by x-ray photoelectron spectroscopy (XPS), scanning electron microscopy-energy dispersive spectroscopy (SEM-EDS) and x-ray diffraction (XRD) to determine the composition and morphology of the initial and corroded surfaces. The initial surfaces were typical of a cored dendritic a-bronze and were dominated by metallic copper together with lead, tin, and zinc oxides and hydroxides. Some of the lead was crystalline. Significant surface enrichment of both lead and zinc was noted. Bronze surfaces exposed to H2S(aq) became a non-lustrious dark gray in color and were very heterogeneous. The surfaces were composed primarily of copper (II) sulfide, CuS2 (both high and low chalcocite forms and djurleite), with minor amounts of copper (I) sulfate, CuSO4∙H2O. Zn(OH)2 and PbS were present in low concentrations, the PbS (galena) redepositing on the surface from solution as flower-like microcrystallites with two different morphologies. Unlike low-Sn bronzes exposed to oxidizing conditions, which develop protective SnO2 layers, the H2S(aq)-exposed surface was considerably depleted in Sn.

166. Gold in Palaepaphos (Cyprus): A Study of Artifacts from the Early Iron Age Necropolis of Skales using Portable X-Ray Fluorescence Spectrometry (pXRF)

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The Island of Cyprus, at the end of Late Bronze Age (around 1200 BC), was facing a transitional situation. Trade networks of the Eastern Mediterranean, which included Cyprus as one of the major suppliers of copper, disintegrated. Civilizations were subdued and important cities of the area, among them the urban Cypriot sites of Enkomi and Hala Sultan Tekke, were either abandoned or permanently destroyed. This situation should had probably affected Cyprus and the trade of Cypriot copper, which would have been exchanged with other precious metals, such as silver and gold, that did not exist in the island. Gold was imported from Cyprus from sources in the neighbouring regions. The most significant gold deposits in the Eastern Mediterranean are those of Egypt and Nubia, while important deposits of gold are also located in Anatolia (Lydia), in Macedonia and Thrace. The study of gold artifacts that seem to have been used during the “Crisis Years” will shed some light to the access of the local craftsmen of Palaepaphos to precious metals, as well as to the prestige and high status of the occupants of this urban centre.

In this paper, a significant number of gold artifacts coming from the Early Iron Age necropolis of Palaepaphos Skales were analyzed using a handheld portable XRF. Moreover, a portable digital microscope was applied to study in detail the surface, and especially the decoration, where exists, of the gold artifacts. The studied assemblage consists mainly of earrings, beads, mountings and various types of thin decorated plaques and fragmentary sheets and disks. The results of the chemical analysis show that all gold artifacts contain a significant amount of silver (Ag) that varies from 3.9 up to 26.2%, while in two cases, a finger- and an ear-ring, the content of silver is much higher, 35.9 and 53.3, respectively. Copper (Cu) was found in the large majority of the artifacts, in a content that varies from 0.1 up to 5.8%. The results indicate that all artifacts were made of a gold-silver alloy, to which copper was probably added in an effort to counteract the whitening effect resulting by the increased amount of silver. The high concentration of silver may have been deliberately added to the gold, or it may indicate the use of electrum, the natural alloy of gold and silver.
167. Evidence of arsenical copper smelting of Bronze Age China: a preliminary study of slag discovered at the Laoniuo Site, Central Shaanxi

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Research into metalwork of Early-Middle Bronze Age China (ca. 2000 BC - 1000 BC) has made significant progress in the past decades. Issues such as the beginning of Chinese metal production, characteristics and casting technology of Shang-Zhou ritual bronze vessels have been taken out from their original containers. The analysis was specifically accomplished by: first, typological and artistic characterization of a sample of cargo artifacts from the site, the latter mainly by means of light microscopy (LM), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDXRS); second, analysis of some technical features of these objects, such as design, alloys, and manufacturing methods; and third, examination of evidence related to novel technologies.

In recent years, a serials archaeometallurgical investigation have been carried out both in the field and in the laboratory by a joint research group based at the Institute of Historical Metallurgy and Materials (IHMM, USTB). Metal production remains dating to late second millennium BC have been found from a site named Laoniuo near Xi’an in central Shaanxi. Analytical result of slag revealed that arsenic content copper smelting has been carried out using naturally compounded minerals of copper, arsenic and other base metals. This research provides the first evidence on the producing of arsenical copper in the early stage of British industrialization, particularly the characteristics of the mass production of artifacts. In this regard, the development of multivariate analysis allowed making a fine-grain examination of the manufacture processes and quality standards. The information obtained was also used to evaluate the technical skills and knowledge of the artisans, and to discuss some aspects for which there are scarce historical written records.

Key words: Archaeometallurgy, Early 19th-Century Shipwreck, British Naval Technology

Reference

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In June 1813, after an unsuccessful expedition to liberate the city of Tarragona of the dominance of Napoleon forces, eighteen ships of the combined fleet of British, Sicilian and Spanish forces supervised by the Lt. Gen. John Murray, were surprised by strong gales and ran aground in the Ebro delta (Catalonia coast, western Mediterranean). Almost 200 years later, one of the ships that could not go ahead was found by local settlers, and has been subject of archaeological study since 2008 by the staff of the Centre for Unitoarchaeological Archeology of Catalonia (Centro d’Arqueologia Subaquàtica de Catalunya). So far, the research conducted in the Deltebre I site has included the survey and recording of the ship’s structure, and the excavation of the cargo located from the stern to the midship section of the vessel (Vivar et al. 2014, in press). The main goal of the present work was to contribute to the knowledge of British metalurgy at the beginnings of 19th century, especially regarding maritime craft. This was specifically accomplished by: first, typological and physical-chemical characterization of a sample of cargo artifacts from the site, the latter mainly by means of light microscopy (LM), scanning electron microscopy (SEM), and energy dispersive X-ray spectroscopy (EDXRS); second, analysis of some technical features of these objects, such as design, alloys, and manufacturing methods; and third, examination of evidence related to novel technologies. It is worth noting the precise temporal definition of the site under consideration, as well as the fact that the ship brought on board large quantities of objects that had never been taken out from their original containers. The analysis of these artifacts shed light upon some technological aspects of the early stage of British industrialization, particularly the characteristics of the mass production of artifacts. In this regard, the development of multivariate analysis allowed making a fine-grain examination of the manufacture processes and quality standards. The information obtained was also used to evaluate the technical skills and knowledge of the artisans, and to discuss some aspects for which there are scarce historical written records.

169. BREAKING FAD: PUSHING THE BOUNDARIES OF METALLURGICAL COMMUNITIES AT THE CENOTE SAGRADO

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148 metals from the Cenote Sagrado at Chichén Itzá in Yucatán, Mexico were investigated in order to characterize the range of fabrication and alteration practices evinced across the assemblage. Recovered with jade, ceramics, wood, and textiles through projects in the 20th century, the metals were imported to the Cenote; no metallurgical debris has been found at the site. Recognizing the diversity among the metal forms and the deposition’s prodigious size, our project aimed to develop biographies of individual metals, group objects by technological patterning, and then compare them to products of known metallurgical communities in ancient Mexica and lower Central America.

Through non-invasive and destructive analyses, our project is the first to reconcile objects from all three museums where the metals are currently held (the Peabody Museum of Anthropology and Ethnology in Cambridge, USA, the Museo Palacio Canton in Mérida, Mexico, the Museo Nacional de Antropología in Mexico City). Optical microscopy (vis-UV-R) was employed for initial characterization of the metals, allowing us to identify such features as the degree of consistency in suspension loop formation on cast objects and the presence of fine depressions that served as guides for designs on sheet. p-ED-XRF spectrometry revealed that 114 of the objects are tumbaga (Au-Cu) with Ag incorporated from the Au source and the remainder, save a high-Sn disc, are Cu-based with As, Sn, and/or Pb as alloying elements; three objects are brass. Fifteen metals were analyzed with RBS to yield elemental depth profiles, revealing enrichment in Au and Ag on two sandsals. Synchrotron-based XRF offered evidence of post-casting hammering on two high-Au bells, and synchrotron-based XRF revealed the correspondences in distributions among major and minor elements.

Metallurgical communities that contributed to the Cenote deposit include the Veracruz-Chiriquí communities of lower Central America, after A.D. 900, who fabricated particular high-Au bells and anthropomorphic figurines and communities in West and Central Mexico, after A.D. 1040, including Tarascan metallurgists whose tweezers were identified in the assemblage. The potential connections to the Mexico tributary system, through such objects as the anomalous sandsals, and the presence of brass extend the development of the Cenote deposit for several centuries beyond the primary occupation of Chichén and into the Colonial period. The alterations of the metals, from burning to crumpling to tearing, illustrate that the smelters, founders, and smiths involved in the primary fabrication of an object are merely one part of a much wider metallurgical community.

170. Thracian Silver Artifacts from Romanian and USA Museums - The Same Provenance Workshop

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We present a comparative technical analysis (elemental composition and method of manufacture) for four famous examples of Thracian art - a silver cup (beaker) and a silver (partially gilded) helmet from Aigaihlo hoard, now in National History Museum of Romania Bucharest, a silver cup (beaker) in The Metropolitan Museum of Art New York and a silver helmet in the Detroit Institutes of Arts. A stylistic comparison was included in “Style and Subject Matter in Native Thracian Art” by Ann E. Parkas, and the technical examination of USA museum artifacts in “Three Silver Objects from Thrace: A Technical Examination” by Peter Meyers, papers published in Metropolitan Museum Journal 16, 1982. The princely tomb at Aigaihlo, near the delta of the Danube River in Eastern Romania, was partly robbed by local inhabitants in late 1930-1931 before being investigated and excavated by Ioan Andriesescu. The USA items are described as discovered in 1913-1914 near the boundaries of metallurgical communities of the Cenote Sagrado.
Danube border between Romania and Serbia, arriving in USA after WW2 from a collection in Vienna, Austria. Our analysis was performed “in-situ” (in the museum) using a portable X-Ray Spectrometer. We also carefully examined the hammering marks, especially those by chasing tools. We observed the thin (approx 30 microns – from Ag K-alpha/K-beta ratio) gold foil used for partial gilding of the helmet was attached after hammering was finished. The silver is very pure - approx 99%, with traces of gold, copper, lead and bismuth from the silver initial mineral. Bismuth is a finger-print of South Bulgaria and Greece silver minerals (argentiferous galena). The compositional analysis and chasing tools fingerprints demonstrated the common provenance (same workshop and probably same silver ore) of the four valuable Thracian silver artifacts from USA and from Romania. Based on 1931 investigation - excavation information from the recent excavated “recurrence book” of Andriesescu the possibility all the four artifacts belong to Agathopolis princely tomb is discussed.

171. Neutron diffraction characterization of pre-Roman coinage from northern Italy: silver debasement and relationships within different emissions

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The pre-Roman coinage from northern Italy gathers together different series of silver coins, mainly drachmas but fractions as well, produced by different tribes settled between the first and latter drachmas emissions, due to inflation processes which can be related with the increasing economic power of the Roman republic in the Po valley. The silver loss can be also used to establish a relative chronology between the different emissions, in agreement with the few dating data available from archaeological research. Moreover, we are now able to assess the ratio between drachmas and the minor fractions, which was still unclear. Finally, these first results are providing new fundamental elements for the study of metrological relationships within the contemporary Roman republican currency, in a period of strong Roman influence followed by the military conquest of northern Italy. This project has been supported by the Cooperation Agreement no. 06/20018 between CNR and STFC.

References

172. Comparison Between Quantitative (ICP-OES) and Qualitative (pXRF) Data of Iron Slag from Sagalassos (SW-Turkey)

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In this research, qualitative and quantitative methods aimed at geochemically characterising antique iron slag, are compared. This study is part of a large scale research project looking at the evolution of iron production in the Sagalassos territory in SW-Turkey. The site was inhabited from the 5th century B.C. until the 7th century A.D. Metallurgical waste found at various locations, often show a range of different functions. Since part of the research is performed in the field, it is necessary to check if qualitative data, gathered with a portable X-ray fluorescence (pXRF) device, can be compared to quantitative results obtained from inductively coupled plasma optical emission spectrometry (ICP-OES). This comparison is performed on smithing hearth bottoms (SHB), furnace cooled slag (FCS) and bloomsmithing slag coming from four localities in the territory. Samples were first mechanically powdered and homogenized, with part of the powder being used for ICP-OES analysis. The extraction of elements was achieved with a modified Lidian technique. A part of the sample was measured with the pXRF at 9 keV and 20 μA for 30 s. No decent standards exist for use with ancient iron slag, therefore, only semi-quantitative results were obtained by using the peak area. To compare the results, the quantitative and the qualitative data were compared. In other words, the tests were employed to check the consistency of both datasets (peaceman correlation and the wiclasen test). Individual element to element comparisons show a strong correlation between quantitative and qualitative results. Density plots show a constant shift for Ca, Cr, Mn, Si and Ti. Despite of this shift, the same conclusions concerning the geochemical fingerprint of the slag can be made. Two distinct groups can be observed when looking at Ti/Fe, Mn/Fe and Ti/Fe ratios. One group shows clear elevated Ti/Fe and Mn/Fe ratios. Since these elements are inherent to ores, it implies the use of a different ore source. Also Ca/Fe plots in two groups. Calcium is probably related to the carbonate rich soils of Sagalassos and was used as a flux in the smelting process. This explains the large spread in Ca/Fe that can be observed in the group with SHB. This study shows that qualitative and quantitative datasets lead to analogue conclusions concerning the geochemical fingerprinting of antique iron slag. It implies that measurements made in the field can be compared to results made in the lab, bearing in mind the shift in certain elements.

173. Methodological Development for the Decomposition of Ancient Iron Slags for ICP-OES Analysis

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Inductively coupled plasma optical emission spectrometry (ICP-OES) is a well established analytical method in archaeometallurgy. It has the advantage that a large number of samples can be analysed simultaneously with high precision. The disadvantage however is that samples have to be introduced in solution. While this is no problem for most materials (stone, ceramic, soils); metallurgical waste materials have a complex, heterogeneous matrix of iron- and silicate rich minerals. Hence, they are difficult to put into solution. Archaeometallurgical literature often does not mention the decomposition technique. In this study, several dissolution techniques were tested on iron slags originating from the Sagalassos territory in the South-West of Turkey. The site was inhabited from the 5th century B.C. to the 7th century A.D. and throughout these periods metallurgical waste was produced in the form of smelting, blooming and smithing slag. Langmuir and Ruff [1,2] described a dissolution method which involves the use of “Parr” bombs and a mixture of HCl-HNO3-HF. However, precipitation was found even after adding boric acid to bring the fluorides back into solution. The acid mixture HNO3-HClO4-HF method, which is often applied on iron- and silicate rich meteorites [3], resulted in incomplete dissolution, even after three runs. Moreover, since HF is used, it would be impossible to measure silica. Fusion is a well established technique to decompose samples with [1,2] described a dissolution method. This method is often used for modern slag [4, 5]. LIBO2 was used as fusion flux and the sample was heated at 1000°C for 10 minutes.
174. Mill scale on historic wrought iron: characterisation and impact on corrosion behaviour

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Context
Mill scale, the oxide layer formed on the surface of iron and steel during hot rolling and forging, is well understood for modern steels but less so for ancient and historical ferrous material. The identification of mill scale on archaeological and historical ferrous objects and the characterisation of its composition and structure are not well documented. Neither is its importance and role.

Does mill scale represent the original surface of the ironwork? Does its presence inhibit or encourage corrosion? What is its impact on adhesion and performance of protective coatings? Some conservation techniques for historic wrought iron involve removing all oxide layers to ‘optimise’ performance of protective coating systems. This inevitably equates to loss of any surviving mill scale and the information contained therein yet evidence relating the removal of oxide layers to reduced corrosion rates is limited.

This paper reports a research project at Cardiff University which seeks to characterise mill scale on wrought iron and mild steel samples and assess how its removal impacts on corrosion rates.

Methodology
The morphology and composition of mill scale on 2nd century AD archaeological forged nails, mid/late 19th century rolled wrought iron bar and plate and modern mild steel samples has been investigated.

Location and thickness of ‘mill scale’ layers and their degree of continuity have been determined using optical microscopy and SEM-EDS. X-ray diffraction has been used to characterise mill scale in the context of the corrosion profiles on uncleaned, cleaned to mill scale, and cleaned to bright metal samples. The results give insight into the nature of mill scale on archaeological and historic wrought iron produced using differing technologies. The corrosion behaviour of these samples is being investigated using Electrochemical Impedance Spectroscopy and corrosion rates derived by measuring oxygen consumption of samples sealed in controlled high relative humidity environments. The decision whether to remove or retain mill scale during a conservation process can now be made with an understanding of its likely survival on historic wrought iron and its impact on corrosion.

175. From sculptures to foundries: elemental compositional analysis to trace modern bronzes provenance

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Modern bronze sculptures produced by European masters in the early 1900’s were cast in Parisian foundries. Different casting methods, namely lost-wax or sand casting, together with a variety of patination processes had a strong impact on the final product resulting in appearances of the metal sculptures ranging from highly polished to heavily patinated. Some artists produced their sculptures not only in France but also in the United States. In the case of Jacques Lipchitz, the artist produced early experiments bearing the Parisian Valaisan foundry stamp and then later works at the Modern Art Foundry in New York.

Regardless of the geographical location, the foundries of the period were reluctant to declare their proprietary casting alloys or patination methods. This suggests that the composition of a particular alloy may be sufficiently different at each foundry where these early modern sculptures were cast.

This study focuses on twenty-three bronze sculptures in the collection of the Smart Museum of Art at the University of Chicago. Cast between the late 1880’s and 1920’s, these sculptures were important works by Rodin, Lépichot, Degas, among other well-known modern sculptors.

Using portable X-ray fluorescence spectrometry (XRF) it is possible to determine the elemental composition of these bronzes, namely copper with variable amounts of zinc and tin. The new results expand the metal alloy database already available in literature (Young et al., 2009, Day et al., 2010) and test the hypothesis of whether it is possible to relate alloy composition, as determined with XRF, to the different foundries active at the beginning of the 20th century. This is of particular importance for art historians and conservators trying to address questions such as authenticity and provenance, since not all sculptures bear foundry marks nor have documentary evidence as to where they were cast. This research addresses questions such as reproducibility of the XRF measurements, the effect of the patina thickness on the XRF response, the impact on composition due to foundry practices (batch to batch variation, adjusting the metal mixture during the course of the work, tailor-made alloy composition etc.) and the importance of testing the method on a large dataset of bronze sculptures. Art historical research on the origin, dating, and provenance of some of the pieces provides useful complementary information to interpret and assess the analytical data.

176. Gilded and Silvered Artefacts from Medieval Tuscia (Italy): Materials and Technological Features

Maiolmo Gaudenzi Annelli\(^1\), Marcos Martín-Torres\(^2\)


The gold and silver plating of base metal objects are well-known and widespread practices through the ages. Different technical solutions are available to obtain a golden or silvery surface, and thus the choice of specific techniques can be informative of cultural influences, technological traditions or object provenance. This paper focuses on the characterisation of a set of gilded and silvered artefacts recovered from two archaeological sites of the medieval Italian region of Tuscia: Leopoli-Cencelle and Mirandaolo (current South Tuscany and North Latium, respectively). These artefacts include different object typologies: structural and decorative items, dress accessories and personal ornaments. Their dates range from the 11th to the 14th century AD.

The method of analysis involves the use of XRF and EDXRF and SEM-EDS microscopy to determine the elemental composition of the alloys and the presence of gold and silver. The results provide useful complementary information to interpret and assess the analytical data.
a smaller number of objects for invasive examination. The microanalytical study of cross-sections allowed a more detailed understanding of the specific materials and techniques employed in the manufacture of each artefact. Most of the artefacts studied showed the presence of a gold-mercury or silver-mercury amalgam layer applied to a base metal substrate. Mercury slivering is mainly associated to brass artefacts, while the predominant metal associated to fire-gilding is copper. The technical and cultural contextualisation of these practices will be discussed with reference to historical sources such as the 12th century De Diversi Artibus of Theophilus, and Arab and Andalusi texts from the 10th to the 14th century, and to archaeological artefacts from Italian and Iberian medieval sites already published, with particular attention to the role of Islamic influences in their spread.

The archaeometric characterisation shows that fire-gilding and mercury slivering seem to have been the most common decoration techniques for small, portable and personal objects in medieval minor centres of the Tuscia region such as Leopoli-Cencelle and Mirandaudo. Although it has not been possible to determine the provenance of the mercury used in the gold and silver amalgam, the choice of these peculiar techniques may have been associated to the availability of mercury at the local mines during the Middle Ages, namely at the cinbar deposit of Mount Amiata.

177. In the middle of it all: metallurgy in Early Bronze Age Palamari (Skyros island, Aegean)

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The fortified site of Palamari on Skyros island, situated in the central Aegean and inhabited through most of the third millennium BC, occupies a nodal position in the maritime network of this period connecting the north-east Aegean urban centers (e.g. Troy, Poliochni) with the Cycladic islands and the south mainland. Over 20 years of excavations have unearthed an important collection of metal artefacts and metallurgical remains from four distinct habitation phases (Palamari I-IV: Early Bronze II to early Middle Bronze Age). These periods are crucial for the development of Aegean metallurgy as they see the dawn of large-scale metal production and circulation in this region and the introduction of tin bronze with progressive replacement of arsenical copper. Within this context this paper discusses the results of the analytical examination of Palamari’s archaeometallurgical assemblage, clarifying the nature and technological parameters of the metallurgical activities at the site, as well as the technology of manufacture and provenance of the artefacts. A representative number of artefacts and remains was selected for sampling on the basis of contextual and typological information, as well as preliminary pXRF analysis of a limited part of the assemblage. Samples were studied using metallography, EDS-SEM, and lead isotope analysis. The results suggest that during all four phases, the dominant copper alloy is arsenical copper. Tin bronze is already attested from the earliest phase, Palamari I. Tin bronze is rare in Palamari II and IV, but significantly more common in Palamari III. The artefacts can be further grouped based on the relative abundance of other base metals and copper sulphides. The majority of metallurgical remains from Palamari were identified as by-products or remnants of secondary metalworking activities, while indications for small-scale copper smelting were also identified only from Palamari I. Copper and arsenical copper were primarily worked at all periods, but in Palamari III there is additionally evidence for tin bronze working. The majority of copper-based samples, whether made of arsenical copper or bronze, plot on the lead isotope diagrams in a wide area occupied by numerous Aegean and Anatolian ore sources, although interesting sub-groupings emerge. Two of the tin bronze artefacts from Palamari III, however, have distinctly higher 208Pb/206Pb and 207Pb/206Pb ratios consistent with other artefacts of the same period identified previously as non-Aegean/Anatolian. The results are considered in relation to those from other contemporaneous neighbouring sites in the north-east Aegean and the Cyclades.

178. On the Distribution of European Copper Artifacts in Northeastern North America

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European copper artifacts appearing in Northwestern North America in the 16th and 17th centuries were highly desired by Aboriginal communities. Ethnohistoric records, morphological analyses of archaeological materials, and basic scratch tests have shown that European kettles and their parts travelled quickly from the East coast of Canada all the way to the west. However, on the existing evidence it is impossible to know whether artifacts were distributed uniformly or preferentially among the Aboriginal communities. In this presentation we use INAA to examine 997 copper kettle artifacts from 16th-17th century archaeological sites in Ontario (56 sites; 585 samples), Quebec (19 sites; 349 samples), and Nova Scotia (3 sites; 63 samples), to establish metal chemical groups and explore their distribution among the different archaeological sites and Aboriginal communities.

We establish 11 coarse chemical groups, 3 of them splitable each into two sub-coarse chemical groups, for a total of 15 distinct coarse chemical groups. This implies that at least 11-15 ore sources and/or copper producing processes were used to make the copper kettles from which our samples came. Although the dataset is heavily biased towards Ontario sites, it is possible to trace tentative trading connections among different Aboriginal groups by sorting the chemical groupings by nation and even by archaeological site. Wendat sites accounted for the majority of sites in Ontario (58 sites; 585 samples), Quebec (19 sites; 349 samples), and Nova Scotia (3 sites; 63 samples), to establish metal chemical groups and explore their distribution among the different archaeological sites and Aboriginal communities.

The results from the database I have collected so far suggest a difference in bronze use between the northwest half of Anotalia and the south east, cut roughly along the Taurus and Anti-Taurus mountain ranges. From the 3rd Millennium to the 2nd Millennium bronze ubiquity dounds regions in the northwest region but increases substantially in the south west. If the Kestel mine was exploited on a large enough scale to be the sole source of tin for Anatolia, one would expect that when it ceased to be exploited, bronze ubiquity across the whole region would decrease. However, if the Kestel mine was only exploited on a small, local scale, accessibility to the northwest region makes it more likely that the Kestel mine mainly supplied this area, rather than the area across the mountains to the south. If this is the case, an alternative source would be needed for the supply of most bronze in southeast Anatolia. Such a source should be looked for to the east of Anatolia. To extend this theory I am currently researching the ubiquity of bronze in Cyprus, Armenia and Georgia, Mesopotamia, and Egypt alongside evidence of trade with Anatolia to ascertain whether an alternative source might be indicated.

The main purpose of my research is to better understand the nature of the bronze trade in Anatolia, which as well as focusing on the sources of tin, hopefully reveal facts about the flow and movement of metal within Bronze Age Anatolia. In order to do this I am applying a technique to...
180. Exploitation of Manganese-Rich ‘Ore’ to Smelt Iron in Mwenge, Western Uganda

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By the later second millennium AD, iron production was a key economic industry in western Uganda, and Mwenge was a prominent centre of production, highly regarded for the quality of the iron it produced. Between 2007 and 2011, excavation and analysis of iron production remains from six smelting sites in Mwenge enabled the reconstruction of local smelting technologies in operation there from the fourteenth century AD onwards.

Chemical and microstructural analysis (PED-XRF, SEM-EDS, and optical microscopy) of approximately 100 samples revealed that slag from three of these sites is typically characterised by a bulk chemistry high in manganese oxide (5–12wt%) and knebelitic olivines. Slag samples from the remainder of the sites contain low levels of manganese oxide (<4wt%) and fayalitic olivines. The majority of the slag samples also contain notable levels of phosphorous (1–2wt%).

Principal component analysis of these data indicated that some smelters in this region were deliberately combining an iron ore with a separate manganese-rich flux, rather than using a naturally manganiferous iron ore. This use of two ‘ores’ has parallels with ethnographic literature from the region, which link the use of a second ore to the production of a harder iron.

It is believed that this is the first analytically documented example of the use of a manganese-rich flux in sub-Saharan Africa. This poster will discuss the impacts of these manganese and phosphorous levels on the smelting systems in operation in Mwenge. Furthermore, in the absence of analyses of surviving iron artefacts, the data also provided an opportunity to consider the quality of the iron metal that would have been produced.

181. The metallographic and lead isotopic research on several bronze weapons corresponding to origination of Qin Dynasty

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As it is well known, the first powerful united Chinese empire is the famous Qin Dynasty, which has a mysterious development from weak to strong. Therefore, the problem of early Qin culture origination is a hot issue in Chinese archaeology. In historical documents, the early Qin people lived in the west border of Zhou Dynasty who consolidated and expanded their territory by fighting with Rong and Di people. The paper introduces the researched results of six bronze weapons excavated in Fengxiang, Li and Longxian County from the West Zhou to the Spring and Autumn Period by metallographic and lead isotopic analysis. The tested results indicate that Sn content is 10–18% and Pb content is 2.12–9.83% of bronze weapons which show a kind of cast structure. Unquestionably, the making technology of these bronze weapons is similar to that of other kingdoms. Lead isotope ratio relationship charts (LRIR) show there is the overlapping area of Longxian and Li county, and sample of Fengxiang is completely separated with others. Fengxiang County is a famous place for the analysis that had become the political and economic center of Qin people as far back as in the Spring and Autumn Period. The sample of Fengxiang county belonged to other people of the Zhou Dynasty which shows different origination of lead mine than that of Li and Longxian County. It is an important finding, because it shows that, as the main residence of early Qin people, Longxian and Li county had used their own lead mine. The results reveal that the bronze smelting and casting technology of early Qin people has already been well-advanced, and they probably exploited their own lead, tin and copper mineral resources. The stable mineral resource is a guarantee of them to lead the early Qin people to survive, fight and finally accomplish their great achievements.

182. Combine XRD, Metallography and Radiography Analysis of Metal and Corrosion Products for Luristan Bronzes, Iran

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This article studied three bronze artifacts related to Luristan, Iran. The label Luristan bronzes designates a series of decorated bronze objects in a specific local style, dating from the Iron Age. These three bronzes were obtained from illegal excavation, and now they belong to Chaharmahal and Bakhtiari Cultural Heritage Organization. Although, based on comparing studies, these two idols and a whetstone handle are from Luristan region.

In this paper for an advanced understanding of the bronze archaeometallurgy during the Iron Age in Iran, metal and corrosion products have been studied by Radiography, X-Ray Diffraction (XRD), Metallography Examination (ME) and Gas Chromatography. Besides, Non-destructive and destructive Analyses were done, i.e. metallography on one of the idols (idol 2) was performed by Non-destructive sampling.

Metallography Examination identified alloying and manufacturing processes and also appreciated the different phases corrosion of the pieces, determined by its coloring, reddish and brown for copper oxides and greenish tones for chlorides, which complements the analysis of the X-Ray Diffraction (XRD). The XRD analysis identified the presence of Paratacamite, Atacamite, Cuprite, Malachite and Quartz. In addition, Radiography performed to recognize density of metal, manufacturing process and damages by corrosion process.

In conclusion, the bronze manufacturing technology used in the manufacture of these objects has many similarities with other production techniques which have been investigated on other Iron Age objects of Luristan region. It provides an important step forward in our understanding of bronze metallurgy in the first millennium BC in Luristan.

Keywords: Iran, Luristan Bronzes, Metallography, XRD, Radiography
184. Embracing In-Homogeneity in Archaeomagnetism: Implications for Sampling and Analysis

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A fundamental difference between archaeomagnetism (AM) and paleomagnetism (PM) is in the nature of most AM sample material. Most individual PM specimens are homogeneous in mineralogy and heating history. In contrast, AM substrates often contain a mixture of heat-resistant components. Another difference is that, in principle, heating may not achieve Curie temperatures, the depth of heating can vary dramatically, and pTRM rather than TRM characterizes many samples. Our work at the Museum of New Mexico over the past decade has focused on improving AM results (precision) by matching sample collection techniques to models of heating and TRM acquisition. Fortuitous sampling opportunities and intentional experimental work have resulted in our shift to the recovery of burned surfaces rather than the recovery of voids in heat-affected substrates. This shift has both maximized the recovery of the strongest TRM or pTRM and minimized the volume of poorly aligned material within individual specimens. The development of an epoxy recovery technique has allowed collection from thin horizontal and vertical surfaces that were not recoverable with our previous conventional sampling technique (plaster encased 1-inch cubic specimens). The epoxy technique also has allowed AM sample collection in settings where other approaches would cause intolerable damage to archaeological material. In addition to increasing the range of features that can be sampled, the surface focus has improved sample precision, with a perceived reduction of alpha-95.

The success of the surface approach has raised other issues. AM analyses and calibrations commonly use strength and intensity data that are calculated using procedures derived from PM theory and practice. Those procedures assume a homogeneous material in both composition and heating history, which in our experience is rarely met by AM substrates. Composition and homogeneity can be evaluated in the field and laboratory (fabric and mineralogical assessment), but heating homogeneity is rarely evaluated. This is especially true when the depth of strongly heat-affected material does not penetrate beyond several millimeters of the heated surface. While some AM substrates are well-behaved relative to the assumptions that are inherent in PM theory and practice, our experience suggests that the performance of AM research and dating can be improved by acknowledging and adapting AM approaches to the realities of the in-homogeneity of most archaeological substrates. This includes how we use strength measurements in the assessment of different specimen contributions to sample results and how we determine which materials are most appropriate for use in calculations of paleointensity.

185. Dating results of new palaeoenvironmental studies conducted in South Peloponnesus, Greece

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It is well established in the literature that palaeoenvironmental studies can produce reliable results concerning past environmental changes but they can also be useful, where possible, in forecasting future trends in the environment. South Peloponnesus, and specifically Mani peninsula, located at southwestern Greece is considered among the most challenging areas for studying past environmental changes, especially during Upper Quaternary, because of its long and complex coastal zone, its active local tectonic regime, as well as its nodal position between three continents. Rich sequences of terrestrial and marine sediments classified by the stratigraphic sense are found in the area. These sedimentary deposits, fluvial or coastal, are an excellent repository of environmental changes that have occurred during the past 120,000 years at least, thus offering the possibility of extensive and in-depth study of these changes. It is worth noticing that Mani is also significant by a number of factors: it is a thick coastal plain that is man inhabited at the area and was active for a long time period. Here, we present dating results obtained by employing optically stimulated luminescence (OSL) dating technique, combined with the single-aliquot regenerative dose (SAR) protocol. These results concern samples collected by a fluvial deposit, situated at an area called Diros where known caves are lying. Specifically, four layers of this stratigraphic deposit were dated and they revealed ages extended from 58,000 to 120,000 years ago. An unforeseen result was that these ages do not follow the stratigraphy of the deposit. Instead, a type of reversion is revealed. In the literature are suggested some mechanisms which could interpret those findings. The transfer of big parts of layers situated initially at a higher place and the reversion during the transportation could be one of the most challenging areas for studying past environmental changes but they can also be useful, where possible, in forecasting future trends in the environment.


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It is clear that chemical analyses of archaeological materials provide important information about cultural and economic practices in antiquity. Over 20 years of research on absorbed organic residues found in archaeological potsherds has been undertaken based on the idea that organic residues are microencapsulated in the pores of unglazed ceramic artefacts. To date, the solvent extraction (chloroform: methanol 2:1 v/v) method has been the most widely used to recover organic residues from the archaeological ceramics. However, organic residues are not ubiquitous and sometimes the recovery rates and concentrations can be highly variable. Herein, we present the results of chemical and physicochemical investigations of replica and archaeological ceramics and discuss how factors such as vessel fabrication, variable uses and burial conditions can limit absorbed residues.
organic residue preservation in archaeological pottery. In order to investigate how different types of vessel fabrication and variable uses of cooking pots can affect organic residue preservation a series of cooking experiments were performed, where food commodities with low and high lipid concentrations (e.g. vegetables and meat) and replica pots with different surface treatments (burnished and unburnished) were used. Scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX) and Brunauer-Emmett-Teller (BET) analyses were carried out to relate the surface topography, chemical composition and porosity of replica and archaeological ceramics with organic residue concentration recovered from the vessels. The results of these experiments are helping us to better understand the mechanisms of organic residue absorption into ceramic matrices, and provide new insights into the interpretation of archaeological residues from plant and animal products.

187. The Rectorate building of the University of Cagliari (18th century): metrological-chronological and material analysis of masonries

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Object of the study is the Palazzo Belgrano, seat of the Rectorate of the University of Cagliari, built during the second half of the 18th century. This building, even if it has been object of some renovation and restoration project, still now maintains its original constructive peculiarities, both by a formal and material point of view. This data emerged during the recent restoration works. In this course an intensive investigation was prepared, following an interdisciplinary approach. Specifically, the research has been carried out integrating historical-archaeometrical and scientific methodologies: on one side, the building has been explored by an architectural point of view, using an approach based on the chrono-typological analysis of masonries, showing their structural aspects and the executive modalities for their setup. Specifically metric and photographic surveys, supported by drawings highlighted the constructive peculiarities of the masonries were applied. On the other side, they have been studied by mineralogical-petrographic and geochemical methods for the characterization of stony elements, the analysis of plasters and mortars. Mineralogical and petrographic characterization has been carried out using optical microscopy of standard thin sections and X-ray diffraction. Chemical analyses of the binder by X-ray fluorescence have been carried out in order to define the nature of the mortar (hydraulic or lime mortars).

The main reason that triggered this study is the lack, with reference to the Sardinian context, of investigations aiming to the chronological definition of buildings, based on the direct and indirect survey. The protocol used for the analysis of these masonries has been conceived in a way that it can be extended to every context, and with reference to every kind of historical buildings.

Following steps of investigation were undertaken:

- architectural survey;
- masonries survey, referred to basements, pilasters, arches, angles, portals, window frames;
- mapping and analytical characterization of materials (stone, mortar, plaster).

The masonry techniques have been studied putting in evidence their shape, their dimension and their materials. By this way, the characteristic of masonries and finishing referred to the 18th century in the local context, inspired to the Piemonte culture, have been defined.

In conclusion, this study represents a reliable tool for ancient edifices chronological definition, and helping in their conservation management especially for the so called ‘minor’ architectures, whose cultural meaning is often unrecognised. This identification is very important nowadays, because of the enlargement of ‘monument’ notion, that includes both instances of historical-artistic significance, and traditional urban fabric.

188. Rehydration-Dating of Pre-Hispanic and Colonial Fired-Clay Artifacts from Aguascalientes, Mexico

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Chronometric dating methods are invaluable in constructing sequences of events in archaeology. Since 2009, rehydration-dating has emerged as a useful alternative for fired-clay artifacts. The key to this method is to identify the weight loss associated with the clay’s dehydroxylation. However, in heterogeneous samples with multiple and overlapping thermal events, calculating this weight loss is often challenging. We intend to solve this problem by combining phase, vibrational, and thermal analyses in a large number of archaeological artifacts from the state of Aguascalientes in Mexico. The samples come from the Pre-Hispanic archaeological sites of: “El Occito”, “Cerro de Santiago”, “La Montesita”, and the colonial convent complex of San Diego. They include: ceramics, clay fragments, bajareque (wattle and daub), and tiles. The presence of hydroxy groups could not be detected by combining the attenuated total reflectance sampling technique with Fourier Transform Infrared (FTIR). This result could be explained by the low concentration of hydroxy groups and the low penetration depth of infrared radiation in the samples. However, the presence of hydroxy groups was verified by weak signals in FTIR spectra using potassium bromide disks. The qualitative phase analysis using X-ray diffraction revealed the presence of associated phases such as carbonates and quartz. The analysis also showed the presence of clays, their dehydroxylated phases, and their thermal composition products. The thermal evolution of the samples strongly depends on the type of archaeological artifact they were taken from (ceramic, clay fragment, bajareque or tiles), the chemical, and the phase composition. The processes of dehydration, organic matter decomposition, dehydroxylation, and carbonate decomposition partially overlap. Therefore, in order to identify the weight loss corresponding to the dehydroxylation process, we needed to simultaneously measure the differential heat flow and weight loss. This allowed us to identify the dehydroxylation weight loss in most of the samples. The methodology described above could be applied to other fired-clay artifacts. We found that, generally, rehydration-dating can be used in multiple chronological phases, without any additional treatment. Based on this, different archaeological artifacts were successfully dated. To the best of the authors’ knowledge, this is the first time the rehydration-dating has been applied to Mexican fired-clay artifacts.

189. COMPARATIVE STUDY OF TWO ETRUSCAN BUCCHERO AMPHORAS

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This study analyzes two Etruscan “heavy bucchero” amphoras also known as “Nitkothenic amphora”. Initial stage of conservation showed differences between them. The first amphora (N 3482) is dated at the second half of the VI century B.C. It can be easily compared to the similar amphora dating in different contexts. This type of amphoras is characterized by significant width of sides, lightly burned ceramics and cracked crouch. The second amphora (N 3449) is dated in the middle of the VI century B.C. Similar amphora were not found so far. It has rather thin, solid and well burned ceramics. The following complex of physical-chemical methods have been used to study fragments of these amphoras:

- optic microscopy in reflected light
- X-ray fluorescence spectral analysis
- emission spectral analysis was conducted on the spectrometer with ICP
- microchemistry analysis
- X-ray phase analysis
- IR-spectrophotometric analysis

Amphora N 3482

All fragments are similar to each other by mineral composition. Quartz is prevailing component; other components are clay minerals, feldspars, muscovite, carbon-containing substances. The element composition of ceramics (Si-Al-K-Mg-Ca-Si) does not contradict with mineralogical data.

Amphora N 3449

Quartz, feldspar and clay predominate in composition of ceramics of this amphora, calcite is also present in a smaller quantity. Organic and mineral black pigments, muscovite are admixture components. The results of chemical analyses (Si-Al-Cr-R-Fe-Mg-Na) conform with mineral composition. X-ray fluorescent and emission spectral analyses (in relative %) demonstrate analogues set of elements in all studied fragments. Nevertheless,
ceramics of each amphora differs in percentage of some elements (mainly by calcium and iron). This is caused by qualitative and quantitative differences in the mineral composition of ceramics of the compared amphoras. Thus, ceramics of amphora N 3482 is characterized by abundance of calcite. In comparison in ceramics of amphora N 3497 quartz is significantly presented, feldspar and clay minerals present in a smaller quantity.

Our data showed that compared amphoras bucchero have the same components in their ceramics. However, they are noticeably distinguished by qualitative and quantitative mineral composition of their chemical elements.

Possibly, similarity of ceramics of both amphoras is for «heavy bucchero», and differences are determined by time and place of their making. This assumption needs further study of analogous works.

190. Putting a Puzzle Together: A Roman Bronze Lamp from Kavastu (Estonia)
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The poster introduces a multidisciplinary study of a unique bronze cache consisting of a Roman bronze lamp and bronze bars discovered in a peat bog in Kavastu (Estonia) in early 10th century. This is an unusual find including the bronze bars discovered in a peat bog in Kavastu (Estonia) and a rare collection of bronzes which contains an assemblage of items of very different origin, some of them also imported while others might be local productions. Items were deposited some time after the mid-1st millennium AD. They were probably concealed as a hoard of scrap metal collected due to the continuous importance of bronze as a precious production material in the northern Europe in the 1st millennium AD. The study on the Kavastu bronze deposit is a good case study of the possibilities of attaining important information about antiquarian finds for their further interpretation based on purely artefactual material.

191. Radiocarbon Dating of Pacific Island Wooden Figures: Multiple Analyses Produce Better Age Determinations
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The aim of the project was to analyse the provenance, chronology, travel routes and the date of depositing the assemblage by combining general archaeological data, the results of metallurgical study carried out after the discovery of the find and employing more recent methods of archaeological sciences: AMS dating and lipid analysis of the fuel residue in the lamp nozzle. The alloys in a lamp and bars are of different composition. Based on those it was initially suggested that the likely date of deposit might be as late as the end of the 1st millennium AD. The residue analysts employed GC-MS and GC-C-IRMS. The results indicate that the fuel is of plant origin (most possibly olive oil), unfortunately without any further diagnostic features. However, it is likely that the lamp has not been used for illumination purposes in the eastern Baltic, as the most common illumination fuels in prehistoric northern Europe are fish oils, animal fats or beeswax. For dating both bulk AMS and SC-AMS (single compound AMS) were used. They date the fuel to the 5th-6th century AD which is several centuries later than the chronology of such lamps in their original Mediterranean context.

These results indicate that we are dealing with the deposit of bronzes which contains an assemblage of items of very different deposition date. An examination of the lamp which must have travelled thousands of kilometres over several centuries, but which has not been as a source of illumination in its final location; bronze bars of different origin, some of them also imported while others might be local productions. Items were deposited some time after the mid-1st millennium AD. They were probably concealed as a hoard of scrap metal collected due to the continuous importance of bronze as a precious production material in the northern Europe in the 1st millennium AD.

The project on the Kavastu bronze deposit is a good case study of the possibilities of attaining important information about antiquarian finds for their further interpretation based on purely artefactual material.

192. Reexamining the Archaeology of the Colorado Plateau (USA) Using Radiocarbon Dating of Collected Wood
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The northern Colorado Plateau of the United States is high, semi-arid desert with some forested areas. The region was occupied by settled Fremont agriculturalists in the early second millennium CE and then by Ute hunter-gatherer-horticulturalists through the colonial period. The widely held view of archaeologists working in this area is that the collapse and abandonment of the Fremont was contemporaneous to that of the Ancestral Puebloan (“Anasazi”) in Four Corners region in the late 13th century. The common argument is that Ute groups then settled the area beginning in the 14th century from the west. Dating these events relies heavily on radiocarbon chronologies on wood charcoal from hearths. We argue that the climate conditions of the Colorado Plateau cause dry wood pieces to remain on the landscape for millennia, and the standard chronology for the Ute and Fremont needs to be reexamined.

This aim of this research is to assess variability in firewood age across the northern Colorado Plateau. In 2011 and 2012, we collected “firewood” tree logs from the forest floor and limbs from dead trees - in five wooded environments located near archaeological sites. AMS radiocarbon dates on more than 30 wood samples range from 1000 BCE to post-bomb, presenting the likelihood that Fremont and Ute people may have collected ‘old’ firewood. Thus the archaeological chronology for the region is built on poor data. As a case study, we looked at the Jutten Lodges site, a Ute settlement dated to the late Contact period by historic artifacts. In a teepee sheltered household, a pile of firewood survives approximately one meter from a hearth pit containing wood charcoal. We compared AMS radiocarbon results obtained on charcoal from the historic hearth directly to results obtained on deadwood that presumably was intended for burning in that same hearth. The dates on the charcoal range from 1300 CE, while the firewood samples date from the 17th-20th centuries. We suggest that the timing of the Ute migration into the northern Colorado Plateau has been misinterpreted in relation to the Ancestral Puebloan and Fremont abandonment due to reliance on ‘old’ wood charcoal dating. The results of this study have important implications for the Fremont and Ute chronologies, interpretations of ethnohistory and past land use practices in the area, and radiocarbon dating of 2nd millennium CE sites in semi-arid areas worldwide.
193. The First Experience of Comparative radiocarbon dating of archaeological monuments of Late Bronze Age Southern Transursals

INVESTIGATION OF ARCHAEOLOGICAL MONUMENTS OF THE LATE BRONZE AGE IN SOUTHERN TRANSURSALS AND IDENTIFICATION OF CHRONOLOGICAL RELATIONSHIPS BETWEEN THE SIBERIAN AND CENTRAL Asian CULTURES

In 2011 while continuing to investigate Kasburun I burials belonging to the Late Bronze Age and located in Duma-Urshak interfluve of Southern Transurals right at the burial site one more settlement was discovered – Usmanovo III. To define functioning time of Kazburun I burial mound and define the site one more settlement was discovered – Usmanovo III.

In the Early and Mid-Pleistocene the Thames River in Great Britain drained much of East Anglia and emptied into the North Sea near Swanscombe in Kent. At some point, presumably as a result of one or more glaciations, the course of the river moved south to its present location. The North Sea near Swanscombe in Kent. Britain drained much of East Anglia and emptied into the Thames River in Great Britain drained much of East Anglia and emptied into the North Sea near Swanscombe in Kent. At some point, presumably as a result of one or more glaciations, the course of the river moved south to its present location. The course of the river moved south to its present location.

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194. Dating of Submerged Landscapes by Electron Spin Resonance

In the Early and Mid-Pleistocene the Thames River in Great Britain drained much of East Anglia and emptied into the North Sea near Swanscombe in Kent. At some point, presumably as a result of one or more glaciations, the course of the river moved south to its present location. The course of the river moved south to its present location. The course of the river moved south to its present location.

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References


195. Geochronology of the Royal Tomb at Ulaanhermni Shoroon Bumbagar, Mongolia

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The ages obtained on different materials using pIRIR180 and d-IR IRSL was applied to the fine grains of fired clay samples and DeIR180=6.50±0.33Gy was obtained using the

N. Zacharias

Poster II abstracts

Poster I abstracts

Luminescence Dating for Artefacts and for Field Studies: Alterations, Variations and the Context

Luminescence Dating for Artefacts and for Field Studies: Alterations, Variations and the Context

More than half of a century after the publication of the first Thermoluminescence (TL) ages on archaeological fired material, the field of Luminescence Dating has reached a level of maturity that serves all fields of archaeological science, from artefacts to anthropological and geoaarchaeological material in a routine base. The key-advent of the Optimally Stimulated Luminescence (OSL) techniques and the potential for exploring a spectrum from mono-mineralic single grains to polynuclear multi-aliquots enhanced the applicability, accuracy and the precision of luminescence dating.

The present contribution reviews briefly on the physical parameters involved in luminescence dating but more is focused on two groups of studies:

1. The effect of alteration and contamination phenomena and of the seasonal/spatial variations on the obtained ages of archaeological materials, artefacts and geoaarchaeological studies

2. The importance of the context for field studies

For that, the results from relevant studies will be demonstrated, namely:

1. dating of mortars from historical and archaeological sites (Late Roman-BYZantine Greece and Medieval Spain)

2. sediment dating from molicoli and Palaearthic sites and from areas of environmental interest (Greece)

The presentation through presenting completed luminescence studies further aims at providing the spectrum of potential sources of errors assisting for accurate and useful chronological data within the limitations of the method.
197. Quaternary Palaeoenvironmental Reconstruction of the Coastal Zone of North Evoikos Gulf (Greece) based on the use of Luminescence Dating Techniques

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North Evoikos Gulf, an extended active graben located in central Greece, comprises a tectonically reformed area of great geomorphological importance. The evolution of the coastal areas of North Evoikos during the Quaternary period was the result of continuous changes in palaeoenvironmental conditions that prevailed in the area. The littoral zone of the Gulf has been affected not only by repeated sea-level fluctuations but also intense seismicity, epigenetic vertical movements and volcanic activity, leaving behind traces which have been recorded on the coastal deposits of the area. Despite the great number of geomorphological studies conducted in the area, little work has been done regarding the geochronology of the different sedimentary formations found in the littoral zone of the Gulf, mainly based on relative dating which bears a number of limitations. It is the first time that absolute dating of the Gulf's coastal sediments, based on luminescence dating techniques is used in this study, as an attempt to reconstruct the different episodes of environmental changes.

Preliminary results of the Ololene-Dating for the coastal sediments of the North Evoikos Gulf, presented here, using a number of Luminescence dating techniques, namely; Optically Stimulated Luminescence (OSL), Isotermal Thermoluminescence (ITL) from quartz and post-infrared stimulated luminescence (p-Ir-OSL) from feldspar. A number of samples from the southwestern coast of the Gulf (Drossia area) were collected, treated in the laboratory and measured. Despite the plenty of quartz found in our samples, problems associated with quartz weak signals and low saturation levels (dyeing data of the technique) led to the utilization of the p-Ir-IRSL signal from feldspar which was proven to be a reliable alternative. In general, ages obtained suggest that the main depositional processes in the area took place during the Early Pleistocene, at around 1.2 Ma. So far, such old ages have never been published for coastal sediments in Greece using luminescence methods, which fact provides evidence that this method has the potential to be used in detritus sedimentary formations substantially older than those which can be dated by the conventional OSL dating techniques.

198. Change in Production and Distribution Patterns of Olivine-Tempered Ceramics Using OSL Dating

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The ceramic assemblages found within the Arizona Strip and adjacent areas of Utah and Nevada are characterized by being widely distributed; uniquely tempered with olivine, a volcanic mineral; and thought to have been created between 100 and 1300. The source of this olivine is thought to be Mt. Trumbull or Mt. Tuweep, which are both located near the northwest rim of the Grand Canyon. Olivine-temperatures are distributed westward from these olivine source areas over a distance of more than 100 km. The ultimate goal of this study is to understand how and why the production and circulation patterns for olivine-tempered ceramics changed over time, with the larger goal being to understand human migrations or exchanges fit into the broader adaptive strategy by which the Puebloan people of the Arizona Strip coped with a marginal environment.

To investigate the source of olivine-tempered ceramics, detailed chemical analyses of ceramic samples and clay were obtained by using laser ablation inductively coupled mass spectrometry (LA-ICP-MS). Eight compositional groups were found in the chemical compositional data of 103 sherds as well as olivine-tempered ceramics. These analyses clearly show the change in the use of clay over time. The study reveals that (1) olivine-tempered pots were moved westward from Mt. Trumbull and the lowland area as a result of sea-level changes. (2) Clay resource specialization (e.g., use of different clay with different performance properties for pots intended for different purposes) was in use in both time periods when the population increased and moved westward. (3) Olivine-tempered pots were also produced in the lowland Virgin area later, (3) clay resource specialization (e.g., use of different clay with different performance properties for pots intended for different purposes) was in use in both time periods when the population increased and moved westward. The ultimate goal of this study is to understand how and why the production and circulation patterns for olivine-tempered ceramics changed over time, with the larger goal being to understand human migrations or exchanges fit into the broader adaptive strategy by which the Puebloan people of the Arizona Strip coped with a marginal environment.

199. Unraveling the Palaeoenvironmental Framework of Southeast Cyprus over the Late Quaternary - Luminescence Geochronology and Quartz Grains-Shape Examination

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Cyprus occupies a key position in understanding the palaeoenvironmental, neotectonic and eustatic evolution of the Levant during the Late Quaternary. Despite the numerous palaeoenvironmental studies conducted in eastern Mediterranean, limited is our knowledge on the chronological framework of the Cypriot coastal deposits. Numerical dating is of great importance in resolving the sequence of palaeoenvironmental events that occurred on the shores of southeast Cyprus during the Quaternary, however many challenges remain in dating near shore sedimentary deposits and surface exposures. Previous studies concerning the age of the coastal deposits of Cyprus were principal based on radiometric and taphonomic exposure geochronological techniques on fossils which bear a range of limitations and uncertainties. Luminescence dating is widely used for sediments that have undergone sufficient exposure to daylight prior to deposition. This requirement is met for the majority of coastal deposits found on the shores of Cyprus. Thus, luminescence dating is considered to be one of the most suitable techniques for the direct dating of the coastal sediments of Cyprus. Further, the study of irregularities on quartz grains using Scanning Electron Microscopy (SEM) techniques has developed into a method used for understanding the role of processes during grains transportation and deposition and thus extracting information on sediments palaeoenvironmental-depositional history.

This paper negotiates palaeoenvironmental and relative sea-level connotations of the coastal deposits of southeast Cyprus and preliminary comments on the Late Quaternary environmental change by employing up-to-date luminescence dating and quartz grain surface features analysis. The results of this study from south east Cyprus are considered on the basis of a wider geographical framework, including the Late Quaternary littoral formations of the eastern Mediterranean. Our luminescence dating estimations assigns the formation of the studied coastal deposits during the last 100 ka when the sea-level was lower than its present position, while quartz surface analysis indicated that the coastal Quaternary deposits of the area are the result of cycles of transportation and deposition through different environments, most probably a combination of marine deposition and subaerial exposure.

This research has been supported by the EU project “New Archaeological Research Network for Integrating Approaches to ancient material studies” (NARNIA), from the FPT, Marie Curie Action-ITN by the European Commission under contract number, 265010.

Forensic Science Investigations in Art and Archaeology

200. Epifanio Garay Between the Truth and the Oral Tradition: A Spectroscopic-Mraman Study

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Up to today, in Colombia archeological studies on the cultural heritage of the country mainly were planned from human and social sciences which often resulted in historic interpretations and attributions very personally connected to the respective scientists. The application of modern instrumental analytical techniques and in this way introducing reproducibility and objectivity may change the history.
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To explore the techniques of ancient Egyptian art and culture, we analyzed proteins in Egyptian Romano portraits painted in about A.D. 180-200 by using enzyme-linked immunosorbant assay (ELISA) and mass spectrometry (MS). Animal glue was detected with ELISA in the ground layers of all the three panels of triptych currently displayed in the Getty Museum. One of the major amino acids constituting collagen, 4-hydroxyproline, was identified with gas chromatography/mass spectrometry (GCMS) in acid hydrolyzate of proteinaceous material. Results were in agreement with ELISA because this amino acid occurs in collagen but not in egg albumin. Animal species from which the glue was derived were distinguished, using nano-liquid chromatography-electrospray ionization-tandem MS (nanoLC-ESI-MS/MS). Several tryptic peptides characteristic of cow collagen were identified by this technique in a fragment of the paint sampled from the central “Bearded Man” portrait, suggesting that animal glue derived from cowhide was used as the pigment binder. Egg albumin was detected with ELISA in some upper paint layers and is probably a material added as part of a modern restoration of the portrait.

Keywords: ELISA, nano-LC-ESI-MS/MS, Fayum, Egyptian, Binding, proteomics

202. The Use of Enzyme-linked Immunosorbant Assay and Mass Spectrometry for the Characterization of Binding Media in Egyptian Romano Portraits

203. Analysis of an Egyptian Sarcophagus Fragment

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A fragment of a painted Egyptian sarcophagus was analyzed with several non-destructive and destructive methods in order to characterize the pigments, ground, textile, and wood present. Non-destructive methods of analysis included imaging techniques such as multi-spectral imaging, infrared luminescence, and x-radiography, along with x-ray fluorescence (XRF). Destructive techniques in this research included polarized light microscopy (PLM), Raman spectroscopy, and scanning electron microscopy (SEM). The resulting analysis showed that the materials used were consistent with those generally used on ancient Egyptian artifacts.

204. Mayans Did Not Just Drink Chocolate?

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The Maya elite used elaborately decorated cylindrical vessels at feasts and ceremonies that are generally assumed to have been used for drinking cocoa. We analyzed sherds from such vessels for cacao residues. The sherds were recovered by Anabel Ford’s Belize River Archaeological Settlement Survey (BRASS) from settlements near the Classic Maya center at El Pilar. The unusual wealth of these settlements suggests privileges conferred upon them by those in control and it is likely that they were producing what today we might call cash crops, probably including cacao, which is still grown in the region today. What is not clear, however, is whether or not the residents of these prosperous Maya villages were drinking cocoa in these distinctive vessels.
We developed a technique that can detect and identify molecular tracers of specific foodstuffs in archaeological artifacts with unprecedented specificity and sensitivity. We use a laser pulse to vaporize very small amounts of material, either from extracts or directly from pottery material without need for extraction or other sample preparation. We analyze the vapor with a combination of laser spectroscopy and mass spectrometry. This combination allows us to identify molecules not only by mass, but also by the color of light absorbed with very high resolution, distinguishing different forms of the same molecule, such as isomers. In the case of cacao the most characteristic molecule, theobromine, also occurs in a much lower abundance in another isomeric form, theophylline and the technique can unambiguously distinguish between them. Surprisingly, the analysis of most of the Mayan pottery revealed a much larger abundance of the minor component theophylline than of normally dominant theobromine. This molecular signature does not fit with what one would expect for a pure cacao beverage. This result suggests that the pottery was used, at least in part, for beverages made from other than the regular cacao plant, or prepared or handled in different ways. However, analysis of a more elaborate potsherd revealed an isomeric ratio with theobromine being the most abundant isomer. This finding suggests that ceremonial vessels may have been used exclusively for cacao containing preparations, while common vessels were not. This finding sheds new light on the early use of this type of beverage in Mesoamerica.

205. Quantitative Elemental Analysis of Historical Soil through XRF, AAS, ICP-OES and EDX

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Elemental analysis of historic soil has been established as a useful technique for assessing soldiers in the original layout of an archaeological site. The most commonly used instrumentation for analysis is atomic absorption spectroscopy (AAS) or techniques that involve inductively coupled plasma optical emission spectroscopy (ICP-OES) and energy-dispersive spectroscopy (EDX) and the results compared. Differences between results are mainly a consequence of necessary extraction and preparation techniques for each instrument; these different techniques sample different fractions of the elements in soil. The complementary information each analysis technique offers and the implications for studying the quantitative elemental composition of archaeologically altered soils is discussed. These elemental analyses, paired with a prior understanding of the site layout at FOVA, led to a fuller understanding of previous historical activities at the site.

206. Application of VPSEM-µRS for SERS analysis of archaeological textiles

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The site of Huaca Malena on the coast of southern Peru is a platform and cemetery of the Wari state from the Middle Horizon period (AD 700 -1100). The cemetery has yielded mummy textiles, some of which are typical for the region, and others with motif traditions indicative of the Sierra Andes of southeast Peru. It is unclear if this indicates migration, exchange, or transmission of aesthetics. Analytical methods for the identification of organic colorants on archaeological textiles can offer a way to retrieve information from these delicate artifacts. Among other analytical methodologies, Surface-Enhanced Raman Spectroscopy (SERS), achieving single molecule detection, has recently emerged as a powerful technique for the identification of colorants from size-limited and irreplaceable archaeological materials. For direct, extractionless SERS analysis of colorants on textiles, silver nanoparticles (AgNPs) are deposited on a single fiber and SER spectra are acquired using a micro-Raman spectrometer (µRS). Since the deposition of AgNPs is a crucial step to generate the SER effect, Scanning Electron Microscopy (SEM) appears to be an ideal tool to evaluate the AgNPs coverage and locate suitable areas for successful and reproducible analysis. In this study, direct, extractionless SER analysis of organic colorants on single fibers was performed for the first time using a µRS interfaced with a variable pressure SEM (VPSEM). An alpaca fiber dyed with Peruvian cacao and a wool fiber dyed with Indian madder were treated with a silver colloid and introduced in the SEM chamber. The high resolution imaging of SE/MA was used to select areas showing dense deposition of AgNPs. SERS analyses were then carried out in these areas without the need of moving the sample. The analysis of areas with a thick layer of nanoparticles or without nanoparticles resulted in low signal to noise ratio or no signal at all. Areas with a thin layer of deposited nanoparticles led to optimal reproducible spectra characteristic of the dye molecules. The results clearly illustrated the potential of this quasi non-destructive approach for the identification of different organic colorants while Information can also be obtained on the AgNPs coverage as well as the morphology of the fibers. This methodology will be applied to study collections of Peruvian archaeological textiles including that from the site of Huaca Malena. The application of VPSEM-µRS, coupled with energy-dispersive spectroscopy (EDS), will also provide a unique opportunity to study a variety of other archaeological materials including pigments, glazes, and glasses.

References

207. Getting to the Root of It: Analysis of Human Skeletal Remains from the New Haven Green

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In October 2012, the Lincoln Oak, planted on the New Haven Green in 1909 to celebrate the 100th anniversary of the birth of Abraham Lincoln, was toppled due to the high winds during Superstorm Sandy. Within its exposed roots, a partial human skeleton was discovered, a visual reminder of the colonial cemetery still located under the present surface of the New Haven Green. An emergency rescue excavation was carried out by the Connecticut State Archaeologist, Nicholas Bellantoni and Gary Aronsen from the Department of Anthropology, Yale University. This assemblage has provided our team with a rare opportunity to carry out in-depth analysis on the bones from this colonial cemetery, which has been estimated to have as many as 10,000 burials. As a result of careful archaeological recovery, historical research, and forensic and other analyses such as CT scans, genetic analysis, and isotopic analyses using ICP-MS, it is now clear that the
exposed bones belong to multiple individuals, including an adult male and at least three children under the age of 10 years old, who all died in the late 1700s. The various analyses of the bones have shown us tantalizing insight into the health and nutritional situation of the individuals that were recovered. For example, examination of the teeth revealed that all of the individuals had experienced periods of nutritional or metabolic stress at an early stage of their lives. In addition, the adult male may have suffered from genetic abnormality that may have contributed to health problems during his life. Furthermore, the analysis of the two time capsules that were also uncovered as a result of the uprooting of the Lincoln Oak, provide us with a view into the lives of the residents of New Haven in the early 1800s. This presentation will summarize the various findings of this multi-disciplinary research project and present our vision for sharing our results with the larger New Haven community.

208. The Characterization of the Lamp Oil and Burning Incense from a Tang Dynasty Tomb in China

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This work presents the results of the analysis investigation of the lamp oil and the lamp oil residue from a Tang Dynasty aristocrat tomb (Shuishan Shi tomb, 901 AD) in LinAn County, Zhejiang Province, China. This archaeological site was excavated in 1980s with a number of findings including bronze wares, lacquer wares, ornaments, jades, as well as a celadon with brown cloud pattern ceramic ware for incense burning, where incense ash/fragments remained, and a celadon with brown cloud pattern ceramic oil lamp with dried oil residue inside. In order to identify the materials used for burning incense and the oil of lamp, and to investigate whether essential oils were used in the burning incense and in the lamp oil, techniques including pyrolysis gas chromatography and mass spectrometry (Py-GC/MS) with and without in-situ hydrolysis and methylation reagent of tetramethylammonium hydroxide (TMAH), as well as Py-GC/MS with double-shot technique were performed for the analysis of the samples. Based on the developed and on the constituted database, in the ash/fragments, significant amount of azulic acid, palmitic acid and stearic acid as their methyl esters were detected, indicating plant oil, perhaps Tang oil, are present, while the oil of the lamp was identified as mixture of plant oil and animal fat due to the detection of azulic acid, palmitic acid, stearic acid, and odd carbon-numbered series fatty acids (pentadecanoic acid, heptadecanoic acid), the marker compounds of bovine or ovine fats. In addition, the detection of marker compounds of cedar oil including cedrene, cedrane, cuparene and cedrol in the lamp oil residue represents cedar oil was used. Cedar oil was recorded as Chinese medicine in the first Chinese pharmacopæa, the Tang Materia Media (Tang Ben Cao) in 659 AD, which perhaps as perfume was added in the lamp oil. The results obtained definitely provide direct evidence of the materials used for the production of the incense and lamp oil in Tang Dynasty.

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Human Environment Interactions and Bio-Materials Bioarchaeology

209. DART-MS for Identification of Dye Colorants in Paracas Textiles

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The Paracas Necropolis is renowned for the elaborate funerary bundles in which the elite members of that society were buried. The complexity of these objects, consisting of layers of plain and embroidered textiles, attests to the advanced society of this culture, which flourished between 400 BCE - 400 AD. The Paracas textiles are remarkably well preserved due to the arid environment of the region. The Paracas textiles, as a celadon with brown cloud pattern ceramic ware for incense burning and in the lamp oil, techniques including pyrolysis gas chromatography and mass spectrometry (Py-GC/MS) with and without in-situ hydrolysis and methylation reagent of tetramethylammonium hydroxide (TMAH), as well as Py-GC/MS with double-shot technique were performed for the analysis of the samples. Based on the developed and on the constituted database, in the ash/fragments, significant amount of azulic acid, palmitic acid and stearic acid as their methyl esters were detected, indicating plant oil, perhaps Tang oil, are present, while the oil of the lamp was identified as mixture of plant oil and animal fat due to the detection of azulic acid, palmitic acid, stearic acid, and odd carbon-numbered series fatty acids (pentadecanoic acid, heptadecanoic acid), the marker compounds of bovine or ovine fats. In addition, the detection of marker compounds of cedar oil including cedrene, cedrane, cuparene and cedrol in the lamp oil residue represents cedar oil was used. Cedar oil was recorded as Chinese medicine in the first Chinese pharmacopæa, the Tang Materia Media (Tang Ben Cao) in 659 AD, which perhaps as perfume was added in the lamp oil. The results obtained definitely provide direct evidence of the materials used for the production of the incense and lamp oil in Tang Dynasty.

DART-MS requires only minute samples with no sample preparation and a less than 5 minute analysis time. Comparative materials for this study were wool yarn dyed with cochineal insects (Dactylopius coccus) both with and without mordant. The archaeological samples were obtained from several different textiles within two different mummy bundles from the National Museum in Lima, Peru. Anthraquinones - pseudopurpurin, purpurin, munjistin, xanthopurpurin and lucidin - make up the primary colorants present in dyes prepared from Relbunium (Saltsman 1978, Jakes et al. 1991). The Paracas samples were studied in negative ion mode both with and without the addition of formic acid. None of the compounds characteristic of cochineal were observed in any of the Paracas samples. Analysis of Sample 421-39 #3 showed xanthopurpurin, xanthopurpurin, and munjistin were all present, as would be expected from the previous identification of Relbunium in this material. These anthraquinone compounds were also identified in all of the other red samples, as was pseudopurpurin in two of the samples. The results from the DART-MS analysis of these red fibers show that the compounds present are consistent with the presence of Relbunium dye, and show that cochineal insects were not used to color these fibers. Green fibers showed the presence of indigotin and its degradation products, though possible yellow dye colorants are still under investigation.

210. Diet and origin of enslaved Africans in Brazil: A multi-isotopic study of individuals buried in the Pretos Novos Cemetery in Rio de Janeiro and in the Catedral da Se in Salvador

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Brazil played an important role in the transatlantic slave trade, receiving 38% of all enslaved Africans that crossed the Atlantic Sea to the Americas during the sixteenth to the nineteenth centuries. During this period the two most important ports in Brazil were in Rio de Janeiro and Salvador. It is estimated that 2,500,000 captives from Africa arrived in these cities between the years 1678 and 1830. In the present paper we did 87Sr/86Sr and 87Sr/86Sr analysis of the teeth from 30 individuals buried in Pretos Novos Cemetery in Rio de Janeiro and 12 from Catedral da Se Cemetery in Salvador. We were able to determine the diet and geographic origin of these individuals. All skeletal remains selected in this study supposedly belonged to Africans. The Pretos Novos cemetery was used exclusively to bury recently arrived enslaved Africans that died before being sold in the slave market, and all selected individuals from Catedral da Se have dental modifications associated with African groups.

The 87Sr/86Sr and 813C enamel analyses were performed in a N isotope-ratio mass spectrometer. The 87Sr/86Sr and 813C enamel collagen analyses were done in a MAT Delta Plus from Thermo Finnigan connected to a CHN analyzer. The individuals buried in Pretos Novos presented 87Sr/86Sr results between 0.7078 and 0.7498 and in Catedral da Se values from 0.7078 to 0.7320. Based on stromont isotopes the individuals from both sites presented a fairly diverse geographic origin, but the results were significantly higher among the individuals buried in Pretos Novos. These results are consistent with the historical records of the transatlantic slave trade to Rio de Janeiro and Salvador. Unfortunately the isotopic analysis could not determine the precise origin of the individuals in the continent due to the high geological diversity of Africa. 70% of the individuals from both sites presented 813C values below 10‰, indicating that plants played an important role in their diets. The 813C of these individuals shows that 71.5% were eating more C4 plants such as sorghum, millet and maize. The other 28.5% were consuming more C3 plants like different species of yams, manioc and maybe rice. Only 30% presented 813C values compatible with significant consumption of animal protein in the diet, including two individuals that were probably eating freshwater fish due to 813C values above 14‰ and very negative results of 513C.
211. Non destructive identification and diagnosis of natural organic substances in cultural heritage: insight from Raman and infrared signatures

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Natural organic substances are wildly used in history and constitute a precious testimony of human exploitation strategies, exchange networks and techniques for their implementation in numerous ancient objects. These materials have been for a long time neglected because of their poor preservation and challenging characterisation. Within different evaluation of vibrational spectrospectrometries (Raman and infrared) potentialities through spectral treatment procedures, alternatives or complements to the current analytical strategies based on separation methods can be proposed. The use of FT-Raman (excitation at 1064 nm) is needed to avoid fluorescence, and infrared measurements are performed using a micro-ATR configuration to eliminate the sample preparation step, both allowing non-destructive analyses.

The first part of the study deals with the differentiation of a broad range of natural organic substances: proteins (animal glues), triglycerides (oils), polysaccharides (gums) and terpenoids (resins from different geographical provenances). This requires specific strategies to differentiate between vibrational signatures with similar features. A methodology here proposed, based on spectral decomposition of CH stretching mass followed by Principal Component Analyses of the extracted decomposition parameters. Applying PCA on the raw data, as common was tried and appeared to be indiscriminatory. However, PCA of the fitting parameters becomes an efficient and powerful tool to cluster the different materials. Indeed, it is highly related to their vibrational features and thus to their molecular characteristics. This approach proved the possibility of identifying the natural organic substances, sometime at the scale of the tree species, and an application on archaeological samples and museum varnished objects showed that some alteration or ageing is not an issue to their recognition.

The second part concerns the quantification of identified organic substances in mixtures. Starting from pure products, a methodology was developed by combining these pure products spectra in order to fit the mixture spectra to provide an evaluation of their proportions. This approach proved its ability to quantify resin/oil proportions first on experimental varnishes, with the aim to quantify museum varnished objects.

These developed approaches can find applications in various contexts (archaeology, museum context, conservation purpose) and for a wide range of natural organic materials as varnishes, binders or adhesives, with the advantage of being non-destructive and even sometimes non-invasive.

References

212. Hybridization of Agriculture In Neolithic Asia Minor: Reconstructing Human Diet and Disentangling Environmental Signals

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The transition to agriculture is undoubtedly one of the biggest revolutions in the history of our species. The domestication of plants and animals, alongside the move to sedentary lifestyles, forms the origin of complex human societies [1-4]. In Asia Minor, Neolithisation on the Central Anatolian Plateau occurred during the early part of the seventh millennium BC - some two millennia after South-Central Anatolia (and the Near East), while the transition to a farming way of life in the North-West regions of Anatolia (e.g. Marmara) took yet another millennium [5-7]. The hiatus in the expansion of the Neolithics from the Near East into Asia Minor has led a number of researchers to investigate the mechanisms behind the movement; with climate and environment, social or economic factors being the most likely explanations [8-11]. One of the key economic aspects of this research is to understand the nature of dietary breadth and subsistence practices at pioneering Neolithic sites.

In North-West Anatolia, there are a number of early Neolithic sites that show evidence for broad procurement strategies, populations that placed a reliance on fishing, mollusc collecting, hunting and gathering, alongside the exploitation of some domesticated animals and plant cultivation [6]. Equally, there are some sites in the North-West that represent the first appearance of cultivated crops, that show evidence for fully farmed agricultural societies that have little or no evidence for the exploitation of wild resources. The expansion from the arid steppe climate of the Central Plateau into the temperate region of the North-West represents a move from the natural habitats of cereals (and their domesticates) into unfamiliar climatic environments - this expansion reflects a distinct change in climatic and environmental conditions. There are a number of environmental factors that can have significant influences on carbon and nitrogen values in human and fauna, such as aridity, precipitation, temperature and light intensity [9].

The aim of this research is to identify the extent of dietary breadth, and to disentangle environmental signals, by analysing 13C and 15N ratios of collagen from human, and wild and domestic fauna skeletal remains. This research produces new stable isotope data for the sites of Akkapinar, and utilizes 13C and 15N ratios data in the published literature [10-11]. The results of the stable isotope analysis highlight significant clustering of the human values in North West Anatolia, whereas those previously reported from the Central Plateau are more dispersed, which is contrary to the archaeological record. The carbon and nitrogen isotope values for the fauna and human samples show considerable variation across both North-West and Central Anatolia, suggesting pronounced differences in dietary choices across the regions. The fauna isotope data show a negative linear correlation against the environmental variables of aridity and precipitation - as moisture availability decreases, δ13C and δ15N values increase. The isotopic data values demonstrate consistent enrichment in both carbon and nitrogen values as the site locations move along a West to East transect.

References

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The use of strontium isotopes to determine geographic origins of humans is now a popular method that typically involves comparing isotope ratios in human dental enamel to local isotope ratios inferred from geological data or from the analysis of biological materials. While the utility of isotopes is beyond debate, we should consider exactly what human isotope ratios are measuring. Specifically, we should evaluate patterns or processes that might be involved in food procurement, the specific dietary sources involved in food procurement, the specific dietary sources what human isotope ratios are measuring. Specifically, the inability of the analysis of teeth and bones, such as waxes or animal fats, could be abandoned. Traditionally, research of the mixture of pine pitch and beeswax were used to obtain more workable and malleable materials. The aim of this work is to evaluate the effect of the beeswax addition on the physico-chemical properties of pitch and tar, a wide variety of organic materials, such as waxes or animal fats, could be included. Additional research of the mixture of pine pitch and beeswax were used to obtain more workable and malleable materials.

214. Thermal degradation chemistry of archaeological pine pitch: alone and mixed with beeswax

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Since early times, the resinous substances secreted by trees have been widely used in their natural form or as tar and pitch to waterproof the planking of ships and the vessels, and as adhesives, tar or pitch were obtained subjecting resinous materials to hard-heating (pyrolysing)-type processes. Tar and pitch have been of great importance for their properties, such as insolubility in water, adhesion and glassy characteristics. During the pyrolysis process to obtain the pitch, terpenoids, the main compounds of resins, experience chemical modifications, such as aromatization, demethylation and decarboxylation, with the formation of new compounds with a lower molecular weight and a high degree of aromatization. The mixtures found in several archaeological objects demonstrate that to modify the physical chemical properties of pitch and tar, a wide variety of organic materials, such as waxes or animal fats, could be included. Traditionally, research of the mixture of pine pitch and beeswax were used to obtain more workable and malleable materials. The aim of this work is to evaluate the effect of the beeswax addition on the physico-chemical properties of pitch and tar, a wide variety of organic materials, such as waxes or animal fats, could be included.

215. Biochemical Indicators of Diet in a Late Muiscan Settlement in the Northern Andes: Stable Isotopes and Trace Elements

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Carbon (collagen and apatite) and nitrogen stable isotopes as well as trace elements (Sr and Ba) from archaeological human bone samples from Tibanica, a Muiscan settlement (1000-1600 AD) were used to study the human diet and subsistence in the region during the Late Muiscan Period (1200-1600 AD). Isotope and elemental data for 60 human and 7 faunal samples were used to perform, in a detailed and quantitative way, dietary reconstructions for both humans and animals inhabiting the study region during the final late Holocene. The carbon isotope-based regression model reflects a diet more centered on maize and other C4 tropical crops played an important role along with C3 plants and C3 consumers like guinea pig, deer and rabbit. The nitrogen values indicate the consumption of freshwater resources (fish, waterfowl, etc.) and likely human influence on some species (guinea pig and dog). The intragroup analysis revealed in both isotope and elemental data significant statistical differences by age and sex. Finally, from a regional perspective the Tibanica diet resembles other Muiscan samples from the early and late period whereas it differentiates from southwestern Colombian and northern Ecuadorian farming societies.

216. Pottery Function in Middle Neolithic Central-Western Mediterranean: an Integrated Use-wear and Biomolecular Approach to the Study of Vessels from the Bau Angius Site (Sardinia, Italy)

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Several studies have highlighted the potential of biomolecular and isotopic approaches to define archaeological vessels contents, with the purpose to investigate pottery function, food habits and economic structures of Neolithic communities. Yet, pottery surface may hold a wider range of traces left by human activities, whose analyses are less frequently combined with chemical studies of organic residues in the same pots. In order to understand vessel function and functioning, all kinds of pottery alterations (use-wear traces, organic residues) have been examined by an integrated tracological and biomolecular approach, which is based in relation with morphometrical characteristics.

In this work, we explore pottery function in an advanced Middle Neolithic (4500/4400-4000 cal BC) context in Sardinia (Italy), focalizing a set of about 50 ceramic containers from the open-air site of Bau Angius, Terraiala (OR). Our methodology combines three integrated steps:
- vessel size and morphometrical characteristics analysis;
- use-wear traces analysis by a macro- and microscopic (low magnification, 20-40x) approach;
- GC and GC-MS analysis of absorbed organic residues in sampled potsherds.

By cross-sectional, tracological and biomolecular data, we distinguish different kinds of use for ceramic containers, which can be classified in four use categories:
- cooking (5-9 L size), with sooting, high to low lipid concentration, internal walls abrasion;
- mechanical processing/serving (2-4 L size), with medium to low lipid content, scratches in inner surface and/ or base abrasion;
- storage (about 5 L), most likely for liquids;
- serving/eating (different shapes from < 1 to 2.5 L), with low lipid content and base abrasion.

Further distinctions are possible into these categories. The most interesting results emerge from cooking pots. The
Keeping in view of the importance of the Roopkund Lake, we have collected around 50 large and small bone samples of Human from this lake. All the samples selected for the study were dried in room temperature as well as hot air oven at 32 degree Celsius. Cleaning, pretreatment and digestion process of bone samples was followed through established scientific methods. Chemical analysis i.e. concentration of different elements such as calcium, strontium, barium, magnesium and zinc as well as isotopic ratios of Carbon and Nitrogen was estimated with the help of Inductively Coupled Plasma Spectroscopy (ICP) and Atomic Absorption Spectrophotometer (AAS). The results obtained from the chemical analysis are interesting and significant. On the basis of concentration of different elements and isotopic ratios of Carbon, the dietary habits of the peoples buried in the Roopkund Lake are identified, which is differing from sample to sample and person to person. Besides this, the results are also significantly helpful for knowing the preservation status of skeletal remains in Roopkund Lake, because as they were recovered in good condition along with flesh. This study finally also suggested the potentiality of chemical analysis for Preservatory status and paleoecot behaviour of bone remains collected from high altitudes.

217. Chemical Analysis of Human Remains Recovered from Central Himalayan Range of Uttarakhand, India: Inferences for Preservatory Status and Dietary Reconstruction

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Present study was carried out in the bone samples recovered from Roopkund Lake in district Chamoli Garhwal, Uttarakhand, the Central Himalayan range of India. This lake is located at 5029 meters from main sea level in between Nanda Ghunghat and Trishuli peak. This lake belongs to an important historical religious event known as Raj-Jat which is dated to 9th century A.D. This religious Raj Jat is still in practice in District, Chamoli Garhwal of Uttarakhand State and is taken up after every 12 years; it involves 280 km trekking of high altitude region for taking the area’s ruling deity — Goddess Nanda to her divine destination of Ghunghat, which is believed to be the abode of her consort, Lord Shiva. At the same time, it is also believed that this Raj Jat stopped for a long time as no one survived during the Raj Jat of 9th century and Roopkund was the place at 5029 msl. in which all the devotees were buried due to some natural causes.

218. Evaluation and Identification of Fatty Acids Contained in Archaeological Ceramics of Sutamarchan, Colombia, for 1000-1200 A.C. and 1200-1600 A.C. Periods

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Archaeometric studies in Colombia have not been amply explored. However, alternative methods using chemical and physical techniques offers access to additional information about the dynamics of the pre-hispanic populations. Studies based on stable isotope, such as paleoecot research, have increased the perspectives about Colombian archeology. Using Gas Chromatography / Mass Spectroscopy (GC/MS) analysis, we have determined the proportion of fatty acids within a clay matrix of the ceramic material obtained from the Sutamarchan archaeological site located in Sutamarchan town. By analyzing the ceramic material via Infrared Spectroscopy (FT-IR) and Thermogravimetric-Differential Scanning Calorimetry (TGA-DSC), we examined the physical characteristics of the clay as well as the relationship between the fatty acids and their preservation environment. According to GC/MS, the fatty acids such as erucic, lauric and oleic acids that are associated with plant foods, where identified in the ceramic of the 1000-1200 AC period. For the ceramic of the 1200-1600 AC period, we identified the following fatty acids associated with animal fats: margaric and vaccenic acids. TGA-DSC and FT-IR analyses showed the properties of the ceramic on the conservation of the organic material. One of these properties correspond to their thermal stability, since it showed a mass loss of only 4% at 1200 °C. Likewise, it is possible to observe the presence of siloxanic groups from sialcates and metsalicates compounds. These compounds have a great importance due to their hygroscopic properties, avoiding the decomposition of the unsaturated fatty acids. These results allowed us to identify a group of possible aliments that were consumed by the pre-hispanic population of the archeological site. In the same way, it was possible to identify the presence of vessels for a specific use such as cook corn. Finally, a set of particular properties in the ceramic was observed. These properties are related to the proper preservation of fatty acids in the archaeological site of Suta.

219. Migration or not? Diet evidence of stable isotopes analysis of human and animal from the Qinglongquan site, China

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The Qinglongquan site, China, including materials during Yangshao (3500-3000 BC), Qiujialing (3000-2600 BC) and Shijiahe (2600-2200 BC) periods, lies within Sui-Zao Corridor which connects Nanyang Basin in the north and Hainjiang River Plain in the south. Therefore, this site presents a unique opportunity to explore facts of cultural interactions and human migration between ancient tribes in the north and south during Neolithic China. Previous research suggested a diet shift between Qiujialing and Shijiahe periods in this site which could be related to paleoenvironment change and cultural interactions. In this study, carbon (δ13C), nitrogen (δ15N), and sulphur (δ34S) isotope analyses was presented on human and more animal bone samples to test the hypothesis of migration. The results suggest that terrestrial food was primary human diet resource excluding sheep/goat. The Shijiahe humans had significant different sulphur values against local animal values which had no relation with the carbon isotope value change. The sulphur value change of Shijiahe human population was seen as ‘migration’ in the Qinglongquan site which matches a Chinese legend ‘Zheng Samiao’ very well.

220. The Holy Wells of Scotland: a geo-hydro-archaeological approach to their study

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Healing springs have played a significant role in the folklore of many cultures in most geographical regions. In Scotland, these natural features are referred to as ‘holy wells’: there exist about 240 recorded in the Royal Commission on the Ancient and Historic Monuments of Scotland catalogue (CANMORE), out of a total of 1700 referred to simply as ‘wells’. Some have been venerated since pagan times, the patron ‘spirit’ of the well being substituted in Christian times by a local early Celtic saint or the Virgin Mary or Jesus. Holy wells are different from therapeutic springs which are usually associated with mineral waters. Furthermore, it is not clear to what extent drinking water from a holy well was actually ‘therapeutic’; it is believed that simply...
221. How to fit vegetation in a box? Building a palaeobotanical and chemical database for the project “Exsudarch”

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The project – Exsudarch – (Archaeological fresh and fossil plant exudates and tars: chemistry, manufacture and uses) focuses on the ancient use of exudates such as resins and glues. Among the latter, birch tar is an adhesive obtained from the heating of birch bark that has been identified in many Eurasian archaeological contexts from the Palaeolithic onwards. Birch tar is used throughout the Holocene, even in contexts such as the Mediterranean basin, where birch does not grow, except in very specific areas. This observation raises the question of the modalities of birch bark procurement (exchange and production networks) over time.

Hence, one of the tasks of the project is to establish the geographic distribution of the natural resources exploited. In the aim of comparing the past natural growth areas of birch to the location of archaeological evidences of birch tar, we built a database containing palaeobotanical and palaeochemical data covering the Northwest Mediterranean area. The challenge was to make this database compatible with the palaeoarchaeological information and chemical data on archaeological samples containing birch bark tar and with the present-day vegetation distribution maps.

The master will focus on central methodological issues we were confronted to and the solutions we adopted. The palaeobotanical records are discontinuous in time and space and sometimes insufficiently dated. In a diachronic reasoning, how to attribute a duration and chronological boundaries to a single pollen or charcoal spectrum? How to reconcile the 14C chronology of “off-sites” records with the archaeological chronocultural attributions?

Targeting a spatial approach, how to integrate several proxies bearing different spatial resolutions (e.g., pollen vs. charcoal; anthropic vs. natural deposits) into a single palaeo-biogeographical reconstruction? How to integrate present vegetation in the database?

The database was constructed by working with vegetation types more than with taxa, excepted for “key-species”, by discarding the data for which the chronological frame was lacking or insufficient, and the use of rather wide chronological periods. Nevertheless, the problem of the spatial resolution remains difficult to solve in what regards the mapping of the data, but we are already able to generate useful diachronic maps.

Although it was built in a very specific goal, this “Betula” database offered the opportunity to unlock the shackles of fitting palaecovegetation data into a rigid numerical box, which we hope will be helpful as regards other palaeoenvironmental or archaeological issues.

222. Anthraquinone Dye Colorants in Red Fibers from the Seip Mound, Ohio

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Among prehistoric native groups of North America, the Hopewell Culture (100 BCE - 900 AD) is particularly notable and defined by elaborate burial mounds, evidence of ritual burial ceremonies, and a multitude of intricately decorated objects formed from materials obtained through extensive trade networks. While relatively few artifacts survive, those that have been preserved reflect an extensive knowledge of plant and animal fiber sources, manipulation of those fibers to create complex fabric structures and knowledge of natural dyes and pigments. The research reported herein is part of a program to understand the materials and processes of coloration employed prehistorically.

To investigate the sources of dye colorants, we applied direct analysis in real time-time-of-flight mass spectrometry (DART-MS) to both comparative and archaeological materials. DART-MS requires only minute samples with no sample preparation and a less minute analysis time. Comparative materials for this study were rabbit hair yarn stained with iron oxide (representative of an ochre pigment), dyed with bloodroot (Sanguinaria canadensis) and dyed with bedstraw (Galium verum), both without mordant and using Rhus sp. berries as a source of tannins. Fibers from a yarn fragment from the Seip Mound located in Ohio were analyzed.

The Seip samples were studied in both positive and negative ion modes. None of the compounds characteristic of bloodroot were observed in the Seip fibers. Anthraquinone compounds were identified in both samples in both modes, with better signal obtained in negative ion mode. In the darker red yarn sample, purpurin and alizarin dominated the spectrum, with significantly less rubadin than was observed in the comparative material. The presence of anthraquinones in these Hopewell textiles, and the absence of the bloodroot alkaloids, supports previous studies suggesting the prehistoric use of Galium species as dye plants in Eastern North America.

223. PALEODIET AND SOCIETY IN MEDITERRANEAN RURAL COMMUNITIES FROM BASQUE COUNTRY (SPAIN)

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The paper presents the results of a palaeodietary study, through Carbon and Nitrogen stable isotopes analysis, performed on five medieval sites located in the south of Basque Country (Spain). Main goal is to improve the current knowledge on Spanish rural communities from 5th to 15th c. through the analysis of the palaeodietary patterns and their implications into the construction of social differences between and within the different sites. δ13C and δ15N were measured through Carbon and Nitrogen stable isotopes analysis, on collagen extracted from 149 human and 48 fauna samples from five sites. The results indicated there were two distinct groups: the first one, formed by Astira and Zornotzari, was characterized by a mixed diet combining C3 and C4 plants with low protein intake; while the main features of the second one, composed by Zaballa and Treviño, were the absence of C4 plants consumption and the high levels of meat intake. The site of Dalantzi showed values intermediate between these two groups. Statistical analysis showed significant correlation between sex and δ15N at the sites.
224. Climate-driven dietary and agricultural change in the late Eneolithic/early Bronze Age Ukrainian Steppe recorded in organic residues in ceramic vessels

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The late Eneolithic and early Bronze Age period (4500 to 2300 BC) of the Dnieper region of Ukraine was subjected to drastic climatic changes, producing a profound shift in the economic practices of this region. In this work, 240 potsherds have been targeted from 5 different Ukrainian settlements. Lipid extraction and screening by gas chromatography has revealed excellent preservation of animal fats. Compound-specific stable isotope analysis (δ13C values) of the fatty acid methyl esters (FAME fraction) indicates exploitation of equine products in two settlements dated from the Middle Eneolithic period, and an absence of ruminant dairy fats in three of the sites. A change in the economic practices of this region seems to occur in sites from different periods suggesting that climatic and environmental changes played an important role in cultural change in Eurasian prehistory. δ13C values of pottery-derived fatty acids are being used to construct a record of climate change across the late Eneolithic/early Bronze Age transition.

Reference

225. Was the Climate Too Harsh for the Late Neolithic Farmers of Finland? Tracing Foraging-Farming through Organic Residues in Pottery

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Finland lies at the northern limit of cultivation such that the first farmers would have had to overcome a number of challenges presented by the extreme climate. The limited archaeological evidence that exists suggests that the Late Neolithic period in Finland saw hunter-gatherers moving to mixed foraging-farming. The earliest evidence of cultivation in Finland comes from grains of Hordeum from a Late Neolithic Kuikainen site in SW Finland. The oldest radiocarbon-dated animal bone, a burnt bone from a sheep/goat, comes from the same period. Unfortunately, soils in Finland are so acidic that unburnt bone is extremely rare at prehistoric sites, and even where it survives is usually highly fragmented. Thus, it has been impossible to discern coherent trends in diet associated with the introduction of farming based on skeletal remains. Significantly, potsherds are evident at such sites providing the opportunity to exploit organic residues, specifically lipids preserved within the clay matrix of the walls of archaeological pottery, to detect processing of different commodities in vessels and thus investigating dietary change. Absorbed lipids are investigated following solvent extraction, using GC, to determine their distributions. GC-MS with selected ion monitoring is used to detect diagnostic biomarkers present in low abundances. Stable carbon isotope (δ13C) values are determined for the major fatty acids using GC-C-IRMS. The δ13C values obtained are compared to values from modern reference animals (terrestrial and aquatic) in order to identify the original source of archaeological residues.

Reference

226. Diagnosis of the Conservation State of a Granitic Outcrop with Rock Art

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Granite rock engravings made by incising, carving or other techniques used to remove part of the surface. Galicia (NW Spain) is very rich in this kind of artistic expression being the outcrops with rock art included in the National Register of Historic Monuments. Despite conservation efforts, many of rock engravings suffer a high risk of loss. Among several reasons, the limited knowledge about the characteristic deterioration processes of this kind of cultural heritage and the absence of a diagnostic protocol adjusted to its particularities can partially explain the conservation difficulties.

The study of one Galician petroglyph that encompasses the characterization of the granite, the geotechnical study of the granite outcrop and the description and analysis of weathering forms has been undertaken in this work. The aim of this study is to set a protocol to diagnose granitic outcrops with rock art, which will allow to establish the conservation measures appropriate to the specific needs of such monuments. The distribution of the several weathering forms affecting the rock art were mapped in a ocrup planimetric view and the analyses of samples of these forms comparatively with the sound granite were performed by several techniques: optical microscopy, X-ray diffraction, X-ray fluorescence, Fourier transform infrared spectroscopy, X-ray photoelectron spectroscopy and scanning electron microscope coupled with energy dispersive X-ray spectrometry. Also, the geotechnical characterization of the granite outcrop was performed following the ISRM standards.

The observed alterations were categorized in two groups: natural alterations related with weathering processes on granitic outcrops, and anthropic alterations. The natural weathering is associated with the kaolinitization of feldspars through hydrolysis processes; this weathering mechanism is favoured by the Atlantic and humid climate of Galicia and is directly linked to the distribution of the intense jointing network which characterizes this granite outcrop. The presence of hematite and the neoformation of mullite indicated that the rock is also affected by high...
temperatures, above 950°C, related to the forest fires and its direct action on the rock surfaces. A diagnosis protocol which includes the geotechnical outcrop characterization and the land use is proposed. In this particular case, preservation activities aimed at slow down the effect of water, through the modification of the drainage network, and at reduce the impact of forest fire, through an implementation of a combined management of land use and archaeological heritage, are proposed.

227. Characterizing organic micro-residues by non- or micro-destructive method: new trends in mass spectrometry (DART TOF) combined with organic and inorganic analysis

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Separative and structural analysis by chromatography and mass spectrometry are suitable methods for the characterization of amorphous organic residues preserved on ancient tools and utensils when sufficient amount of matter is preserved and can be sampled. However in case of microscopic remains, chemical characterization still remains a challenging task. By focusing on the study of residues exploited during the Holocene by pre- and protohistoric societies in the north-western Mediterranean area, we have developed an innovative methodology for non-destructive direct analysis using a combination of DART-TOFMS (Direct Analysis in Real Time), vibrational spectroscopy and SEM-EDX analyses. The DART atmospheric pressure ion source allows direct non-destructive analysis by vibrational method, particularly ATR-IRIFT provided complementary information, and SEM-EDX allowed the determination of mineral particles detected in the organic adhesive matrix. When possible, complementary analyses by GC-MS were also performed to assess the degree of transformation and degradation of the samples.

Using this multi-step methodology that includes innovative use of DART-TOFMS, it was possible to gain new information on the exploitation of adhesive substances during Neolithic and Prehistory. Our results highlight the most southern use of birch bark tar in Europe. In addition, the use of complex multi-components adhesives (birch bark tar, pine resin and beeswax) could be also determined. Based on a series of data from several sites of different periods from Neolithic to iron age, it is now possible to propose new scenarios of cultural influences in the Mediterranean area and to assess the over-time evolution of natural substances used for their adhesive properties.

Reference

228. The POMEDOR Project: People, Pottery and Food in the medieval Eastern Mediterranean

S.Y. Waksman1, A. Pecci2, R.S. Gabrieli3, E.J. Stern4, J. Wrobel and the POMEDOR collaboration

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The aim of the POMEDOR project is to explore and develop research on food and foodways in the medieval Eastern Mediterranean, using an interdisciplinary historical, archaeological and archaeometric approach. Special interest is granted to the evolution of dietary practices in contexts related to the arrival of new populations with different cultural identities (Muslim and Seljuk conquests, Crusades), and to the on-going interactions between them. One of our main sources of information is pottery, through its relationships to food procurement, processing and consumption. Various indicators are looked at, in cases studies from the Levantine coast, Turkey, Cyprus and Greece: changes in food products as seen by residue analyses in pottery; evolutions in the pottery repertoire; adaptation of pottery production to new uses and fashions, with special focus on the introduction of technological features related to the Islamic world, etc. Connections with other trends, observed i.e. in archaeozoological and archaeobotanical studies, are looked for, through the constitution of the POMEDOR network and collaborative platform.

It is hoped that this new tool will make more data available and stimulate interdisciplinary research on food and foodways in the medieval Eastern Mediterranean. The first results presented here correspond to investigations on cooking wares coming from well-dated contexts in medieval Cyprus. Different types were attributed by chemical and petrographic analyses either to Cypriot production or to imports from the Levantine area, especially from Frankish Beirut. Samples were selected for residues analyses in order to examine on the one hand what changes in use, if any, may be identified between the local and imported cooking vessels, and on the other, whether there is a differentiation of function between glazed and non-glazed cooking vessels of the same shape.

Reference

229. The Study of Hyena Coprolites from a Paleolithic Site of Central China

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Lingjing site is located 15 km northwestern of Xuchang city in central Henan Province, central China. The occupation of the site extends from approximately 100,000 BP to 80,000 BP. The most important findings from the excavation of the site are the fragments of the skull of “Xuchang Man,” as well as a great number of lithic artifacts, faunal remains, bone tools and over ten thousand fragments of animal bones. In addition to these, several dozens of coprolites were found in the same stratigraphic layer where the Xuchang Man was recovered. These coprolites probably belong to a kind of hyaena. The excavation of Lingjing site in Xuchang City recently especially draw the attention of specialists and publics, since it is the first Paleolithic site to be excavated in central China. In comparison with the number of animal fossils and stone implements, coprolites constitute only a small part of the archaeological record, but they play an important role for the interpretation of the site. They are not only the best sources to observe the information about carnivore-feeding activity but also a good representation of an individual’s and communities overall health. Since the 1960s, using coprolite to obtain ancient information is an important component of archaeology and anthropology. This paper describes the identification of the biological remains preserved in coprolites. Analysis of coprolite samples consisted external and internal observation, including color, volume, measurements, texture, inclusions and the state of preservation. Microscopic examination of the coprolites was conducted by examining a glass slide directly after dissolution followed by minimal grinding of the samples in water. The remains of parasite, fungi and animal hairs were identified in some of the coprolites. This information provides significant new evidence about the diet, individual health, environment of the ancient hyaena species in Central China.
230. A Stable Isotopic Analysis of Dietary Patterns in Individuals Interred in the Late Neolithic/Copper Age Burials of Anta da Rego da Murta I and II (Alvalázaré, Portugal): Preliminary Results

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This study uses stable isotopic data from bone samples taken from 19 individuals interred at the Late Neolithic/Copper Age burial sites of Anta da Rego da Murta I and Anta da Rego da Murta 2 (located in the Ribatejo of Portugal near the town of Alvalázaré) in order to understand dietary variation in the region and between the burials. The Late Neolithic/Copper Age of Portuguese prehistory is a dynamic time period marked by changes in social organization and technology. While the dietary attributes of communities and individuals can provide important information about social organization, labor activities and environmental resources, quantitative studies of human diet based upon bone chemistry are still limited in the region. In this study, measurements of δ15N and δ13C from bone collagen and δ18O from bone apatite were obtained to quantify the intake of marine versus terrestrial protein, and δ13C and δ18O from bone apatite were obtained to quantify the intake of marine versus terrestrial protein, and δ13C and δ18O from bone apatite were obtained.

231. Identity, Mobility, and Childhood Origins of African Abductees at the End of the Transatlantic Slave Trade: a Strontium Isotopic Perspective

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The mass enslavement of millions of Africans and their transportation is well documented in terms of numbers, points of embarkation and destinations, but little is known of the lives or origins of the individuals. As a step towards reconstructing aspects of the lives of captives, strontium isotope analysis is being conducted on 50 males excavated on St Helena Island in the South Atlantic. The Liberated African Depot on St Helena received approximately 25,000 abductees from Africa between 1840 and 1864 when illegal slave voyages were interrupted. A stable isotope analysis on their way to the Americas by the British Royal Navy. An estimated 7400 people died after landing at St Helena. A small area of the Liberated African Graveyard in Rupert’s Valley was excavated in 2008 and the remains of 325 individuals were found. Information about individual origins and lifeways provided by isotope analysis will contribute to our understanding of ancestral origins of modern people in the Americas, as well as the geographical scope and extent of abduction within Africa at this time. In addition, many of these individuals had dental modifications, and knowing location of origin would help us understand the meaning and practice of dental modification. Initial results and discussion will be presented.

232. Reconstructing Diet in Neolithic of northern Greece using Stable Isotopes of Lipid Residues in Pottery

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The transition to a settled, agricultural way of life, including the domestication of cattle, sheep and goats, followed by the uptake of a ‘secondary products’ economy has been the subject of considerable research in European prehistory. The emerging view is that early farming practices developed in varying ways in different regions, depending on local conditions and cultural practices. However, to date, dietary and subsistence patterns in Neolithic of northern Greece have been little studied.

Faunal records from the region show the presence of cattle, although domesticated cattle, goat and sheep (domino-prodomo) and wild boar with kill-off patterns suggesting that herd structures maximized the availability of meat rather than milk. Archaeobotanical remains imply a reliance on grains, comprising mainly cereals and pulses. Hence, the picture so far is that the people of Neolithic of northern Greece consumed a predominately terrestrial diet, despite the close proximity of several sites to the coast.

This project aims to build a more detailed model for the subsistence patterns and dietary changes throughout the region, both chronologically and spatially, based on a wide range of proxies. One aspect is based on exploiting the lipid biomarker approach, involving HT-GC, GC-MS and GC-C-IRMS to determine the origin of organic residues preserved in the fabric of pottery vessels. Here we report the results of analyses of >300 potsherds from seven sites dating to the Middle and Late Neolithic of northern Greece, including: Apsalos, Makrylianos, Palamibeta, Ritini, Stavroupoli, Thermi, Toumba Kremasti, Koliadas and Paliambela. The lipid recovery rates were 20-30% of potsherds analysed, consistent with those previously observed for Neolithic pottery from central and southern Europe. Lipid biomarkers (vinylid hydroxy fatty acids (OHFA) and α- (o-alkylphenyl)alkanoic acids (APAAs)) and compound specific stable carbon isotope values of fatty acids indicate that despite the close proximity of sites to the coast processing of aquatic commodities was negligible. Furthermore, despite the high abundance of ruminant animal remains in faunal assemblages, compound specific stable carbon isotope analyses of cooking pot residues suggest that dairy farming was not intensively practised. Indeed, isotope results are consistent with the high abundance of pig, sheep and goat in faunal assemblages. Possible evidence of the processing of plants within vessels has been detected through the presence of long-chain alkanes, resin acids and triterpenoids.

233. The relationship between archaeological site distribution and shoreline changes of Taiwan

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The lack of archaeological records from late Paleolithic to Early Neolithic time is a big riddle for archaeologists in Taiwan. The first appearance of human activity can be traced to around 27,000 years ago at Pahsian (Pahsiang) cave site) in eastern Taiwan, and this cultural stratigraphy is continued to be about 15,000 years ago. After then, neither Late Paleolithic nor early Neolithic (earlier than 6000 yr BP) sites had been reported except the Hsiaoalangdong site which is also a sea cave located in eastern Taiwan. Archaeological remains burst out presenting among Taiwan and surrounding areas during the so-called Taipenkeng cultural stage (~6,000-4,800 yr BP), and the time of Neolithic site explosion is comparable with the shoreline changes and coastal plain development in Taiwan.

Taiwan is an interesting region for the study of neotectonics in an area containing an ongoing thrust belt and foreland basin. In particular, the active tectonics of the coastal plain around the Taiwan Island is deposited thick marine sediments since the postglacial marine transgression. Hence, in this study we first use about 200 boreholes and C14 dating data to reconstruct the stratigraphic architecture and construct the shoreline since the Last Glacial Maximum (LGM, 18,000 yr BP). During the last interglacial period (18,000-6,000 yr BP), the eustatic sea-level rose about 120m in the world during the transgression, and a few tens to two hundred meters of marine-fluvial sediments were accumulated in the coastal areas of Taiwan. The shoreline moved landward due to rapid rise in sea-level from 18,000 to 6,000yr BP, and the shoreline retreated seaward due to larger sedimentation rate since 6,000 yr BP and resulted in extent coastal plains forming. The newly formed coastal plains could provide a good inhabitant for the Neolithic migrating population.
Remote Sensing, Geophysical Prospection and Field Archaeology

235. Subsurface Survey and Spatial Analysis on Chalcolithic Settlements From Eastern Romania

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The study of arctic or sub-arctic indigenous skin clothing, which is known for its design and warm keeping, not only provides information about the tanning techniques, but also gives a clue about the culture that created it, since tanning processes are often specific to certain indigenous tribe or group. Non-invasive and portable techniques become more and more important in cultural heritage research, since sampling in valuable conservation objects is often prohibited or very limited. MRI studies are non-invasive and could also provide spatial information from within the samples. In this study, both untreated samples and samples treated with salix and cod liver oil are compared. The study shows that samples treated with salix have a shorter T2 than untreated samples, which implies that the skin becomes more mobile after oil tanning treatment. This is mainly due to its thickness, since samples treated with salix and cod liver oil are compared. The T2 values of the untreated samples are lower than those of the treated samples, indicating that the oil treatment caused the skin to become more mobile. This result is in agreement with previous studies that have shown that oil treatment increases the mobility of the skin.

236. Geophysical studies of ancient tumulus in Azapa Valley, Arica, Chile

Luis Baris1, Ivan Muñoz2, Agustín Ortiz3 and Jorge Blancas4

As a result of a joint project between the Universidad Nacional Autónoma de México and the Universidad de Tarapacá, Norte de Chile a geophysical study including magnetic gradient and georadar was carried on by the first time in the Azapa Valley. This valley has been the origin of early human settlements, like the Chinchorro tradition, after them the mound builders tradition produce the tumulus perhaps as a way to reproduce the environment, but also as funerary mounds.

Results of this first approach revealed that magnetic gradient and georadar survey are highly useful in archaeological prospecting and their different application in the study of tanting processes.

237. Geophysical studies for the location of a mammoth remains in Mexico City

Luis Baris1, Agustín Ortiz2, Jorge Blancas3 and Joaquín Arroyo4

A great opportunity for the application of geophysical prospection techniques to a paleontological problem was presented during 2013, when the inhabitants of Santa Ana Tlactoceno, Milpa Alta, D.F. found molar of a mammoth digging a trench. Then the Universidad Nacional Autónoma de México and Instituto Nacional de Antropología e Historia set a joint project to study and eventually excavate, the bone remains of this Pleistocene animal. The project included three main steps: geophysical prospection, excavation and treatment of the recovered bones. In this paper we mainly present the results of the geophysical studies that included the topographic survey, magnetic gradient, electrical resistivity, electrical tomography and georadar survey. Except for the magnetic gradient, all geographical techniques detected clear anomalies in the same place and at the same depth of all which suggested the presence of bone remains of the whole mammoth and guided the later archaeological excavation. During excavation we realized that bones were recovered embedded in grey fresh volcanic ash matrix that badly damaged the bone characteristics, but perhaps the same matrix made it possible to find clear contrast in geophysical properties that produce consistent anomalies to detect the place where bones were burned. In this paper we present results from geophysical studies and the recovery process for the mammoth remains.

238. Preliminary conservation issues study of unearthed marble ruins in the Plutonium of Hierapolis (Denizli, Turkey)

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The ancient Persian city of Hierapolis in the Denizli district in Turkey, today named Pamukkale ("Cotton Castle")
Due to Viritneo instruments likewise industrial background the modifications and adoptions, which were carried out during the interdisciplinary collaboration of conservation scientists and engineering professionals, needed to be scientifically evaluated in respect of the applicability in cultural heritage preservation and collection care. The evaluation included preliminary tests in laboratory environments and was followed by twelve month test-runs in archaeological museums, which are situated in different climatic regions. All collections are housed in solely naturally climatized buildings, therefore daily and seasonal fluctuations were most likely to convey significant results.

Final recommendations for the applicability of the radiotelemetric measurement Viritneo devices for archaeological collections or site contexts and their potential to enforce (preventive) conservation measures can be given after termination of the test-runs. Preliminary evaluations may expect good results for the ongoing measurements.

240. Photogrametry and Visualization of the Viminacium

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2. Archaeological Institute, Project Viminacium, Belgrade, Serbia.
3. Center for New Technologies - Viminacium, Belgrade, Serbia. Viminacium, capital of the Roman province Moesia Superior (Upper Moesia) and fort of the Legio VII Claudia is now the testing ground for multidisciplinary methods in archaeological research. City and suburban surroundings of Viminacium extends to over 440 hectares of fields, while urban core and fortification system cover zone of 220 hectares. The fact that there is no modern settlement over ancient ruins is of enormous importance. This makes it ideal for archaeological, geophysical and other scientific research. Viminacium Scientific team consists of mathematicians, geophysicists, and researchers that are focused on remote sensing and 3D modelling.

Constant exchange of the ideas between researchers of different profiles offered the chance to combine methods and get better and more accurate results. Remote sensing and analyze of a sequence of aerial images helped us to identify 21 macro features in the zone of the city and legionary fort. Excavations were undertaken to explore some of these features and confirm interpretation of remote sensing: amphitheatre, porta praetoria and suburban roman villas.

During campaigns 2012-2013 rapid increase in intensity of excavations on several sites emerged the need for more efficient documentation. Photogrametry proved to be entirely practical solution for problems.

We are now offering overview of two separate projects - Roman amphitheatre with space for 8000 spectators and villa rustica excavated at outskirts of the urban zone. In this paper we will present results achieved during excavation of Roman villa and amphitheatre as examples in documenting some of the largest structures of ancient origin.

Amphitheatre is one of the most prominent buildings on the site. Since it existed and was rebuilt in several phases total visual documenting was crucial for the reconstruction. Villa along the limes road to Lederna was the example of the documenting building that was utterly destroyed during expansion of the coal mine.

Development of software for photogrammetric processing enabled us to gather data fast and with adequate high accuracy to use it in archaeological documentation. 3D models of these buildings generated with these methods proved to be cheaper, faster generated and easier to provide than classic survey with 3D scanner - ideal for visualization during both systematic and urgent salvage excavations.

This documentation is the base for ongoing full reconstruction of the Roman city and legionary fort.
The Indus-Saraswati civilization played a crucial role in the process of urban development, art and artefacts cultural and intellectual gains of the community. The neo-tectonic movements, climate change and human activities leading to environmental degradation are considered to be the causes for the eclipse of this civilization, but its impact had been strong enough to be reflected in the modern day culture and society. It is this uniqueness of the region and the process of change which has been explored in a project entitled ‘Atlas of Indus-Saraswati Civilization’, undertaken by the Indian Archaeological Society, New Delhi during 2007-2017. The observations from this project are being placed in this paper.

The main objective of this study is to map the geo-spatial expansion of this civilization through time, reflected in its early, middle and late stages. A number of references consulted provided the list of explored and excavated sites. After a rigorous scrutiny, 1215 sites have been identified that existed during early, mature and late stages of Indus-Saraswati civilization and are plotted on the maps. The geo-coordinates of the sites have been converted into GIS coordinates for mapping. The conversion of geo-coordinates into GIS coordinates has been done using ArcGIS 9.2 software. The maps have been prepared at a scale of 1:100,000 and are based on historical maps. Coordinates into GIS coordinates have been done by using techniques in archaeological birch bark

The availability and unique physical properties of wood and bark have made them the materials of choice since ancient times for the production of everyday life and artistic artefacts. Objects constituted by wood or bark are preserved for long periods of time only under particular conditions, such as very dry conditions in arid or cold climates or wet environments. In this field is our work, being its primary aim to assess the preservation and the state of degradation of archaeological findings made up of birch bark. In particular, we studied samples from a Neolithic bowl case conserved in permafrost and samples of a Neolithic bark vessel recovered from a waterlogged environment. Suberin, an extracellular lipid polymer, along with triterpenoids are the main chemical components of birch bark. The monomer composition of the suberin and the triterpenoids distribution of reference bark birch and of four archaeological was investigated using alkaline hydrolysis followed by gas chromatography-mass spectrometry (GC/MS). In particular, two different KOH hydrolysis conditions were tested: hydrolysis assisted by microwave and hydrolysis in a water bath. In addition, SEM observations were used to state the morphological aspect and thus, the condition of preservation of the birch bark objects. The chromatographic profiles of reference bark revealed that the hydrolysate in a water bath is better than in a microwave oven: water bath allows us to preserve the

243. Mapping of Indus-Saraswati Civilization (Using Geographical Information System)

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The Indus-Saraswati civilization seems to have existed from 3rd to 2nd millennium BCE and extended to more than one million sq. km. It covers a large area of North-West India. In India, in the region covered under this civilization form parts of the States of Gujarat, Haryana, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh and Uttarakhand.

The Indus-Saraswati civilization played a crucial role in the process of urban development, art and artefacts cultural and intellectual gains of the community. The neo-tectonic movements, climate change and human activities leading to environmental degradation are considered to be the causes for the eclipse of this civilization, but its impact had been strong enough to be reflected in the modern day culture and society. It is this uniqueness of the region and the process of change which has been explored in a project entitled ‘Atlas of Indus-Saraswati Civilization’, undertaken by the Indian Archaeological Society, New Delhi during 2007-2017. The observations from this project are being placed in this paper.

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244. Elucidation of the degradation mechanisms in archaeological birch bark

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Mechansims in archaeological birch bark

242. Contribution of new geophysical measurement of previously excavated Neolithic roundel area near Bylany

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Archaeological site Bylany near Kutná Hora has become due to long-term systematic archaeological research and excavation one of the most important Neolithic settlement areas of the Linear and Stroked pottery culture in Central Europe. Site was discovered in the 1950’s by Soudkyj and large-scale archaeological excavations were undertaken here mainly in 1955-1964 and 1966-1967. Other smaller areas were verified by excavations during 1977-1980, 1990-1993 and 2004. During more than 6 decades ofarchaeological work on site were excavated approx. 7 ha, but the whole extent of Neolithic area covers dozens of hectares. In particular situation were also applied various non-destructive methods including geophysical surveys. The main magnetometric measurements were concentrated to area Bylany 4 where in 1980 started the first stage of identification of circular ditch enclosures (Fálysová-Marešek). Newly identified one double circular ditch enclosure was subsequently verified by archaeological trench (Zápotocká) with dating of settlement from the Stroke pottery culture. A new observation of the same area by new survey after 12 years was initiated by result of archaeological trench from 1991-1992 (Pavlů). The second stage of magnetometric measurement in 1992-1993 (Majer) of outer area of known double ditch enclosure brought new separation of the third more irregular outer ditch and also new segment of different unknown triple ditch enclosure in superposition near the edge of surveyed area. Subsequent excavations (Pavlů) in more areas of the Stroke pottery roundel verified 2 entrances, remains of palisade and confirm older stages of Linear pottery culture settlement with long houses existing in area before ditch enclosure. Later geophysical methods were applied in different areas of the Neolithic Bylany micro-region. A new motivation of geophysical measurements of wider area of known and partly excavated roundel offered new project of systematic processing and web-presentation of Bylany site and possibility of use of more powerful magnetometer system.

The result of the third stage of magnetometric measurement of larger area of roundel in 2012-2013 (Křivánek) gives to archaeologists the first complete plan of both triple ditch enclosures. Neolithic roundlets in superposition have different dimensions, shapes, construction and probable dating. More intensive and precise collection of data by 5-channel magnetometer offers also separation of specific shapes of entrances, intensive settlement activity on site and also places of former excavation trenches. In long-time agricultural land use geophysical results also could inform about depth of terrain changes by plowing and about the real state of subsurface archaeological situations.

Poster II abstracts
245. Application of REMPI Laser Mass Spectrometry to Cultural Heritage

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Pottery sherds from common and ceremonial Maya vessels dating to the Late Classic Period (c. 600-900 CE) were analyzed using resonance-enhanced multi-photon ionization (REMPI) laser mass spectrometry to confirm the presence of cacao, the beans used extensively in Mesoamerican cultures to make chocolate beverages. Three ‘molecular markers’ are commonly used to confirm the presence of cacao: caffeine, theobromine and theophylline. The identification of each of these small organic molecules, two of them being isomers, in the complex matrix of pottery is challenging without considering factors endangering wood and without factors potential for resolution of archaeological wood. In the early period of deposition, degradation processes have already started but they slightly affected wood. In addition the wet peat conditions provide information at a molecular level. The results highlighted that the external parts of archaeological wood had undergone loss of the polyaccharide components, whereas the internal part were in a relative good state of conservation. A certain degree of oxidative degradation was also noticed, probably occurred before the submersion.

For the monitoring program samples of sound oak wood were put into two stations (wet peat and lake water). The analyses described above were performed on the sound wood and on samples taken after 2, 4, 6, 8 and 10 years of deposition in the stations. The results showed that during ten years only little differences can be noticed, proving that degradation processes have already started but they slightly affected wood. In addition the wet peat conditions seemed to accelerate degradation in comparison with lake water conditions. The monitoring will be continued in the following years hoping that the obtained knowledge will be helpful for the planning of in situ conservation of wooden objects.

246. The examination of dynamics of oak wood degradation process in the wet peat and lake water conditions

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The archaeological site of Biskupin (Poland) is a prehistoric settlement dated back to 8th century BC, situated on a marshy island of about 2 ha. Excavations started in 1934 and a considerable amount of wood artifacts was found sunken in the water of the lake. The ancient village was reconstructed and nowadays the site is an open-air museum (Museum of Biskupin), whereas the archaeological wood is still kept underground.

Storage of archaeological wood in natural environment (in situ) is very common in Poland, but it is often done without considering factors endangering wood and without answering to the question how quickly wooden remains will undergo destruction.

The aim of this research was first to assess the degradation state of archaeological oak wood and secondly to plan a monitoring strategy, in order to describe dynamics of degradation processes in the early period of deposition. Different techniques were used to assess the physical and chemical degradation of the oak-wood. Physical properties, such as moisture content and conventional density were determined on the basis of the mass of absolutely dry wood and the volume of the sample in the state of maximal saturation. Morphology was observed by scanning electron microscopy (SEM). The chemical state of conservation was evaluated by using classical wet chemical analysis (TAPPI methods) and analytical pyrolysis coupled with in situ silylation, which has the main advantage to provide information at a molecular level.

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Twin Rivers Kopje is a Middle Stone Age archaeological site located 24 km southwest of Lusaka, Zambia and contains the oldest Lupemban Industry deposits in Central Africa, dating to approximately 100,000 – 140,000 years during the Middle Pleistocene. The site was first excavated by J. Desmond Clark in 1954-56; more recent excavations by Lawrence Barham (1990s) yielded evidence of extensive collection and utilization of ferruginous mineral pigments from Lupemban Industry and more recent contexts. Barham analyzed several ochre artifacts using X-Ray Fluorescence, Inductively Coupled Plasma Mass Spectrometry (ICPMS), and Scanning Electron Microscopy (SEM) and speculated on their derivation from local sources. In the study presented here, we took the next step in the provenance research initiated by Barham and collected samples of ochre and iron ore from sources within 25 km of Twin Rivers for Laser Ablation-ICPMS, Electron Microprobe Analysis, and SEM. In addition, samples were collected from every ochre artifact excavated by Clark and presently curated at the Stone Age Institute in Bloomington, IN. Although Clark’s publications on Twin Rivers acknowledged the presence of pigments, this ochre was never before studied with regard to mineralogical identity or modification type. The Clark Twin Rivers ochre assemblage (N=195) represented a novel opportunity to conduct a new analysis of ochre provenance and use that complements the work of Barham. Among the most important conclusions regarding the Clark assemblage is that while the visually striking mineral specularite was extensively collected (n=47) and predominantly ground or scraped into pigment, iron ore with relatively high Fe content but lacking the reflective properties of specularite was collected at greater frequency (n=56) than specularite and was flaked three times as often as it was ground or scraped. This suggests visual criteria were used to distinguish between ferruginous materials collected for use as pigment and those treated like any other lithic material for knapping. Geological surveys conducted during July 2013 identified a major source of vein mineralization specularite located 19 km northwest.
of the site at Sanje Hill on the Kafue Flats. Sanje Hill is a prominent conical hill composed entirely of specularite, massive hematite, and hematite conglomerate. Micro-
sources of hematite and goethite were identified in the vicinity of Twin Rivers but Sanje Hill remains the only known source of specularite and is the most probable origin of the specularite artifacts found at Twin Rivers.

248. Examination of the Structure of Jiroft Marble Stones Discovered in South Konar-Sandal

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Placed in the southeastern Iran, Jiroft region is one of the most historical cities of the country and, in fact, its history dates back to the second millennium B.C. The ancient history of Jiroft and its proximity to the River of Halil Roud has attracted archeologists during the recent decades. So far various historical works have been published on the region of which marble ones are especially noteworthy. Basically, marble works were used more commonly in central plateau of Iran than other ones. The marble works discovered in jiroft region are only comparable with those of unearthed Burnt City of Zabol. The scientific examination of such works may pave way to identify their structure and become the major method to cast vessel in Erlitou period. The piece-mold casting technique to make artefacts can be traced to Jiroft period. So far fewer studies on the smelting and casting technology in early bronze age of China are discussed based on the experimental data. During this period, the usage of copper alloy seems gradually increased, while the usage of tin bronze was widely used, but tin oxide inclusions were found both in crucible slag and bronze wares. It imply that some technological obstacle maybe still exit in the smelting and compounding process. The usage of piece-mold casting technology to make artefacts can be traced to Jiroft period and became the major method to cast vessel in Erlitou period. The microscopic examinations show the Erlitou moulds' fabrics are composed of silt particles, void and clay matrix and characterized by their low clay content and high porosity, quite like to those moulds from other later sites such as Yin Yu and Xinxing. It seems to be a start of forming the technology tradition by using high silt and low clay material during the whole Bronze Age in China.
Ceramics, Glasses, Glass and Vitreous Materials

250. The Application of Laser Ablation ICP-MS and HH-XRF Techniques for Chinese Porcelain Dating and Provenance Research
Rita Giannii1, Andrew Shortland2

More than one hundred Chinese blue-and-white porcelain objects from excavated archaeological sites, surface archaeological deposits, shipwreck cargos and private collections (from the Tang to the Qing dynasty periods, 618-1911 CE), have been fully quantitatively characterised with LA-ICP mass spectrometry. The primary aim of the study was the acquisition of a significant amount of consistent and accurate data from material of securely dated context and/or known provenance. Interpretation of Chinese porcelain ware types can be complicated by the presence of ceramically sound fragments of unknown origin unearthed from kiln sites and kiln waster deposits, unusual features displayed by some early analysis where reference materials were lacking, as well as the circulation of numerous, high-quality imitations appeared both in later dynasties and in modern times (Xie Guoxi et al., 2009). However, since most ancient Chinese kilns employed raw materials quarried from local sources, variations in the geochemical and mineralogical features of their ceramic products are typically expected (Tite et al., 2012, Ma et al., 2012). In this study, new analyses of major components, trace element patterns and R1E geochemistry were interpreted and integrated in light of previous published research, the particular Chinese geological setting (Zheng et al., 2013; Sun et al., 2011) and how the influence that ancient raw material processing techniques might have changed the finished artefact composition (Guo Yanyi, 1987; Wu et al., 2000).

Statistical treatment of the results allowed the definition of compositional reference groupings which could be used, within certain limits, to assign the provenance of sherds of unknown origin. Besides providing a large compositional databank for Chinese porcelain, the analytical approach successfully revealed some provenance misattributions among the studied samples. Finally, the possibility of distinguishing these groups by HH-XRF was also assessed on selected reference pieces to check its effectiveness as a preliminary screening method in the examination of Chinese blue-and-white porcelain.

References

251. Clays, Kilns and Ceramic Productions in Northern Apulia
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As archaeometric capacities to finely delineate the geochemical, micro-structural, and mineralogical components of archaeological pottery have proliferated, so too have grown archaeological scientific abilities to examine more macro-scale, yet visually obscured variation in ceramic vessels. This paper outlines how digital radiographic methods are being marshalled by the MAK to provide significant and complementary structural perspectives to micro-scale analyses of vessel composition and components. In contrast to previous digital radiographic efforts which have primarily been used to evaluate museum objects or archaeological finds of particular heritage import, the authors offer a digital radiographic application for the analysis of large archaeological potsherds datasets (n > 500), the basic fragmentary data of traditional archaeology. Eight years of research and experimentation with the digital radiographic analysis of archaeological potsherds assemblages are presented, with particular attention to discerning and distinguishing techniques of paste preparation and vessel formation. The particular imaging protocols for producing image sets of maximum quality are delineated, including “integration time,” peak kilovoltage, milliamperes, and geometry. The authors also outline the post-processing tools that take advantage of the metric-matrix qualities of digital imagery. These software tools have been custom-written in interactive data language (IDL) to evaluate image quality through modulation transfer function (MTF), and to equalize, filter, and code polished imagery for their structural attributes. The paper outlines the significant benefits of digital radiography over older analog techniques, the types of formation mechanics discernable, and the way digital image manipulation can identify and discriminate between different paste preparation strategies. Finally, the authors present case studies from the Eurasian landmass that produce fabric typologies in part through digital radiographic evaluation. They conclude that digital radiography, and in the future its partner X-ray computed tomography, can become a crucial tool in the archaeometric examination of ceramic macro-structures and potting strategies.

252. Digital Radiography of Macro-Scale Variation in Archaeological Ceramics: The Assemblage-Based Analysis of Ancient Eurasian Potting Techniques
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As archaeometric capacities to finely delineate the geochemical, micro-structural, and mineralogical components of archaeological pottery have proliferated, so too have grown archaeological scientific abilities to examine more macro-scale, yet visually obscured variation in ceramic vessels. This paper outlines how digital radiographic methods are being marshalled by the Making of Ancient Eurasia (MAE) Project to provide significant and complementary structural perspectives to micro-scale analyses of vessel composition and components. In contrast to previous digital radiographic efforts which have primarily been used to evaluate museum objects or archaeological finds of particular heritage import, the authors offer a digital radiographic application for the analysis of large archaeological potsherds datasets (n > 500), the basic fragmentary data of traditional archaeology. Eight years of research and experimentation with the digital radiographic analysis of archaeological potsherds assemblages are presented, with particular attention to discerning and distinguishing techniques of paste preparation and vessel formation. The particular imaging protocols for producing image sets of maximum quality are delineated, including “integration time,” peak kilovoltage, milliamperes, and geometry. The authors also outline the post-processing tools that take advantage of the metric-matrix qualities of digital imagery. These software tools have been custom-written in interactive data language (IDL) to evaluate image quality through modulation transfer function (MTF), and to equalize, filter, and code polished imagery for their structural attributes. The paper outlines the significant benefits of digital radiography over older analog techniques, the types of formation mechanics discernable, and the way digital image manipulation can identify and discriminate between different paste preparation strategies. Finally, the authors present case studies from the Eurasian landmass that produce fabric typologies in part through digital radiographic evaluation. They conclude that digital radiography, and in the future its partner X-ray computed tomography, can become a crucial tool in the archaeometric examination of ceramic macro-structures and potting strategies.
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Grog, or crushed pottery, is a technological phenomenon present in archaeological assemblages spanning cultural-temporal contexts around the world. Traditionally defined as a grounded down, previously fired ceramic used as temper in ceramic production, grog belongs to a wider additive category of materials - including sand, plant fiber, grit, shell, and crushed rock - which has proven to open clay and reduce plasticity, thereby reducing the likelihood of vessel crack progression during drying and firing (Rice, 2006; Gibson and Woods, 1997; Sinopoli, 1991; Shepard, 1956).

Beyond this normative definition, grog has been the source of virtually no in-depth research. The identification of grog in archaeology is characterized by a corpus of generalizations. Grog is typically distinguished from similarly textured natural materials, like iron-rich clay nodules and mudrock, based on the singular subjective criterion of shape, which is applied to rounded (Petersen and Watters, 1991). Furthermore, a distinct ring, indicating a pre-fired condition, is present around grog particles in petrography (Braekman, 2011). Excluding grog of diverse size, shape, and color, these properties are based on high-fired pottery assemblages (Petersen and Watters, 1995; Donahue, Watters and Millsappa, 1990; Goodwin, 1979).

This sampling bias highlights the inadequacy of grog identification and the gap in our understanding of ceramic innovation. Our study investigates the under-explored definition of grog in past Caribbean societies by assessing grog identification in a low-fired ceramic assemblage. By applying fabric analysis, petrography, microscope examination (EMPA) and XRF spectroscopy, the research analyzes an assemblage of decorative lugs (adornos) from the site of El Cabo in the Dominican Republic (Hofman, Hoogland, Oliver, and Samson 2008; Samson 2010). Using a variety of selection criteria including size, amount, inclusions, and firing temperature, we differentiated four general grog types in a set of four experimental test bars which were confirmed by the petrographic results of an archaeological sample (n=30). In order to refine the technological features and sourcing of grog, the samples were subjected to microprobe study to reveal the chemical composition of individual grog grains. Preliminary findings suggest a scholarly underrepresentation of grog diversity in the archaeological record and challenge traditional definitions of natural and cultural-occurring ceramic inclusions. Building on studies exploring issues of technology and provenance, this study will (a) establish parameters for identifying grog, (b) encourage integrated approaches, and (c) contribute to the limited Caribbean technological studies (Hofman, Isendoorn, and Booden 2000; St. Jean 2008; Hofman, Isendoorn, Booden 2005; Hofman and Jacobs 2000/2001).

254. Assessing heating efficiency of archaeological cooking ware - the potential of 3D computer simulations
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Archaeological cooking vessels come in a large variety of shapes, and a host of different methods of clay paste preparation have been used in their manufacture. The influence of both material and shape, and ultimately ceramic manufacture, on material properties such as strength and toughness but also on thermal shock resistance have received considerable attention in the archaeological literature. Indeed, the presence of specialized paste recipes for this particular class of pottery, for example, has frequently been related to the specific demands placed on cooking pots. In addition to the above, however, of particular importance for vessels used for cooking are also heat transfer processes, which are governed by parameters such as physical properties of the ceramic, vessel shape, but also by cooking methods employed.

Each vessel is examined for heat transfer in cooking pots by assessing ‘heating efficiency’, defined as the time that is needed to bring a certain amount of water in a replica vessel to the boil. While providing useful information on potentially behaviourally relevant differences in affordance between particular cooking vessels, the experimentally determined ‘heating effectiveness’ remained a complex parameter affected by thermal conductivity, heat flux, heat capacity, permeability and shape of the vessels, as well as depending on external constraints. In order to overcome these difficulties, digital computer models and simulations of the cooking process can be employed. In particular the finite element approach, employed in the present study is uniquely suited to the problem, as it allows to selectively evaluate the influence of parameters of interest on heating rates and energy transfer, may these parameters be material or shape related, or in fact be external constraints, thus excluding experimental uncertainties.

This paper presents a novel approach to examine heat transfer and quantify the heating efficiency of archaeological ceramics, being the ratio of the heating energy absorbed by vessel content and the energy applied to the cooking pot, in a systematic way using computer modelling. Digital models of cooking vessels are developed and investigated with the finite element method. Heating efficiency is evaluated and the influence of parameters of interest and of external constraints on heating rates and energy transfer are investigated. In this way parameters which play a critical role in a vessels’ heating efficiency are identified, ultimately providing a basis for the assessment of variation in archaeological fabrics and vessel shapes.

255. Non-invasive Analysis of Chinese Blue-and-white Porcelain from Indonesia and the Philippines
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Blue-and-white porcelain has been a symbol of Chinese material culture for the last seven centuries and has spread all over the world with high impact on other cultures. Export blue-and-white porcelain was usually manufactured in common kilns as opposed to the ware from official kilns reserved for imperial court use, rewards and diplomatic purposes. During the 16th-17th century, Jingdezhen and Zhanzhao were the two main production centers from which blue-and-white was exported following newly established global trading networks. The distinction between products from these two centers is of prime importance for archaeological research because it relates to topics such as trade routes, value or class. However, while the provenance of complete porcelain pieces can often be easily identified from stylistic and technology-related features, attribution of small sherds to specific production sites remains a challenging task that requires a more in-depth analysis of the material. During the last decades, most scientific studies have focused on ware from official kilns (Yu and Maoc, 1996; Wu et al., 2000; Wen et al., 2007) and only recently, owing to archaeological excavations of common kilns at both sites, useful reference data became available (Wu, et al., 2007; Na et al., 2012; Parshall and Lopansri, 2013). In the research presented here, blue-and-white porcelain sherds from Banten (Indonesia) and Visayan (Philippines) were analyzed with handheld XRF (p-XRF) and UV/VIS/NIR spectroscopy to acquire compositional data of the ceramic body, slip and blue pigment and to evaluate the potential of these non-invasive and portable techniques at discriminating different source materials and production sites. Beside the expected use of Mn-rich cobalt ores for the blue pigment, p-XRF results have indicated that products from Jingdezhen and Zhanzhao common kilns can be successfully differentiated based primarily on the concentrations of some key trace elements such as Zr, Ti and Sr, most likely correlated to the composition of local raw material sources. The approach appears therefore promising and could offer a fast and cost-effective way for the characterization and sourcing of export blue and white porcelain sherds, especially for field analysis.

References.
The analysis showed that the bead is made of glass layers of different colors. The studied glass of beads from the Middile Danube has a number of special features of the composition similar to glass of jewelry from the Tibiskum workshop. As D.Benea had fairly considered, production of the latter was focused on the barbarians, who lived along the Roman limes. Probably such glassworking centers worked using imported raw glass. Our research allowed to assume, that the glass arrived to danubian bead workshops from several sources. Perhaps some part of it was colored locally and other arrived already colored.

257. The Making of the Glass Tesserae of Hellenistic Mosaics in Delos, Greece: an In Situ Study Using pXRF, Colorimetry and Microscopy

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The mosaics from Delos (130 to 88 BCE) are one of the most relevant collections of the Hellenistic period. They are about three hundred and fifty, made up using techniques such as tessellatum, vermiculatum, chip and pebble mosaic. An important feature of these mosaics is the use of artificial materials, in particular of glass and its color was established. Glass of different recipes containing distinct proportions of ferric oxide to silica. Such technical choices, together with the specific “model values” (Read, 2007) displayed in vessels’ metric measurements among separate working groups, shed light on cultural idiosyncrasy and control over ceramic production at the domestic level and could also help to further unravel the social meanings of the vessels in different contexts of use.

258. Prehistoric Ceramics from the Chengdu Plain: Scientific Analysis and Cultural Significance

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This research focuses on Bronze Age ceramics from Sichuan in Southwestern China and shows how both environmental and cultural factors have shaped craft production. The complex geological setting and diversity of ecological systems of the Sichuan Basin have historically influenced economic activities in this region, especially the development of ceramic production. Several vessel types (e.g., pointed-bottom vessels) were analyzed to understand manufacturing processes and social functions. Such vessels were spread widely across and beyond an area of about 180,000 km² and have been found in various contexts. We have drawn our examples from three site clusters: Sanxingdui (Sichuan, 1999), Shi’enqiao (Sichuan and Chengdu, 2009), and Jinsha (Zhu et al., 2002), and have grouped the ceramic sherds based on the results of petrography and XRD analysis. Each grouping is based on the nature, abundance, orientation, sorting, and shape of the grains and the presence or absence of particular minerals and/or rock fragments in the temper and groundmass as well as on the oxidation/reduction degrees of the ceramic body. Our results suggest that these three nearby sites produced similar types of vessels using different techniques while sharing certain traditions. In part, craftsmen were collectively influenced by their common clay resources and a larger manufacturing tradition. Nonetheless, individual variations and technological choices among different working groups are reflected in how the potters processed, tempered, and fired their clays. Beside mineralogical analysis, compositional data were also collected with XRF to study additional samples from neighboring areas. Our goal was to compare the pottery recipes used at different sites in the Chengdu Plain, where clay sources are a feature only of minor variations as revealed by mineralogical analyses. Multivariate statistics on major and minor elements has shown that different settlements seem to have adopted different recipes containing distinct proportions of ferric oxide to silica. Such technical choices, together with the specific “model values” (Read, 2007) displayed in vessels’ metric measurements among separate working groups, shed light on cultural idiosyncrasy and control over ceramic production at the domestic level and could also help to further unravel the social meanings of the vessels in different contexts of use.

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259. Texture Recognition in Ceramic Samples Through The Implementation Of Gabor Filters And Artificial Intelligence Techniques

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260. Identification and Restoration of Late Roman Amphora, 4th - 6th Centuries AD from El-Bahnasa Site, Egypt

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Commercial amphorae are large ceramic vessels which were used, in the Greco-Roman period, to ship wine and other liquid products throughout the Mediterranean. It dates back to the Late Roman period (4th-6th centuries AD) and was excavated at El-Bahnasa archaeological site at the south of Egypt. The condition of the Amphora was very poor and suffered from many deterioration phenomena including: accumulation of dirt and soil residues, narrow and wide cracks, decay and fragility of pottery body and crystalization of salts. Furthermore, many shards are broken from the body and some are missing. The aim of the present paper is to study the chemical and the mineralogical composition of the clay body, the soil residues and the crystalized salts and to restore it. Different analytical methods were used including: X-ray diffraction (XRD), polarizing optical microscopy (POM) and scanning electron microscopy (SEM) coupled with energy dispersive X-ray spectroscopy (EDS). The results obtained by XRD reported that clay body contains quartz, calcite, halite, magnetite and hematite, while the salt is halite mineral (sodium chloride). The soil residues sample consists of halite, quartz and calcite. The chemical composition and the texture obtained by SEM-EDS for clay samples revealed high proportions of silicon, aluminium, iron and relatively low concentration of calcium, sodium and potassium. Different restoration treatments were carried out on the amphora comprising; mechanical and chemical cleaning with various solvents, consolidation of the fragile body using PVA, followed with Paraloid B-72 40%. In addition, replacement of the missing areas was carried out using polyfilla (calcium sulphate with cellulose fibbers). After the restoration process was completed, the amphora was safely in the condition of storage or display, and to prevent it against the various environmental conditions.

261. Analytical Study of Archaeological Ceramic and Glass from Different Periods Excavated at Egypt

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Features of a chemical composition of ancient ceramic and glass samples from excavations on the territory of Egypt are investigated in this work. The analysis of composition was carried out with a method of emission spectroscopy. Ceramic fragments were excavated from Al-Fustat and El-Bahnasa and date back to Fatimid period in Egypt (969 - 1171 A.D), to Mamlouk period in Egypt (1250-1517 A.D) and to Late Roman period in Egypt (4th-6th centuries). Al-Fustat is the first capital of Islamic Egypt, located at the eastern bank of the Nile in Old Cairo. The village of El-Bahnasa is situated on the west bank of the Nile, to the west from the road between Maghagha and Beni Mazar and out towards the edge of the cultivation. Today the village occupies part of archaeological site. This site is about 200 kilometers from Cairo at the south. The pottery, which fragments were investigated, has various coloring and painting. Results of the analysis showed that all ceramics were covered with the glaze containing 35-60% of lead, except of one fragment of Mamlouk period from Al-Fustat site in old Cairo. This blue glaze is made on the basis of sodium and colored by cobalt. Interesting feature of some samples is the presence of essential amount of sodium (7-11%) in lead glaze. Glaze of one fragment is made of lead and tin mix. Such composition of glaze is typical to the Turkish glaze ceramics. The part of objects has antimony as micro impurity, the glaze of other samples contained a bismuth (to 0.12%). The investigated samples of glass were excavated from El-Bahnasa site and date back to Late Roman period in Egypt glass (4th-6th centuries). The analysis of a chemical composition shows that all glass is made with use of natron. The characteristic peculiarity is very low content of iron (<0.01%). The content of other components also is small: K2O and MgO <1%. Al2O3 1-2%. It means that sand of high quality was used in glass production.
using scanning electron microscopy coupled with energy-dispersive X-ray spectrometry (SEM-EDS) for textural and qualitative chemical analyses, electron microprobe (EMPA) to determine quantitative chemical compositions of the glass matrix and X-ray powder diffraction (XRPD) to define the crystalline phases of the opacifiers. The results of the analysis allow us to throw light upon the evolution of production technologies and the relative differences in the composition of glassy matrices, and in the opacifiers and colourants used, from both a chronological (from the Roman and Late Roman period) and geographical (between coastal and inner towns) perspective. Because of the identical methodological approach, systematic comparisons among tesserae from the three sites are considered here, as well as with mosaics from Padova and Vicenza mosaics, providing valuable insights into the complexities of mosaic glass technology in the Roman – Early Medieval period in the Northern Adriatic area.

263. Glass-working or glassmaking? New evidence from the site of "Fondi ex Cossar" in Aquileia (Italy)

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The archaeological and geochemical study of glass assemblages from Aquileia can provide useful information about the evolution and circulation of glass objects in North Adriatic Italy. A large number of glass finds have been discovered in Aquileia in the past and, despite the lack of archaeological evidence, the city is still often considered to be a primary glass production site. In order to clarify the provenance of glass and raw materials in this area, a systematic approach, which integrates archaeological characterization, geochemical study and statistical analysis, like that used on the assemblage of the Domus delle Bestie Ferite (Aquileia), has been applied. Statistical analysis of the chemical data allows us to identify six major clusters, which were compared with published compositional groups. Most of the samples show similarities with the late antique groups widespread in the Mediterranean (HIMT, Series 3.2 and Levantine 1). Samples from 'Roman' composition were also identified. The relationships between the chemical compositions, archaeological typology and the chronology of the glass have also been investigated and correlations and associated patterns within the data, previously identified in the Bestie Ferite assemblage, are confirmed here. It is also interesting to note the presence of glass working residues (in particular glass chunks) and objects with the same composition, which raises a question about the source of the supply of glass worked in the area. In order to investigate the provenance of the raw materials, isotopic analysis of Sr and Nd were conducted on a selection of samples. The concentration of Sr and the isotopic ratio of Sr and Nd detected are consistent with the use of a Levantine coastal sand in all the samples. This latter result, together with the presence of working waste and raw glass chunks belonging to specific late-antique compositional groups supports the hypothesis of the existence, in Aquileia or in the surrounding area, of a secondary workshops where, in the Late Roman period, raw glass coming from the Levant was worked.

264. Slipped and Unslipped Common Wares of Hellenistic Tradition Produced at Kampyr Tepe in Ancient Bactria (Uzbekistan)

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Kampyr Tepe was a Hellenistic fortress founded at the end of the fourth century BC in the banks of the Amu Darya (Oxus River), on the route connecting Bactria with Sogdia. This centre played an important military and commercial role during the Hellenistic-Sasanian and Greco-Bactrian periods. It consisted of an elevated Citadel, a walled Lower City at the foot. Outside the walls a pottery workshop was discovered indicating local pottery production. Painted and unpainted wares recovered in the production centre as well as in other inhabited areas closely resemble prototypes of Greek tradition (kraters, cups, bowls, paterae, plates and platters). In order to characterise the pottery production at Kampyr Tepe, a large analytic program comprising techniques of chemical (XRF), mineralogical (XRD) and petrographic analysis was undertaken on reddish or black slipped and unslipped wares and local raw materials. Provenance was investigated by establishing the reference group/s and the petrographic fabric/s. Technological processes involved in manufacture and surface treatment were examined by XRD, OM and SEM-EDS in order to assess the degree of technological development and standardisation as well as possible technological correlations with regards to contemporary Mediterranean pottery productions. The results provide important information about the emergence and evolution of pottery production in the Hellenistic tradition in ancient Bactria. Most of the wares analysed were attributed to a local origin since they grouped in a main calcareous reference group/medium-low petrographic fabric. Secondary calcium carbonates, calcium sulphates and sodium chlorures were identified in most of them by OM, SEM-EDS and XRD, as a result of weathering processes occurring during their deposition in a semi-arid environment. Pottery technology appears to be much standardised, proved by the use of consistent raw materials and practices. Several materials and techniques were identified in terms of surface treatment, consisting on reddish and black slips achieved under specific oxidised and reduced firing conditions. These data suggest the development of a long-lasting ceramic production in Kampyr Tepe, which was consistent in forms, decorations and technological processes for a long period but also somewhat localised, probably with a scarce commercial significance.

265. Late Bronze Age Borosilicate Glass Layers: Borax as Adhesive for Gold Covers on Mycenaean Vitreous Relief Fragments

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Ancient glass samples from Greece were studied in terms of their chemical composition and the structural variations at the samples surface compared to the bulk glasses using Scanning Electron Microscopy (SEM/EDS), Infrared (IR) and Raman spectroscopy. Chemical analysis confirms that the deep blue colour of the samples is caused by the absorption of Co2+ ions which are dissolved in glass of typical soda-lime-silica composition. Of special interest areoriginal surface modifications in Mycenaean relief fragments from the Late Bronze Age. The vibrational spectra show not only a high degree of polymerization of the surface, but also characteristic bands of borate groups and the spectra resemble closely low alkaline borosilicate glasses such as the technical glass Duran®. Gilding may explain these findings, since the relief fragments were found in a burial context where matching gold plates of the same form were also excavated. Similar gold plated glass fragments are also known from museum collections. The high reactivity of borate with silicates at high temperatures is well-known and the formation of a very thin borosilicate layer (<1 to 10 μm) can be expected when gold is attached at elevated temperatures to a glass while using borax as adhesive. This theory is tested on model glasses which were prepared in the laboratory and were gilded with the help of borax. However, surface modifications can also be caused by weathering. Typical examples include (i) depolymerization due to the attack by water, (ii) polymerization of the leached silicate network in a subsequent condensation step, or (iii) salt formation by the reaction with atmospheric molecules. In most vitreous samples vibrational spectroscopy reflects the nominal glass composition, with a predominance of
266. Prehistoric Pottery from SE Albania: A Compositional and Mineralogical Study

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This work presents an archaeometric study of prehistoric pottery from the Maligrad islet (Great Prespa Lake) and the Vithkuq heights (NW of Korçë), Albania. The strategic position, bearing history of both sites attracted the interest in a Greek-Albanian archaeological cooperation and several excavation campaigns were conducted since 2007, by the Institute for Trans balkanic Cultural Cooperation (ITCC) and the Institute of Archaeology of Tirana. A set of 69 pottery sherds (57 from Maligrad and 12 from Vithkuq), recovered during the excavations, were selected for this study. The sherds date from the Late Bronze Age to the Early Iron Age and belong to either handmade or wheelmade large vessels intended mainly for the storage of foodstuffs. Compositional analyses of minor and trace elements were performed using a radiostotope-induced, Energy-Dissipative X-Ray Fluorescence (EDXRF) spectrosopy arrangement. The EDXRF data were treated statistically by Principal Component Analysis (PCA) and three distinct compositional groups were established. The first group was exclusively composed of potterg sherds from Vithkuq and was clearly isolated in the PCA scatter-plots due to different concentrations of rare earth elements (mainly La and Ce), indicating that the two pottery groups were manufactured using raw materials from different mineralogical deposits and thus represent pottery of different provenance. The sherds from Maligrad were separated in two groups, owing to different concentrations of predominantly alkaline earth elements (Sr, Ba, Ca) and to a lesser extent rare earth elements (La, Ce) suggesting different manufacturing procedures.

A mineralogical investigation by X-Ray Diffractionmetry (XRD) was carried out on selected sherds, considered to be representative of the groups identified by the PCA. The XRD patterns provided additional support to the statistical analyst, as different mineral assemblages were evidenced in sherds from each chemical group. Firing temperatures below 700 °C and up to 900 °C were inferred for different groups, based on the presence of amphibole and illeite mineral phases, respectively.

267. The New AGLAE project: Improvements and applications to Cultural Heritage artefacts

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For more than 20 years, the AGLAE facility has been exclusively dedicated to the study of Cultural Heritage objects in the Louvre premises. Because Cultural Heritage artifacts are unique, sometimes sampling cannot be considered. The conservation state may also prohibit to work under vacuum. For that reason, an extracted beamline has been developed especially for Cultural Heritage objects on the AGLAE facility for 20 years [1]. Multidisciplinary, the New AGLAE project will provide an exceptional and multipurpose beam line with a performance in spatial resolution, beam stability and a capability of multi-particle detection much higher than for the previous facility. One of the objectives is to increase the X-ray measurement detection, enabling to reduce the beam intensity thus the interaction with sensitive artworks by a ten factor. To reach that purpose, the surface and the number of PIXE detectors have been increased. Indeed, a 10 mm2 and a 30 mm2 Si(Li) detectors respectively dedicated to low and high energy measurements, were replaced by five 50 mm2 SDD detectors. If this multi detector enables to decrease the intensity of the incident beam by one order of magnitude thanks to the beam maximum irradiation during the analysis, it can also provide large and/or fast maps. A Digital X-Roy Processor provides both digital data and control signals compatible to a multiparameter multichannel system, which saves each event from EDX, gamma and particle detectors and simultaneously the X, Y positions of the beam on the sample as a list file. Furthermore, to draw several cm-sized maps with a 20/40µm resolution, the scanning of the area originally combines a fast vertical magnetic deflection of the beam and a mechanical movement of the target. To process the data, several homemade softwares have been developed so as to rebuild any matrix of spectra, to re-bin maps and to make quantitative calculation on global spectra or on each pixel of the maps (quantitative maps). The spatial repartition of elements with selected ROIs can be visualized and spectra corresponding to selected pixels directly drawn on a map can be saved. The first images collected on prestigious Cultural Heritage objects made of glass and ceramics will be presented and commented, showing the limits and the perspectives of the technique.

Reference

268. Studying a Luxurious Roman Vessel Glass Collection from Patras, Greece. An Interdisciplinary Characterisation, Use and Provenance Study Using p-XRF, SEM/EDS, RAMAN and IR

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Introduction: During a systematic excavation of a Roman funerary complex at the city of Patras, Achaila, Greece, an assemblage of luxurious glass vessels was recovered all found as placed together in a wooden chest; the assemblage was composed of 16 complete items and 11 glass fragments varying from transparent to translucent colourless, blue, green and purple. Some of the items are considered unique artefacts among the roman production of the Aegean. Here we present the results from the physicochemical examination of the collection by a combination of optical microscopy, p-XRF, SEM/EDS, Raman and infrared (IR) techniques. The analysis’ basic aims were the chemical characterization of the glass, the provenance of basic glass used for the production of the vessels, the study of corrosion processes and, further, the possible use of these glass containers.

Chemical characterization: All samples belong to the general type of soda-lime-silica glass; according to their basic glass composition they belong to the Levantine I type. The alkali source used is natron, with the exception of one sample in which plant-ash is used instead, indicating a different provenance. In the colourless samples, a combination of both antimonate and manganese is introduced as an opacifying agent. The most significant colourants used are iron, manganese, cobalt and copper, combined accordingly in order to achieve blue, green and purple hues. Corrosion Processes: A number of samples demonstrate areas of corrosion patterns. A detailed spectroscopic analysis was carried out on areas of healthy glass to monitor the alterations of the structure of glass caused by corrosion; additionally, corroded areas were scanned by Raman and IR to assist the identification of corrosion products and also to provide information on the use of the
vessels. Use: The examination of colourful crests found attached on some of the glass fragments provided an indication of the vessels’ contents. The chemical analyses have identified so far two types of residues: (a) pink coloured areas showing high aluminium values and high sulfur and potassium that points to an aluminosilicate substance of the alumino- type mineral group, known in antiquity for its astrigency and styptic/haemostatic properties and (b) black spots containing lead and titanium and elevated concentration of calcium that could be some kind of medicinal clay. Conclusions: A holistic study of a luxury glass collection is reported, combining standard non-invasive and advanced spectroscopic methods to tackle questions of material characterization, corrosion, use and provenance of the collection.

269. Local production and long-distance trade: Chemical analysis of Medieval glass beads from Imperial Mali

Lylliam I. Pouadari


Glass excavated in West Africa is often attributed to the trans-Saharan trade or to European maritime trade along the Atlantic coastline. However, chemical compositions from well-provenanced glass artifacts are facilitating an understanding of the extent of imported and recycled West African glass use, as the presence of a West African primary glass production tradition (Lankton et al. 2006). This project explores the chemical composition and microstructure of Medieval glass beads recovered from excavations at Sorotomo, an urban center that dates to the 11th century to the first half of the twentieth century were analyzed by INAA, ICP or XRF. However, even the analysis of ceramic vessels and sherds is still experimental. At present portable or handheld XRF instruments are the only devices for non-destructive elemental analysis of archaeological and museum specimens. Whereas the main difference between obsidian technology ‘sheer mass composition. This is not an issue if powdered ceramic samples are analyzed by INAA, ICP or XRF. However, even partial destruction of archaeological material is getting increasingly restricted in many countries, and is anyway prohibitive for studying artifacts in private and public collections.

In case of obsidian the determination of Rb, Sr, Y, Zr and Nb turned out to be fully sufficient for regional provenancing. In pottery the list of useful discriminative trace elements is even shorter, since Y andNb concentrations are typically at the limit of detection by XRF. Moreover, the analysis of the bulk composition of ceramic bodies is complicated by paints, slips, glazes, use residues, post-depositional modifications (1,2)- and for methodological reasons - by the geometry of the sample surface [3]. As a feasibility study up to 200 sherds each from ten late pottery collections.

270. INAA, PGAA, PIXE and DRX Analyses of Portuguese Glazed Tiles. A contribution for production technology

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Portuguese glazed tiles (azulejos) are one of the most important building and decorative materials of the last four centuries. In this work glazed tiles from seventeenth century to the first half of the twentieth century were studied in an interdisciplinary approach comprising historical and chemical and mineralogical characterization of tile’s glazes and bodies by INAA, PGAA, PIXE and XRD. Chemical results of tile bodies enhance a more diverse firing temperatures, phases, use residues, post-depositional modifications (1,2) - and for methodological reasons - by the geometry of the sample surface [3]. As a feasibility study up to 200 sherds each from ten late
medieval/early modern pottery-making centres located all over Germany were analyzed. Cleaning with water and light brushing was the only surface treatment. Fabric groups covered by the assemblage include grey, yellow and red low-fired earthenware, high-fired grey earthenware, proto-stoneware, stoneware, and the respective misfirings. Intentional surface modifications include Fe-paintings, slip and salt glazes. Admixture of coarse tempering materials was exceptional. Each production centre consisting of one to several workshops had at least the potential for regional distribution. Hence, some kind of standardization in clay sourcing and paste production is assumed, which makes it promising to look for elemental patterns/clusters per site. Obviously some wares, vessel forms, and vessel decorations were highly desired and traded over long distance, but were also made locally or imitated at several sites. It is therefore of interest, whether in an archaeological or a museums context, to assign vessels and vessel fragments without known provenance to their potential production origin.

The sherds were analyzed with a portable XRF instrument, the Bruker Tracer III-SD. An empirical reference set was established using x-ray fluorescence (XRF) spectroscopy, backscattered electron (BSE) imaging and wavelength dispersive spectroscopy (WDS). Additionally, lead isotope ratios were collected using multi-collector ICP-MS to determine variation in use of lead ore sources among potters. Our sample was selected from sherds with good provenence and chronological data excavated during the Animas-La Plata (ALP) Project in Ridges Basin and Blue Mesa, near the modern town of Durango, CO. Results show a pattern of traits involving raw materials, processing, properties and performance of the final product suggesting the existence of a patterned technological behavior.

Previous research from the ALP Project suggests that during the Pueblo I period, people with different cultural histories came together in the first attempts at village formation in the Upper San Juan. Our technological reconstruction and provenance analysis has the potential to provide important information regarding relationships and interactions of potters and their role in negotiating differences among the various groups who were living in the Upper San Juan at that time.
275. Local Production vs. Importation of Ceramics in Late Bronze Age Sicily: Non-Destructive Elemental Analysis Using pXRF

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By the Late Bronze Age in Sicily and the Mediterranean overall, long distance exchange was well established as proven by materials such as copper oxide ingots, amber, glass, ivory, and both decorated pottery and ceramic transport vessels. At some sites in the Mediterranean, the large quantity of Mycenaean-style ceramics suggests the existence of established commercial routes with the Aegean. Similarly, Maltese-style ceramics have also been found in this region. Regular maritime connections were an important feature of the Bronze Age central Mediterranean. In this study, non-destructive elemental analysis was performed on ceramics from both the Museo Archeologico Regionale Paolo Orsi in Siracusa and the Museo Civico in Milano. Specifically, a portable Bruker III-SD X-ray fluorescence spectrometer (pXRF) was used with filter, voltage and amperage settings chosen to enhance results for trace elements Rb, Sr, Y, Zr, and Nb, as well as major elements including Fe. Multiple spot analyses, for 120 seconds each, were performed on each ceramic object, with painted areas avoided. More than 30 vessels from the Paolo Orsi museum were tested, including 15 from the cemetery of Thapsos, and 40 from the Milano museum, in an attempt to distinguish elemental signatures in these geologically distinct areas and provide the circulation of ceramics in the region non-destructively. Analyses were also conducted on painted areas of the decorated vessels, using a vacuum and no filter, to identify the types of paint being used. We report on the identification of local vs. imported wares, and possible imitations. The use of a non-destructive instrument permitted the analysis of otherwise inaccessible materials and provided results that can be combined with studies of other classes of materials, providing the opportunity for low cost multi-disciplinary research on ancient trade.

Finally, we report on a separate test of a set of Neolithic ceramic idols that are stylistically similar to the paintings in the Grotta di Genovese on Levanzo in the Egadi Islands, off the coast of Sicily, which provides a small case study of a multi-disciplinary science-led research project.

276. Studying Ceramic Production and Trade in the Gamo Caste System in Southwestern Ethiopia

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More than 240 ceramic artifacts from 11 archaeological sites in southwestern Ethiopia were tested for pottery studying and the socioeconomic characteristics of the Gamo caste system which still exists today, and their precursors. Potters generally produce pots for people in their own community and thus the chemical composition of ceramic artifacts should be homogeneous in communities with resident potters, allowing us to identify the presence of certain groups. Prior to the development of the caste system, a greater range of clay source usage was likely, since there was not the establishment of the patron-client system between potters and farmers. The ceramic jars, bowls, and plates tested in this study come from both historic Gamo sites, dating back at least several hundred years, and prehistoric cave sites dating back to about 2000 BP. To support our identification of different pottery source groups, nearly 40 clay samples were also collected from Gujda, Ochollo Lante, Chilile Fagna and Borada. These vary some in their color, and come from different highland regions. Ethiopian Antiquity regulations forbid the export of artifacts, so it was necessary to use a portable X-ray fluorescence spectrometer to conduct all analyses while in Ethiopia. A Bruker III-pXRF was used, with the same filter, voltage and amperage settings for other ceramic research projects, providing quantitative data for elements including Fe, Rb, Sr, Y, Zr, and Nb. Along with visual assessment of the pottery sherds, we attempt to identify the number of different ceramic production areas utilized in this region of Ethiopia. Our scientific analyses of ceramic artifacts thus may provide important information about socioeconomic practices in southwestern Ethiopia, including the identification of craft specialization, the association between material variability and individual and group identities, and the formation of complex societies like the caste system.

277. Glass of the Volga Bulgaria Towns.*

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All Volga Bulgaria towns have rich collection of medieval glass; these materials were derived from expedition studies, and hence stratified and provided with archaeological context. It is particularly important that numerous Islamic glass imports was accompanied by imports of the Middle Eastern pottery, from the early Abbasid luster to minai, Islamic luster, laddihrvand, etc. Peculiar chronological rasper is a “closed” complex - the pre-Mongol capital Biljary - not revived after Mongol devastation of 1236. Among the abundance of imported oriental products, including highly artistic wares, especially ones of the second half of the 12th -first third of the 13th cc, in Biljary as well as in other destroyed and not restored towns, there was no vessel painted with enamel and gold. These wares include lumps, glasses, cups, bottles were an integral part of urban culture of Bolgar, which had been the capital of Volga Bulgaria from the middle of the 13th to the early 15th cc.

Morphological and stylistic characteristics of the products are accompanied by data on the chemical composition of the glass. The chemical composition was determined using X-ray analysis (analyst: B. Gareev, G. Batalin) and scanning electron microscopy (analyst: A. Trifonov). Studies were carried out on an auto-emission scanning electron microscope Merlin. Microscope is combined with spectrometer of energy dispersion INCA X-MAX. Resolution of the spectrometer is 127 eV, Detection limit is 1500-2000 ppm. Measurement accuracy is 0.01-1 %, depending on the state of the investigated object. Shooting of the surface morphology was carried out at an accelerating voltage of 5 keV to increase the depth of field of the image. The analysis was performed at an accelerating voltage of 20 keV and the working interval of 9 mm, to avoid the minimal errors. Probing depth is less than 1 micron. Scanning electron microscopy has been particularly useful in the analysis of polychrome enamel painting on glass wares and mirror, all the elements responsible for enamel colors were determined as well as the sequence of applying the decor. Also, this method has been proven to be indispensable in
Includes materials of the key monuments of the Bilyarsk micro region within 25 km: ceramic samples from Proto-Hungarian burials of Bolshie Tigny of the 9-early 10th c., pottery and raw clay from the pottery workshop in the center of the capital Bilyar of the 10-early 11th c., ceramics and clay of Bulumur town (Torezkoye) of the 15th c.

Application of Mössbauer spectroscopy (MS) on the 57Fe nuclei is determined by the fact that the shape of the Mössbauer spectra of ceramic samples may be associated with the procedure firing, which can be determined by transformation and/or absence of certain iron-containing component present in the spectra of the feedstock at room temperature.

For the production of the studied samples used local red and grey clays. The minerogenic composition of the clay according to X-ray structural analysis is typical of Quaternary loams and are the main component of clay minerals, which are widely distributed in the structure, representation by a combination of different types of non-swelling and swelling layers. MS spectra of red clay is typical for clays of mainly montmorillonite composition, which are characterized by the presence in the interlayer space of iron oxides. Gray clays are mainly hydromica composition, characterized by a lack of iron oxides associated, apparently, with a significantly lower interlayer capacitance of hydromicas. Parameters MS spectrum of gray clay are almost identical for MS spectra of monomineral illite (Murad, Wagner). Clays significantly differ in content in the structure of iron ions Fe+2, less than 10% in the red and over 20% in the grey clay.

Samples of ceramics from all three monuments inherit these structural features of clays and are divided into groups containing and not containing the following oxides of iron and, consequently, small and large content of ferrous iron, which indicates a relatively low (up to 400°C) firing temperature. At the same time there was a trend increasing firing temperature samples Mature and late Middle Ages.

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279. Chemical Composition of the Early Hungarian Rings from Bolshie Tigny Burial*.

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Bolshie Tigny burial of the 9-10 c., the largest in Eastern Europe Early Hungarian monumnet, was discovered and investigated by archaeological expedition of the Kazan State University in 1974 -1986 (heads - E.A.Hakilova, A.H.Hakilov). For several decades, one of the main problem of interpretation of materials from this burial as well as from other monuments of its circle, has been the problem of determining the production base which provided richly material nature of artifacts of nomads, proto-Hungarians.

High quality of art products indicates the urban nature of the craft. At the same time, the study of funeral inventory only on the basis of morphological features does not allow the projection of this material to a specific craft center(s).

Pilot analyzes series of glass jewelry, textiles, silverware, with use of scientific methods showed the prospects of this direction of research, which can be determined by the fact of the shape of the nuclei is determined by the fact that the shape of the Mössbauer spectra of ceramic samples may be associated with the procedure firing, which can be determined by transformation and/or absence of certain iron-containing component present in the spectra of the feedstock at room temperature.

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References


280. Clay Chemistry and Mineralogy in Florida and Georgia: Implications for Pottery Provenance

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Stylistic and typological attributes of Pre-Columbian Native American pottery in Florida and southern Georgia indicate that vessels may have been widely transported during every cultural historical period in which they were produced. Yet provenance studies of pottery have sometimes proved difficult due to the lithology of the southern coastal plain. Clays across the region are expected to be fairly homogenous in terms of chemical and mineralogical composition, owing to derivation of sediments largely from the same Appalachian protolith. However, subtle, patterned regional scale variations do exist and have been the basis for successful identification of pottery provenance over the last two decades. This research investigates the bulk chemistry and mineralogy of raw clays taken from deposits throughout the Florida peninsula and southern and central Georgia, and considers their potential for informing pottery provenance studies. Collected over the span of many distinct projects, 297 unique clay samples from Florida and Georgia were curated at the Florida Museum of Natural History. Of these, 74 clay samples have so far been analyzed by NAA. The results reveal broad geographic trends that are significant for provenance research. Many of the 33 elements measured by NAA (particularly the transition metals) are positively correlated with latitude, becoming increasingly enriched toward the north, which is closer to the Appalachian protolith. In contrast, Ca and Sr are enriched toward the south and likely correspond with closer proximity to the underlying limestone platform. Other elements show distinctive enrichment within single sub-regions, such as Fe on the Atlantic coast, Sb in Tampa, and Ba in southwest Georgia.

Several dozen clays also have been subjected to petrographic analysis and add another dimension of spatial variability, primarily in terms of the presence and frequency of mica and silicous microfossils such as diatoms and sponge spicules. The broad geographic patterning among clay samples supports several identified cases of pottery transport: Orange fiber-tempered pottery (ca. 3400 to 1900 cal B.C.) transported between Southwest Florida and central Georgia, Orange fiber-tempered pottery (ca. 2000 to 1900 cal B.C.) transported between Southwest Florida and southern Alabama, and Orange fiber-tempered pottery (ca. 1250 to 1160 cal B.C.) transported between Southwest Florida and southern Georgia.

281. The rectification of name of Proto-celadon – Discussion on the origin of celadon also
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It is difficult to understand there are no scientific definitions for pottery, proto-celadon and celadon or porcelain. The definition for pottery is relative simple, so it was not discussed here. It is easy to be found that the definition of proto-celadon was the outcome of concessions from different ideas in 1971. Display of Chinese Cultural Relics would plan to hold in France, some glazed ceramics wares excavated from Zhengzhou Shang City site were selected as exhibits on the display. How to name these wares? There were two entirely different opinions. Prof. Jinhuai An, the explorer of these wares, named them “celadon wares”, but Prof. Vadim Eliseev, the organizer of this display, Russia with France nationality, considered they are glazed pottery. Prof. Moruo Guo, the director of Chinese Academy of Sciences, invited some famous historians and Geologists to discuss the name for these wares. At last, Prof. Guo realized that it was impossible to get the same name, so he suggested a compromise name called “proto-celadon”, which became a popular name since then. In 1978, Prof. Jiashi Li published his paper “Study of the appearing period of Chinese celadon” on Journal of the Chinese Ceramic Society, and gave a talk on a national conference on ancient Chinese ceramics and kilns. He introduced the measuring data of ceramics sherd HS excavated from Shangyu city, Zhejiang province, that the original firing temperature is 1310°C, with Fe content of 1.64 %. According these data, he told us that the sherd HS is up to celadon standard, and the Chinese celadon originated in late Han dynasty. The original firing temperatures of all celadon samples were statistically analyzed. The firing temperature of sherd HS is much higher than them of others from Yue kilns, and is the highest in all of Chinese celadon. It is entirely wrong, despite some experts in ancient ceramics and science circles supported Prof. Jiashi Li’s proposal. It is necessary to define the celadon standard. After seriously considering, the new celadon standards were suggested as follows. First, the body material of celadon should be kaolin or bentonit clay, which is probably a kind of kaolin no fully weathering. Second, there should be glaze on the body, which was produced under high temperature. Third, its firing temperature should higher than 1150°C, which is higher than that of changing to glass state and forming the primary milite. According to these new standards of celadon, so-called proto-celadon absolutely satisfied these standards, so it should be called celadon, not proto-celadon. Chinese celadon should originate in Xia-Shang dynasties at the latest, not late Han dynasty.

282. Preliminary Scientific Analysis of Iron Age Glass Beads from Chiuhsianglan, Taiwan
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Glass beads are thought to be luxury items in Iron Age Taiwan, being imported from South East Asia through the exchange network around the South China Sea. Chiuhsianglan (CHL, 3rd century BC - 7th century AD) is a site located in eastern coastal Taiwan, and the excavation in 2004 revealed thousands of finished glass beads and a small amount of glass residue thought to be associated with glass beadmaking. The finished glass beads recovered resemble Indo-Pacific beads from contemporary South East Asia. Forty-five samples, including some of the glass residues and finished beads, were selected for scientific investigation. Microscopic observation suggests most of the glass beads were made by the drawn method, like other examples in south East Asia. However, the beadmaking evidence from CHL suggests the possibility of the use of the wound method of bead production instead of the drawn method.

This study reports the preliminary study of the chemical composition of glass beads from prehistoric Taiwan, using SEM-EDS, in an attempt to understand the connection between the beads from this site and others in South East Asia in this period. The first results suggest the presence of m-Na-Al glass and the use of copper oxide and lead tin oxide as colourants in the beads and the glass waste. This is consistent with the South East Asian tradition of using mineral soda as a flux in glass production, and therefore may point to a South East Asian origin for the CHL beads. However, analysis of some of the glass residues reveals a slightly different composition that does not match the composition of the beads analysed. The different compositions and the different methods of production suggest that the waste and fully formed beads may not have the same origin (and that the fully formed beads may be imported). Further investigation is required in order to obtain a more complete picture and a better understanding of the production and consumption of beads at this site and others in Taiwan, and this is now in progress.

283. The Composition and Manufacture of the Glass Beads from Balikun Site Xinjiang China
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The Balikun is an Iron Age site located in the northern foot of the Tianshan Mountains, east part of Xinjiang area. The site is located on the northern route of the Silk Road, and on the boundary between Agriculture and Nomadic civilizations. 15 glass beads excavated from a high status tomb of the Balikun site in 2012. The study focused on the techniques and provenance of these glass beads. The chemical composition analysis and the manufacturing trace analysis include XRF, LA-ICP-MS and Microscope were used in this study. The results show that these beads are soda-lime glass. It is quite different with the most glasses found in central part of China which mostly BeO-BaO or potassium glass. However, the chemical significance of Balikun glasses is close to Mesopotamian and Central Asian glasses at the same period. The complicated traces observed on the surfaces of the glass beads include parallel polishing lines, irregular grooving lines and weathered traces. Every single bead is with a central through hole but the diameters of the holes are inconsequent. The analyses results suggest that these glass beads came from the west. The route connects the Central Asia and Eastern Xinjiang had been built up no later than 200 BCE. The multi-techniques applied on these beads indicate drilling, coloring and polishing. The matured bead quickly spread from the West to the East indicates that the fine glass beads and glass beads with other materials were popular in 2000 years ago and the Balikun was the one of the main spot to connect north and south Tianshan Mountains.
284. Etruscan Trade Networks: Ceramic Sourcing without Sampling using pXRF Spectrometry

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The Etruscan civilization was rich in local and interregional trade. Its exchange networks were vital in establishing relationships with other societies, importing exotic materials and products, as well as disseminating and assimilating information. But how extensive were the trade networks established by the Etruscans? Were they limited only to the coastal cities such as Populonia, Tarquinia, and Caere or extend throughout Etruria, reaching even the most remote regions? Discovering imported material artifacts in remote settlements throughout Etruria adds to the significant impact placed on interregional and international trade.

Etruscan sites in the Tuscan region of Italy are being studied today to understand not only their culture, but also their relationship with other societies. In 2013, non-destructive elemental analysis was performed on ceramics from the excavated sites of La Piana and Cetamura, two smaller settlements in the rural regions of Etruria. Based on the clay type and elemental composition, these analyses are used to determine whether the ceramics were locally crafted or imported.

More than 100 ceramics ranging from storage containers, bricks and roofing tiles, amphorae, loom weights, and tableware (including red and black gloss) from Cetamura, La Piana and Tarquinia were selected to represent a tableware (including red and black gloss) from Cetamura, two smaller excavated sites of La Piana and Cetamura, two smaller settlements in the rural regions of Etruria. Based on the clay type and elemental composition, these analyses are used to determine whether the ceramics were locally crafted or imported.

285. Analytical study of Achaemenid Glazed Bricks of Persepolis by multiple instrumental analysis methods

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Achaemenid glazed bricks of Persepolis, studied by multiple Instrumental chemical analysis methods such as scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS), X-ray florescence (XRF) and laser ablation inductively coupled plasma - optical emission spectroscopy (ICP-OES). The colors of the glaze samples was almost faded because of corrosion mechanisms during thousands of years, microscopic studies which has been done on the white substrate of glaze layer of bricks shows blue areas. The colorant elements of glaze samples were almost faded because of corrosion mechanisms during thousands of years, microscopic studies which has been done on the white substrate of glaze layer of bricks shows blue areas. The colorant elements of glaze samples were almost faded because of corrosion mechanisms during thousands of years, microscopic studies which has been done on the white substrate of glaze layer of bricks shows blue areas.

286. Investigation of early Chinese Faience

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This paper will concentrate on the composition and structure of early Chinese faience formed distinct groups based on the composition of the glass phase and glaze present:

- Tubular and rounded beads from Shanxi, Middle West Zhou, 10th century BCE: soda glass with low potash and very low calcium.
- Rhomboidal and tubular beads from Shaanxi, Middle West Zhou, 10th century BCE: potash glass with high calcium and very low calcium.
- Tubular and ring beads from Shanxi, later West Zhou, 9th to 8th century BCE: potash glass with high calcium and very low calcium.
- Funerary and building bricks from Gansu and Inner Mongolia, Late Shang to Early Western Zhou, 12th to 10th century BCE: soda glass with high potash and very low calcium.

Metals and Metallurgical Ceramics

287. The role of brass, and its use as surface plating of copper alloys

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The paper outlines a number of surface plating techniques identified on copper alloy objects from Danish museums. The emphasis is on unusual techniques as high tin bronze in the Bronze Age to brass plating on bronze objects from the Roman Iron Age.
Examinations of Roman officers belts from the sacrificial offerings in Nydam and Ejsbøl indicate that brass was perceived as what can best be described as a kind of semi precious metal. In the belt of the highest ranking officer fittings made from solid brass was used alongside silver and silver-gilt plateings. On a less prestigious belt only rivet heads were silver plated, and brass was used only as plating on bronze fittings. On a belt signifying an even lower rank, brass was only seen as occasional rivets, probably made from pieces of scrap.

The perception of the use of brass as a status indicator is confirmed by brooches from of burial finds dated to the Roman Iron Age. As a rule a woman was in possession of two brooches made at the same time and probably cast from the same crucibles as the compositions are often identical. The brooches are often, but not always of the same type. Looking at a larger number of graves, one type of brooch could be made from a wide variety of alloys including brass. Brass brooches were primarily found in graves in which the presence of silver brooches or tutaful brooches signified the high social status of the buried.

288. Biringuccio-style casting, hessian crucibles and alchemy - Casting of copper alloys and traces of alchemy in medieval and renaissance Denmark

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Findings from Danish excavations has recently shown two different technologies used for casting of copper alloys in the 15th century. From Elsinore, Copenhagen, Ribe and other places, fragments of imported, probably hessian, crucibles are known. Often used for the casting of tin-bronze or leaded tin-bronze. Opposed to these highly refractory crucibles stands a number of apparently very different technologies used for casting of copper alloys with arsenic is known to have been used in connection with alchemy, and the finds were made not far from the place where Sophie Brahe, sister of the astronomer Tycho Brahe, lived in Elsinore. As one of the most learned women of her time, she is known to have been dealing with both astronomy and alchemy.

289. Counting hammerscale - The systematic sampling of workshop remains, developments in methods and results

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During the last years, the application of new systematic sampling strategies and chemical analysis has made it possible to obtain detailed information about the layout and function of excavated workshops. The physical distribution of slag, hammerscale, charcoal vitrified clay and other types of debris from ironworking can yield information about the structure of the Smithy and the organization of the work within it, whereas the chemical characteristics of slag, hammerscale and slag spheres will tell about the processes used in the workshop. The work of the blacksmith consisted basically of three different processes: cleaning of bloom iron, welding together pieces of iron and/or steel and the forming of the object. Although superficially similar, the hammerscale from these processes will have different chemical composition. It is therefore possible, on the basis of chemical analysis, to establish which processes took place within a given workshop.

Analyses of excavated workshops have shown that they can be divided into different categories. One type only showed slight signs of bloom-cleaning and welding. They probably represented farm-smithies where simple tools and fittings were made from available pieces of iron. Other workshops was somewhat more advanced, employing both the bloom cleaning and the smiting of finished objects, although not using welding to any significant extend. A third type of workshop seemingly produced more advanced tools or weapons needing the welding of pieces of iron or steel. Apparently the raw material for these smithies was bar iron, as they only occasionally performed the cleaning of bronze or leaded tin-bronze. High amounts of arsenic was identified. The silvery colouring of copper alloys with arsenic is known to have been used in connection with alchemy, and the finds were made not far from the place where Sophie Brahe, sister of the astronomer Tycho Brahe, lived in Elsinore. As one of the most learned women of her time, she is known to have been dealing with both astronomy and alchemy.

291. Han Dynasty metal production in Southeastern China: copper smelting and bloomery iron

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The area of Daye county in Hubei province has long been an important region of metal production due to its mineral richness. As a matter of fact, the copper mine of Tonglushan is "undoubtedly the biggest and the one with longest service life" with activities well documented for the Spring and Autumn period (4th century B.C.) and currently still under exploitation. Notwithstanding its historical relevance, only scant archaeometric research has been devoted to the smelting furnaces and slag of Tonglushan. Moreover, the area around Tonglushan contains several ancient copper and iron smelting sites - some with tonnages of metallurgical residues and evidence of prolonged settlements - that remain unstudied.

The nature, scale and chronology of these archaeological sites is quite diverse. However, fieldwork directed by Professor Li Yangxian since 1993 has identified some patterns concerning the metallurgical remains: first, the slag is often associated to fragments of domestic pottery typical of the Han Dynasty; second, when this is the case, and in contrast with the heterogeneity of waste products seen in earlier metallurgical sites, there are two standardised slag types: a bulbous flow slag and an even platy slag. Technical materials -namely slag and furnace wall- were surface-collected from 11 sites within 40 kilometers around Tonglushan, 9 of them conforming to the above pattern. The analysis of the waste products (by OM, EPMA, X-ray fluorescence) reveals that the flow slag exhibits a microstructure dominated by angular crystals of fayalite and iron oxides (magnetite, wüstite), few copper prills, scant sulphides, and occasionally large inclusions of iron rich minerals (possibly hematite). The second type presents with a very lean matrix containing laths of fayalite, dendiric wüstite and few metallic iron particles. The first group is clearly related to the primary smelting of copper whereas the second one likely corresponds to bloomery iron slag.

Some preliminary observations are presented from the ongoing investigation concerning the technological aspects of metal production: first, the possibility that copper and iron smelting may have been taking place simultaneously; second, the possibility that the standardised waste products may be indicative of a single "Han method" of production; and lastly, the identification of bloomery iron during the Han Period, which was so far absent in China.
Furnace construction material plays a key role in metallurgical processing, such as maintaining the furnace structure stability, providing silicate materials into the slag and maintaining the high temperature in the furnace. Though ancient furnaces have been found throughout China, only a few of these sites have been studied in detail. In order to promote a systematic study on furnace material, samples from 4 sites, located in different regions and periods, were collected. The aim of the research is to understand the material features, the source of raw materials, the fabrication technology and their functions; this approach allows a better understanding of the various stages of technological development. Through this study, microstructure, chemical composition, physical properties and heat processing of the furnace material were tested. This work showed that the smelting furnace material developed from simple clay material to stone and clay in a co-existing structure. The simple clay furnace originated directly from copper furnace design. The co-existing stone and clay structure developed because of a need to keep structural stability, while the clay furnace lining provided refractory and sacrificial material during longer operating times of the smelting furnace. Moreover, as sacrificial material, the clay provides enough Na2O, Al2O3, and SiO2 into slags. The results also showed that raw materials were mostly locally collected. In the early period, clay processing was much more complicated, it was first sieved, the silt material was collected, sized quartz sand as well as fiber material were added, and the final clay material was shaped in the furnace. In the late period, unprocessed clay was used directly for furnace construction. During the earliest period of development, the melting furnace material was as the same as that of smelting furnace material. However, the traditional melting furnace was supposed to be replaced by the crucible method in the late period.

Key words: Furnace material, Refractory material, Blast furnace, Cast iron, Shiquangou site, Dengping site, Quqcheng site, Jiudian site.

294. Revisiting Free Silica Slag

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‘Free Silica’ slag is defined as a type of metallurgical slag which bears numerous unreacted inclusions. This slag type is most commonly associated to copper or lead/silver smelting processes, and has been found widely around the Mediterranean, the Alps and north China, spanning a very long chronological range. In spite of the frequent occurrence of this slag type, there is not as yet a convincing interpretation regarding the specific role these unreacted fragments played in the ancient metal production process.

Our research attempts to test two new hypotheses on the phenomenon based on data from two case studies and a series of experimental reconstructions. The first case concerns copper smelting during the Late Bronze Age within the Austrian Alps: the most common slag type consists of lumpy round cakes of typical porous fayalitic furnace slag with inverse aggregation of bulky (~1-3 cm) chunks of quartz. The second case regards to lead/silver smelting found in north China, dated between 12th and 13th century: cylindrical crucibles with a diameter of 7-10 cm were used in this site as reaction containers. The lime-rich slag that fills the crucibles contains approximately 20% (in volume) quartz fragments of various sizes (several millimeters to 3 cm). Our working theory is that the free silica fragments may have been able to influence kinetics of smelting system in two different ways, and that their role in the specific system was determined by temperature. In the Alpine copper smelting case, gangue quartz fragments entering the furnace charge through a non-extensive beneficiation system was determined by temperature. In the Alpine Alps: the most common slag type consists of lumpy round cakes of typical porous fayalitic furnace slag with inverse aggregation of bulky (~1-3 cm) chunks of quartz.

In the Chinese case, silica fragments were used to prevent the draining of matte. Here, metallic iron was used as a reducer to combine with sulphur and release lead and silver from the sulphide ore. However, as PbS, Ag2S and FeS can form a silver-rich eutectic melt, there is a high risk that the liquid sulphide will drain before metallic iron has time to replace any Pb and Ag. Free silica fragments increased the viscosity of the slag and prevented the separation between matte and slag in an early stage of the process. Temperature in this case had to be increased quickly in order to form liquid slag. A series of experiments were designed to test these two theories seeking new arguments to enhance our understanding about this long lasting enigmatic problem.

295. CHAVIN CULTURE METAL VESSEL: DETERMINATION OF ELEMENTAL COMPOSITION AND THICKNESS OF MULTILAYER BY PORTABLE ENERGY DISPERSIVE X-RAY FLUORESCENCE (PXRF)

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A Pre-Columbian metal vessel belonging to the collection of Enrico Poli Museum in Lima was analyzed with a portable X-Ray Fluorescence (PXRF) system. This vessel is supposed to be from the Chavin culture, which flourished in the North of Peru in the period 1200-200 B.C. Through the analysis it was deduced that this artifact is composed of silver alloy Tumbaga (Ag-Au-Cu) enriched on gold at the surface by chemical process defined “depletion gilding”. This process was widely used by pre-Hispanic cultures to enrich gold on the surface of poor gold objects. After silver or copper are heated, they oxidize in the alloy and tend to come out leaving the surface with a dark shade, leaving oxides on the surface which is removed with acid solutions obtained from plants. After that, a thin layer of gold remains on the surface, that decreases continuously with the depth. At the end, the piece is then polished up leaving it with the final desired golden appearance. A portable X-Ray Fluorescence (PXRF) system was employed, composed of a Si-drift detector with a thickness of approximately 500 μm, an active area of 7 mm2 and a Be-window with 12.5 μm thickness. An Ag-anode X-ray tube was also employed, working at 40 kV and 100 μA maximum with a 5-mm diameter beam. Standards samples of gold, silver and copper were employed for calibration and quantitative analysis. Au, Ag, Cu and Pb were detected in the various analyzed areas of the vessel. Following average concentration was calculated: Au (6.0 ± 1.1), Ag (91.9 ± 0.3), Cu (1.9 ± 0.3). The Ag-thickness determination was performed using the methodology of the altered differential attenuation of Silver (Ka / Kβ) and...
A three-stage process of iron production involving ore smelting, iron refining, and iron smithing processes has ethnographically been documented in eastern and central Africa (cf. Greig 1937, Chaplin 1961, Fagan 1962). Macroskopically, site remains of the three-stage process in Tanzania were initially examined in 1990s (cf. Mapunda 1995, 2010). Until recently, the presence of this tradition had not been accepted archaeometallurgically. This paper examines the chemistry and mineralogy of slags from the three stages, with the view to discuss (technical) efficiency and nature of the final products of the three-stage process. This unique tradition produced high carbon steel, as evidenced by the presence of iron droplets in the slags of the second refining stage (cf. Tholander 1989). It is imperative that we stop overlooking this tradition, in order to verify the presence of this tradition elsewhere especially where it has ethnographically been documented.

References

297. Preliminarily Investigation of the Sri Lankan Copper-alloy Statues
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Sri Lankan works of art are generally attributed to one of four historical major periods: Anuradhapura (ca. 269 B.C–993 A.D.), Polonnaruwa (993–1235), Divided Kingdoms (1235–1342) and Kingdom of Kandy (1342–1815). In this technical study, twenty-eight copper-alloy statues in The Metropolitan Museum of Art and four belonging to the Archaeological Department of Sri Lanka, representing all four major historic periods, were investigated. Methods including the examination of the works under magnification and X-ray radiography, elemental analysis using X-ray fluorescence spectroscopy, and metallography were employed to characterize their manufacture, composition, and condition.

The close investigation of the figures demonstrates that they were cast using lost-wax techniques. Radiographs indicate that armatures varying in thickness, size, and shape are present inside the hollow figures, sometimes despite their small size. The casting method used seems inefficient, in particular at least one further stage. Most of the small seated figures are solid cast, but several are hollow. Generally, metal of low porosity and few casting defects are observed in most of the radiographs, indicating that the castings are generally of good quality. Traces of five gates (or vents) were observed on the backs of a group of five Lokapala figures examined, indicating that they were cast face-down in a horizontal position. Ten figures, particularly those later in date, bear traces of gilding or intact gold layers. In all but one case, gold was found in association with mercury, confirming that they were amalgam gilded. Metallurgical studies were carried out on the four figures: a Buddha, a Bodhisattva and two Hindu deities. All four have different microstructures, reflecting dissimilarities in composition, thermal history, and state of preservation. A sample from a tang that was cast-onto a goddess figure in antiquity proved to be a quenched high-tin bronze, as evident from its microstructure; a tin content of 24.8 wt% was confirmed using X-ray energy dispersive spectroscopy in a scanning electron microscope. The Buddhist bronzes of the Anuradhapura period represent a highlight of Sri Lankan metal statuary and in particular warrant much more attention, including quantitative analyses, studies of microstructures, investigating the presence and types of armatures, evaluating the quality of the castings, looking into the beginnings of gilding.

298. Metals and Alloys from the San Pedro de Atacama Region, Northern Chile: A Multi-Approach Perspective
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Studies on ancient technologies cover the entire range of production, manufacturing and use of objects and materials, as well as the analytical techniques and the scientific principles that underpin them. Methods derived from physics, chemistry, biology, biochemistry, earth sciences, material science, mathematics, statistics, and computing, are used to enlighten specific questions from archaeological and historical data-sets. Important insights can be gained by applying and integrating an appropriate variety of methods to archaeological research and interpretation. Archaeological science has an array of methodological approaches at its disposal. In addition to fieldwork data, artificial studies, experimental approaches and archaeological techniques, this endeavor often draws upon mathematical modeling.

The present paper presents the general results of a systematic study of the archaeometallurgy of copper in the Atacama region, which involved documentation and quantification of 80 already excavated artifacts, from the Archaeological Museum in San Pedro de Atacama, as well as collection of copper-rich mineral samples from different mining locations in the Atacama region. Different categories of artifacts including implements such as axes, maces, chisels, and tweezers, as well as adornments which include pins and metal discs, have been recovered from funerary contexts of thirteen small agricultural oases of San Pedro. Results of scientific analysis of these materials have enabled us to characterize the different elements present in the metal objects. Further qualitative and quantitative data analyses provide important information on the nature of the raw materials used.

299. Perspectives for Isotopic Analysis of Copper Alloys: the case of the Late Bronze Age city of Nuzu
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The importance of isotopic studies in archaeometallurgy does not need to be emphasized: since many decades, Lead isotopes have been used to distinguish different metal sources (Brill & Wampler 1967). By the combination of Pb isotope ratios and trace elements analysis it became possible to relate with high probability metal artifacts to specific ore deposits, however significant overlaps exist between different areas (Gale & Stos-Gale 1982, Yener et al. 1991, Stos-Gale et al. 1997, Rehren & Perrick 2008). The advent of ICP-MS instrument has made possible precise and accurate measurements of isotope ratios of other metals of archaeological interest for provenancing, such as Copper and the newly developed Antimony (Lobo et al., 2012). Since differences in Cu and Sb isotopic composition of different ores exist, and can be used to distinguish the type of ore used in metallurgical or pyrotechnical processes, their application in combination with Pb offers new perspectives to differentiate between different groups of artifacts and metal sources (Asael et al. 2009, Klein et al. 2009, Gale et al. 1999).

In a further step to reconstruct the trade of Copper in the ancient Near East, the present paper focuses on the applicability of a combined isotopic approach to trace the...
300. ADVANCE RESULTS OF ARCHEOMETRY INVESTIGATIONS ABOUT A TREASURE FROM BODROGOLASZI, HUNGARY

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The treasure from Bodrogolaszi (Borsod-Abauj-Zemplén County, Hungary) is one of the most significant finds, which can be dated to the 15th-16th century. Unfortunately only 72 coins remained from the original 200, but it was a huge wealth in those centuries, and it’s worth big today too. In my study I’d like to present the site, circumstances of finding the treasure, and also a short numeric introduction about these coins. The site is floodplain covered by Holocene sediment from the Bodrog River. Farmhands found the treasure in 1990. Unfortunately there weren’t any other artifacts, so we don’t know those coins were in a box, in a pot or in something else. My mentors and I used stereomicroscopy to investigate the surface of coins, searching for additional artificial interventions (breaking, cutting, and filling). During the analysis of images about cut and broken surfaces, we discovered dark reddish-brownish spots on several coins. We applied RAMAN-spectroscopy to find the origin of spots. Results revealed those spots are parts of a limonite-goethite covering layer from the soil. XRF measurements were used to prove, that the fineness is different from historical data (98.9 % was the prescribed fineness). Our measurements gave a different average (97.8 %). We also could separate four groups and a subgroup, and found trends within the treasure based on fineness values. Silver and copper values correlate to gold, so we didn’t need to revise groups. Only the subgroup (2/a) is enriched with copper. At last I tried to localize the provenance of the gold material. That’s the hardest part of our research, because the high fineness, useful artificial enrichment processes and the widespread reuse of older artifacts. Against all difficulties, we compared XRF values to the location of issues. Silver-rich coins are from Transylvania (Nagybánya and Nagycsoben), but copper enrichment were in Austria and several of its individual provinces, such as Salzburg and Carinthia.

Although, we applied several scientific methods during our investigations, we need more measurements to answer all of our questions, especially about the provenance of materials.

301. Ready, Aim, Fire! The applicability of hand held portable XRF to the characterization of heterogenous archaeological metals

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Characterisation of bulk alloy composition of archaeological copper alloys is important for studies that investigate innovation and technological changes in past communities. The ease of data collection using modern hand held portable X-Ray Fluorescence (HIPXRF) and the non-destructive nature of the technique has drastically increased its use in heritage science. In the recent past this has led to debates in conservation and archaeological literature. Modern HIPXRF technology is sometimes marketed as requiring little from the analyst other than to ‘point and shoot’, yet analysis of archaeological metals - often heterogeneous even before corrosion has begun - present significant challenges. The impact of physical and chemical matrix effects on the analysis of archaeological metals has been studied in-depth predominantly on bench top XRF equipment. Comparatively little study has been undertaken on the methodological challenges and opportunities presented by HIPXRF employed on the surface of archaeological copper alloys.

This paper builds upon results from the experimental corrosion of reference alloys with the analysis of an archaeological assemblage of 736 early Anglo-Saxon copper alloy objects from three cemeteries in Erriwell, Suffolk, UK. These results are used as a case study to discuss the applicability and limits of the technique with an assessment of the margin of error that can produce an effective archaeological interpretation. The requirements of compositional statistics and problems concerning the comparison of HIPXRF data with that acquired using different techniques will also be examined. The paper contributes to continuing discussions on the role of HIPXRF and qualitative analysis of heterogeneous archaeological non-ferrous metals.

302. Metal Rivets in Norse Antler Comb Manufacture at Bornais, South Uist, Western Isles of Scotland

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This paper discusses the development of a research project on antler comb production from 9th-12th Century AD at the Norse site of Bornais, South Uist, Western Isles of Scotland (Sharpley forthcoming) focusing on the metal used for the rivets in composite comb manufacture. The illustration of Norse antler combs, comb fragments and comb manufacturing debris from Bornais has revealed numerous tool marks and manufacturing techniques that provide new details for the research produced. Research on the proposed techniques of antler working (e.g. Ambrosiani 1981, MacGregor 1985) led to the development of a project studying antler combs from first principles, involving the illustrator/craftsman in comb production from red deer antler to finished objects. During this process it was possible to make a series of observations about the craft, fully engaging with the physicality of the material and with the possible stages of comb production. The iron and copper rivets used in the making of the composite combs had not previously been examined. The combs recovered from Bornais predominantly have iron rivets (as do the combs found at Coppergate, York, Birka, Sweden and Ribe, Denmark) with the remainder being copper alloy. The role of the rivet is very important in fixing together the brace and tooth plates. The metal has to be fairly soft to allow the rivet to expand when hammered to bind the components together. Examination of the iron rivets from Bornais using optical microscopy and SEM/EDS revealed the composition and microstructure of the iron rivets and helps to understand how they were made. The use of copper for rivets has also been examined. It has been observed that many copper rivets from Bornais are of rolled sheet copper, with others being made of beaten out copper in the form in to rod or thin wire. Further analysis using SEM/EDS/WDS will tell us more about the composition of these rivets and could help source the origins of the copper. It is planned that the results of the analyses of the metal rivets used in Norse antler comb manufacture at Bornais will allow the craftsman to refine the process of replica comb production in order to give a more accurate picture of the original working materials and processes.
303. Metallurgical Traditions Under Inka Rule: A Technological Study Of Metals And Technical Ceramics From The Aconcagua Valley In Central Chile

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The Aconcagua Valley (Central Chile) is located in the southernmost limit of the Tawantinsuyu or Inka territory. In this paper, the authors explore the technological and metallurgical traditions in this area, focusing on the presence of typical Inka perforated crucibles and the scarcity of bronze, which is consistent with the Inka ideology and the spread of technological knowledge. However, in-depth examination of crucible assemblages is necessary to address questions of production processes, such as melting, refining, alloying, and casting. Crucibles are commonly used for secondary metallurgical production processes, and their presence and distribution can reveal important insights about the cultural choices and social dynamics of the groups using or producing metals in the area, and the influence of the Inka in those technologies.

304. Methodological Issues in Understanding Ancient Crucible Metallurgy

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Crucibles are commonly used for secondary metallurgical production processes, such as melting, refining, alloying, and casting. Their representation in the archaeological record can vary from a single sherd to thousands of crucibles and from tiny fragments to complete examples. The study of such assemblages can address questions of technological choice and material use within a particular archaeological context, and inform on wider issues such as metals trade and the spread of technological knowledge. However, in-depth examination of crucible assemblages is time-consuming and a methodological framework for best practice is currently absent. This paper aims to present some methodological issues when examining and interpreting results for (assemblages of) metallurgical crucibles. Firstly, the heterogeneity in crucible slag resulting from a non-equilibrium crucible process is considered. Secondly, the variability in technology and material use that can be expected in a large assemblage is discussed. These have important consequences for the sampling strategy both on the crucible and assemblage scale, and for the interpretation of final results. The methodological discussion focuses on the use of macroscopic observation, surface analysis using handheld XRF and microscopic analysis of polished sections using transmitted light, reflected light and scanning electron microscopy (with energy dispersive spectroscopy). The benefits and disadvantages of these methods with respect to different possible research questions for metallurgical crucible assemblages are debated. Using results from multiple assemblages studied for the author’s PhD research, these hitherto unpublished methodological issues are illustrated and some general recommendations for the study of ancient crucible assemblages are offered.

305. Silver in Dnieper Hoards of the 6th-7th cc.: First Results of the Analytical Study of the Metal from the Sudzha-Zamoste Hoard

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In 6th-8th cc. on the compact territory of Middle Dnieper and Dnieper left-bank region the phenomenon of the emergence of a large number of hoards containing silver jewellery and standing out against poor settlement culture of the early Slavic population happened. The unexpected appearance of these hoards together with the sudden unexpected termination in hiding them is noticed. The hoards have been divided into two chronological groups: the hoards of the 1st group – the end of the 6th - the middle/third quarter of the 7th cc.; the hoards of the 2nd group – the third quarter of the 7th to the first half/middle of the 8th cc. The hoards contain works dated back to West European and Byzantine culture. Moreover, the hoards of the 1st group contain less percent of silver works in comparison with the hoards of the 2nd group, which appeared in the first half/middle of the 8th cc. According to some indirect indicators it is suggested that silver was delivered to the territory of Dnieper from Balkan mines. However, it is known that the mines of Asia Minor and North Africa were being intensively developed at the same time. The silver from the mines was delivered as to the central manufactories as the remote Byzantine provinces and the periphery. In 2009 in Kusk oblast on the border with the Ukraine in the course of three hoards of the end of the 6th - the middle/third quarter of the 7th cc. the fourth hoard was found including more than 500 items made of metal (the Sudzha-Zamoste hoard). The hoard contains jewellery pieces (in which had been used of repaired). There are no full private collections of jewelry sets, it contains items of different chronological periods, from the 2nd-3rd cc. to the 7th cc. The complex also contains about 50 items made of silver alloys dated from the late Roman period to middle Early Middle Ages. There is a unique find for the territory in its contents which, probably, is the source of silver for jewelers of Dnieper region: three fragments of the Byzantine silver dish cut in antiquity with the Constans II (641-668) or Constantine IV (668-685) stamp. In this context the study of the chemical composition of the metal dish fragments and receiving their isotope lead “marka” has special significance for identifying the source of these works. Dish fragments have been studied with stereomicroscope Stermi 2000C and electronic scanning microscope Hitachi TM 3030. The study of the chemical composition of the metal, the mapping of the elements dispersion on the surface and phase analysis have been done with XFA spectrometer M4 Tornada (Bruker) To identify possible area of silver works development the analysis has been done with the high of the precision method of multicollector mass-spectrometry with inductively coupled plasma (MC-ICP-MS). Mass-spectrometric studies of isotope proportion of lead have been done with mass-spectrometer NEPTUNE (ThermoFinnigan, Germany). To do the high quality comparative analysis of data on metal’s chemical composition (in particular, on micro alloys) and isotope composition of lead the analytical examinations of other silver items from the Sudzha-Zamoste hoard have been done. The results of the analytical examinations of the silver items of the Sudzha-Zamoste hoard are given in our report.

306. Archaeometallurgical Fieldwork and the Use of a Portable X-ray Fluorescence Spectrometer: Revisited

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In 1989, Helming et al. published a paper on the use of a portable X-ray spectrometer (pXRF) for archaeometallurgical fieldwork. This work provided an overview of the best method for using pXRF in the field for the analysis of metal slag and ores. Now, 25 years later, technology has advanced and we are able to take handheld X-ray spectrometers (HH-XRF) into the field. Yet, has the methodology for the analysis of material also advanced? Do we even need to change the methodology? A recent project aimed at provenancing metal slag from the Saphalara mine in Turkey Although previously samples of the slag material had been exported from the country for the purposes of analysis, a method of analyzing...
307. pXRF ‘in-the-Field’ Fluctuations

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Recent fieldwork at Sagalassos, Turkey, involved the use of a portable handheld X-ray fluorescence spectrometer (pXRF). During the field work it was noted that the ambient temperature of the device (defined as the internal temperature of the machine) increased during the course of the day. This phenomenon was systematically monitored since the portable XRF was supplied with the pXRF recommends that the ambient temperature be kept below 115°F (46°C). It was noted that the ambient temperature increased by an average of 4°F for every 3 samples (9 measurements). This meant that work with the pXRF had to stop on a routine basis in order for the machine to cool down. It was decided to investigate whether this was the result of the environment (i.e., summer in Turkey), the amount of work being performed with the pXRF (on average 22 samples per day, 66 measurements per day), or the type of material analysed (metal slag). The data collected in the field was compared with results collected from laboratory analyses, museum analyses and those collected from a non-temperature controlled environment in Belgium. The comparison indicated that the quantity of the samples was not a problem and although the other analyses (laboratory, museum and non-temperature controlled) did show fluctuations, this was c. 4°F over the course of the whole study period. Similarly, a study of the same material but collected in a laboratory environment indicated that the fluctuations in the ambient temperature were not the result of the material being studied. This led to the conclusion that the fluctuations in the ambient temperature of the pXRF were related to the environmental conditions surrounding the machine. The temperatures in the Sagalassos region during the field work ranged from 70-93°F (21-34°C), and the ambient temperature of the pXRF rose over the course of the day. These results show that although this is a very powerful field technique it does have limitations. The principal limitation being that it can only be used in the field provided certain environmental constraints are met, therefore, to what extent is it viable as a field technique?
310. Metal Objects in the Paolo Orsi Museum (Siracusa, Italy): Non-Destructive Compositional Analysis

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A large number of copper-based and other metal artifacts in the Paolo Orsi Museum in Siracusa, southeast Sicily, were analyzed to determine the original composition and address issues such as the beginnings of alloy technology in Sicily. A small sample of comparative analyses has been carried out at the Luigi Bernabò Brea museum in Lipari. Non-destructive analyses were performed in the museums using a portable X-ray fluorescence spectrometer. A Bruker III-SD was used, with settings chosen to focus on major element composition including Cu, Sn, Pb, As, Fe, Ag, Au, Sb, and Zn. Since XRF analyses are only of the surface, multiple spots were tested on each object in order to assess variation due to original casting or other treatment, as well as post-depositional oxidation or contamination. Copper and Bronze Age artifacts tested include swords and daggers, to see whether there may have been intentional alloying with arsenic or tin. Several objects, including a knife, a blade, and a pin, were indeed arsenical copper, while many others were tin bronze. These included several knives and swords, pins, beads, bows, and a statue of a bull. Some daggers had very high (~20%) tin concentrations. Lead was not a significant component for most of the objects tested, including necklaces, pendants, rings, and a fibula. As part of our work, the results are checked to discover the use of conservation chemicals, which may affect the concentrations as well as adding elements such as zinc. Sicily appears to have introduced metalworking much later than the Italian peninsula and this study can contribute in determining the socioeconomic dynamics at work, particularly regarding the possible introduction of technologies through long distance exchanges. In addition to better understanding of ancient technology, the results of our studies will be used for better labeling and description of the many objects which are on display in the museum and to complement the modern re-publication of many artifacts discovered over a century ago.

311. Metal Production at the Late Bronze Age Site of Kalavasos-Ayios Dhimitrios, Cyprus

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During the Late Bronze Age (ca. 1650-1100 BC) Cyprus played a principal role in the Eastern Mediterranean trading networks as a dominating producer and exporter of copper. By the 13th century BC Cypriots could have had regional political in which different settlement types took part in an economical and socio-political network. These regional networks may have been defined by the transshipment of copper from the mining villages to the primary coastal sites (Keswani 1993). However, the evidence of large-scale production to be expected of a primary copper-exporting agent is basically missing on Cyprus, with perhaps the exception of Enkomi. But at nearly every known Late Bronze Age site some remains of metal production have been found. Also at the primary site of Kalavasos-Ayios Dhimitrios, dated to the 13th century BC and located on the south coast, a fairly large amount of metallurgical remains was recovered with a remarkable variability and distribution. Due to limited research the nature, size and organisation of the metallurgical practices they may have derived from remain until today undecided. As metallurgical remains do conceal the wide range of technological choices made by ancient craftsmen during the production of metals, this project aims to reconstruct not only the multi-phase production process but also its social and spatial organisation by the study of these material remains.

By means of a variety of analytical methods like optical microscopy, SEM-EDS, XRF and XRD, is the complete metallurgical assemblage found at Kalavasos-Ayios Dimitrios being examined and will be brought in comparison with those from the neighboring sites of Marathoni Vouni and Marathoni-Tsaroulas, and in a further extent with the published and unpublished material from contemporary sites located in other regions. The results of this comparative study will hopefully reveal the function played by Kalavasos-Ayios Dhimitrios within its regional network and its importance on an island-wide scale, and hence contribute to a further understanding of the copper production on Late Bronze Age Cyprus.

References

312. Iron on the Imperial Frontier: Evidence from Angkorian Period (9th-15th Century AD) Iron Smelting Sites in Lao PDR and Thailand

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At its apogee the Angkorian Khmer Empire (802-1435 AD) controlled vast areas of mainland Southeast Asia. Angkorian wealth and power are commonly considered to have rested heavily on mastery of hydraulic engineering for intensive wet-rice agriculture, and an integrated temple-based economic and transport system for redistributing this surplus. This wealth was then drawn upon for civic and military projects. Nonetheless, the production, organisation, and distribution of fundamental materials, such as stones, laterite, and metals, for executing state projects, are not well understood. Here we focus on how the Angkor population managed to procure iron for imperial consumption, very little evidence for iron production has hitherto been presented.

Current knowledge of the Angkorian iron industry is based upon the long known production sites at the walled complex at Preah Khan of Kompong Svay (PKKS) and the iron oxide deposit at Phnom Dek (PD), located close to the political core at Angkor. This paper offers two complementary cases of iron production in this period. The first cluster of smelting sites, located outside the political core, in Ban Kruat, Buriram, Thailand: no major urban infrastructure likewise PKKS has been documented locally. The second smelting site cluster at Saphim and Ta’ko Kao, Luang Namtha, Lao PDR, at or even beyond the limit of Angkorian influence, provides evidence of intensive organised production in a very remote mountainous zone. Based upon technological and linguistic evidence, both sites may represent upland ethnic minorities supplying goods to lowland majorities, but the precise historical relationships and mechanisms are yet to be determined. One route to this outcome lies in analytical technological reconstructions. Of special interest is Ban Kruat, where we propose that smithers produced steel directly, exploiting alumina-rich, iron-poor nodules of local laterite and processing them under very high temperatures. The interpretation is supported by the alumina-rich slag, that chemically matches the laterite nodules excavated, and contains prills of carbon-rich (and, occasionally, phosphoric) iron. The technology observed contrasts to the conservative tradition of magnetite smelting probably practised at PKKS and PD. Located near a Khmer temple with a major settlement 40 km away, the Ban Kruat scenario could have been the production that was controlled hierarchically by the local temple and larger administrative centres. Given this circumstance, the organisation of production in Angkorian industries might be quite flexible depending on each controlled area.

313. A PRELIMINARY STUDY ON A BRONZE INCENSE BURNER DATED TO THE EASTERN JIN DYNASTY (317-420A.D.) IN NANJING CITY, CHINA

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One of the significantly archaeological discoveries in the year of 2011 in Nanjing city, China, was a grand brick-chambered tomb dated to 317-420A.D., associated with many spectacular findings, such as golden ornaments, lacquer vessels, natural beewax, celadon containers, alchemical pills as well as other metal objects. In terms of historical documentation, the tomb location belonged to a cemetery of a high rank honorable family, mostly presumed to be well-known alchemical pioneers and active practitioners during the Eastern Jin Dynasty (317-420A.D.), a flourishing period of Taoism in ancient China. Aided by local archaeologists, a metal incense burner composed of a bird-formed lid, a body decorated with birds and human-
shaped figurines and a plain basin-patterned base with an auspicious animal lying in the center, was chosen to be firstly explored by scientific methods. The whole vessel was well preserved and nearly intact, except base edge with a small-sized cut. Therefore, a tiny piece along the cut was sampled and analyzed by using μ X-ray fluorescence, μ X-ray fluorescence, metallurgical microscopy, as well as scanning electron microscopy coupled with EDS to determine the composition, structure and manufacturing technology. The semi-quantitative X-ray fluorescence analysis showed the sample mainly had copper, silica, tin, lead, iron and aluminum, with potassium, chlorine, calcium and phosphorus in minor. After detection by using μ X-ray fluorescence on a fresh section, map scanning revealed copper was mostly rich in the whole body, with minor evenly distributed tin and dottedly distributed lead, whereas other elements including silica, aluminum, potassium, chlorine, calcium and phosphorus were mainly found along the surface, which were attributed to the contaminants from the burial soils, and iron probably due to an adjacent iron ink slab. The metallurgical observation unveiled a typical dendritic casting microstructure, but dendritic segregation was unsousible because of low tin content. The results conducted by scanning electron microscopy equipped with EDS were in consistent with metallurgical observation and μ X-ray fluorescence result, especially EDS analysis indicated tin content was averagely over 4%, whereas lead was 1% to 2%. The experiments revealed the burner base was mainly made of copper by casting technology; tin was purposely added in; lead was probably spontaneously brought in from either copper ores or remelting process. It was different from local archaeologist’s original presumption that the burner together with other excavated artifacts in order to seek more powerful evidence to provide a reasonable answer.

314. Research on gold and silver gilding technology on copper wares of Han Dynasty excavated from the Three Gorges

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This paper aimed to research copper wares of Han Dynasty decorated with golden and silvery design excavated in Chongqing Municipal, China. Egyptians began to make artifacts with wholly gold or embellished in part with gold, which may be dated to at least 3000 B.C. At that time, many objects are gilded only, either with gold foil or with gold leaf (T. G. H. James, 1972). The large amount of early gold antiquity indicated the special favor of gold to ancient Chinese people, so it was as a historical tradition and continues to this day. The gilded objects of the late Zhou period in China of the third century B.C. were confirmed to use mercury gilding technology (P.A. Lins, 1975). The samples were analyzed by scanning electron microscope (SEM) and energy dispersive X-ray analysis(EDAX). The results indicated that main part of copper wares were made of rose copper by means of hot forging and metal coating were dealt with gold gilding and silver gilding technology. The high content of Hg element indicated that the mercury amalgam used to gilt gold layer was once popular in Chongqing three gorges region. At that time, craftsmen usually had tailored gold foil into viminaceous pieces to make gold easily to mixture with mercury. Especially, it is an important finding to observe silver gilding layer which can be verified by its silver lustre, and by elemental mapping analysis with high content of element Ag and Au. As we known, silver has a weak affinity to bronze, so the silver gilding should be gilded above a gold gilding layer (Anheuser, Kilian 1989). The added Au will make the gilt layer easier to stick to the cu-sn alloy. These findings supplied important information to realize the manufacture of copper wares and the development of gold gilding and silver gilding in ancient China.

References

Directions

Northbound to UCLA (LAX to UCLA):
- 405 N
- Exit Wilshire Blvd East and follow the road to the right and stay on the far left lane.
- Left on Westwood Blvd and go straight up into campus where it will change to Westwood Plaza.

Southbound to UCLA:
- 405 S
- Exit Wilshire Blvd East and stay on the far left lane.
- Left on Westwood Blvd and go straight up into campus where it will change to Westwood Plaza.

Westbound to UCLA:
- Take Wilshire Blvd and head west towards UCLA.
- Right on Westwood Blvd and go straight up into campus where it will change to Westwood Plaza.

- A parking permit may be obtained at the information kiosk towards the end of Westwood Plaza.
- Parking Structure 9 is located on your right, park at the top level.
- The CNSI building is built onto the roof level of the parking structure. Use the walkway/bridge on the far left side to make your way around to the front entrance of the CNSI building. Once at the front entrance, please use the call box to the left of the doors to gain access to the building.
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The art of Raman

Advantages
- In situ analysis using optical fiber probe up to 100 m from instrument
- Non-destructive
- 1 µm spatial resolution using microscope
- No sample preparation

Identify pigments

In situ analysis of a 12th century fresco in the S. Pietro di Avigliana church in Turin, Italy. Pigments are identified from their Raman spectra enabling sympathetic restoration.

Repair of a damaged wall-painting of St. Merkourios in Protato church, Greece. Analysis of small particles of paint (< 1 mm²) with a Renishaw Raman microscope identifies the original pigments.

Investigate authenticity

Renishaw’s Raman system provides evidence for the Vinland Map being a very clever forgery. In situ analysis of materials used on the map allows dating of the artwork.

Other applications

Gemstones
Corrosion processes
Ceramics
Marble
Surface treatments