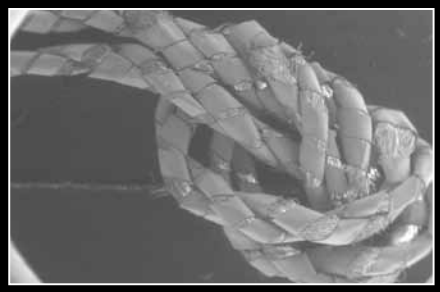

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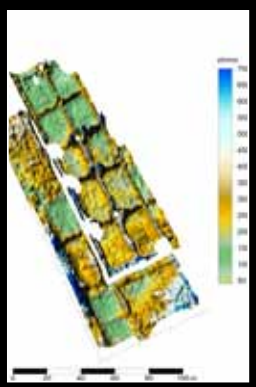






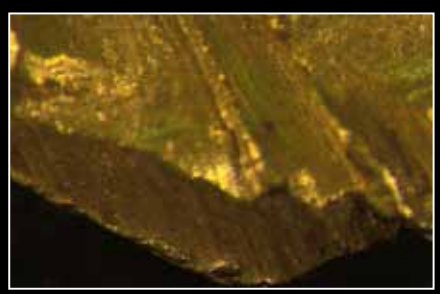


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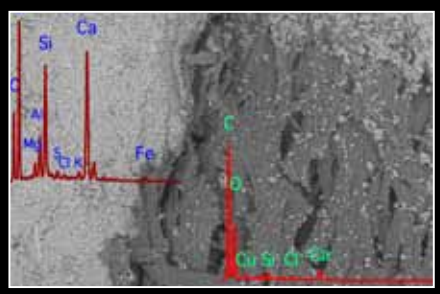

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40th International Symposium on Archaeometry

ISA 2014

May 19-23, 2014

Los Angeles, California

Program and Abstract Book

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Mark Pollard and Sturt Manning

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Josefina Pérez-Arantegui and Patrick Degryse

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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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Program Outline

Monday, May 19

8:00 AM-7:00 PM	Registration and Check-In at the Getty Villa
8:30-8:55	Welcoming Remarks and Orientation
8:55-10:20	Session: Stone, Plaster and Pigments I
10:20-11:00	Coffee Break
11:00-1:00 PM	Session: Stone, Plaster and Pigments II
1:00-2:30	Lunch Break
2:30-4:35	Poster Session I
4:35-7:00	Session: Ceramics, Glazes, Glass and Vitreous Materials I
7:00	End of Symposium Day One

Tuesday, May 20

8:00-9:00 AM	Coffee and Pastries
9:00-10:40	Session: Stone, Plaster and Pigments III
10:40-11:20	Coffee Break
11:20-1:20 PM	Session: Ceramics, Glazes, Glass and Vitreous Materials II
1:20-1:30	Presentation of the Next ISA Venue
1:30-2:25	Lunch Break
2:25-4:30	Session: Metals and Metallurgical Ceramics I
4:30-4:55	Coffee Break
4:55-6:30	Special Session: The Transition from the Bronze to the Iron Age
6:30-7:00	Keynote: Ian Freestone, University College London *Small Compositional Groups, Production Events and the Organization of Production*
7:00-9:00	Opening Reception at the Getty Villa

Wednesday, May 21

8:00 AM-7:00 PM	Registration and Check-In at the California NanoSystems Institute, UCLA
8:30-8:55	Welcoming Remarks and Orientation
8:55-10:40	Session and Special Sub-Session: Archaeochronometry and New Trends in Luminescence Dating
10:40-11:10	Coffee Break
11:10-1:15 PM	Theme Session: Forensic Science Investigations in Art and Archaeology Panel & Forum Discussion
1:15-2:30	Lunch Break
2:30-4:25	Poster Session II
4:25-6:30	Session: Human Environment and Bioarchaeology I
6:30-7:00	Keynote: Terry Brown, University of Manchester *The DNA Sequencing Revolution: New Opportunities for Biomolecular Archaeology*
7:00-9:00	Gala Dinner, UCLA Faculty Center

Thursday, May 22

8:00-9:00 AM	Coffee and Pastries at CNSI
9:00-10:20	Session: Human Environment and Bioarchaeology II
10:20-10:55	Coffee Break
10:55-12:40 PM	Session: Remote Sensing, Geophysical Prospection and Field Archaeology
12:40-1:15	Technical Session (ISA Gold Level Sponsors)
1:15-2:30	Lunch Break
2:30-4:30	Poster Session III
4:30-6:50	Session: Metals and Metallurgical Ceramics
6:50-PM	End of Symposium Day Four

Friday, May 23

8:00-9:00 AM	Coffee and Pastries at CNSI
9:00-11:20	Session: Ceramics, Glazes, Class and Vitreous Materials
11:20-12:00 PM	Coffee Break
12:00-1:00	Prizes and Closing Ceremony
1:00	End of the Symposium
1:30-4:00	Offsite Excursions: Eames House and Watts Towers

Time Monday 19 May 2014

8:00 AM	*Registration and Check-In at the Getty Villa* *Coffee and Pastries in the Auditorium Lobby*
8:30 – 8:55 AM	Welcoming Remarks and Orientation Jeanne Marie Teutonico, Getty Conservation Institute Charles Stanish, Cotsen School of Archaeology
8:55 – 10:20 AM	**SESSION *Stone, Plaster and Pigments*** Convenors: Robert Tykot and Christian Fischer
8:55 – 9:00 AM	Chairperson: Robert Tykot *Introduction to the Session*
9:00 – 9:20 AM	1. Pouyet, E., Cotte, M., Fayard, B., Monico, L., Mass, J., Nuyts, G., Radepont, M., Sciau, P. - *Full-field X-ray spectroscopy offers new possibilities for the study of paintings*
9:20 – 9:40 AM	2. Prochaska, W., Attanasio, D., Bruno, M. - *Trace Element and Fluid Analyses for Identification of Marbles - Systematic Provenance Analysis of the Imperial Portraits*
9:40 – 10:00 AM	3. Wright, V., Pacheco, G., Torres, H., Huaman, O., Watanave, A. - *Mural Paintings in Ancient Peru: The Case of Tambo Colorado, Pisco Valley*
10:00 – 10:20 AM	4. Abd El Salam, S., Maniatis, Y. - *Identification and Characterization of Painted Wall Plasters and Mortars at Villa Silin, Libya, Using a Range of Analytical Methods: "Part 2"*
10:20 - 11:00 AM	*Coffee Break*
11:00 AM – 1:00 PM	**SESSION *Stone, Plaster and Pigments*** Chairperson: Christian Fischer
11:00 – 11:20 AM	5. Miriello, D., Barca, D., Pecci, A., De Luca, R., Crisci, G.M., López Luján, L., Barba, L. - *Characterization of plasters from different buildings of the Sacred Precinct of Tenochtitlan (Mexico City)*
11:20 – 11:40 AM	6. Crisci, G.M., La Russa, M.F., Rovella, N., Ruffolo, S.A.,Andaloro, M., Pelosi, C., Pogliani, P. - *An archaeometric study of Mortars taken from Rupestrian Churches in Cappadocia (Turkey)*
11:40 AM – 12:00 PM	7. Jackson, M.D., and Oleson, J.P. - *Validating Roman Descriptions of Harbor Concretes through Fine-Scale Archaeometric Studies*
12:00 – 12:20 PM	8. Lluveras-Tenorio, A., Birolo, L., Blaensdorf, C., Bonaduce, I., Cotte, M., Galano, E., Pouyet, E., Colombini, M.P. - *GC/MS, Proteomics and Imaging techniques to reconstruct materials and techniques of the Western and Eastern Buddhas of the Bamiyan valley (Afghanistan).*
12:20 – 12:40 PM	9. Douglas, J.G., Carò, F., Polkinghorne, M. - *Angkorian Stone Materials from 9th century Hariharalaya Workshop and the Temples of Bakong and Preah Kô*
12:40 – 1:00 PM	10. Manrique Ortega, M.D., Ruvalcaba Sil, J.L., Claes, P., García Bucio, M.A., Casanova González, E., Wong Rueda, M., Maynez Robles, M.A., Delgado Robles, A.A., González Cruz, A., Cuevas García, M. - *Technical Examination of the Red Queen's Burial Offering of the Maya site of Palenque, Mexico*
1:00 – 2:30 PM	*Lunch Break*
2:30 PM – 4:35 PM	**POSTER SESSION I**
4:35 PM – 7:00 PM	**SESSION *Ceramics, Glazes, Glass and Vitreous Materials*** Convenors: Josefina Pérez-Arantegui and Patrick Degryse
4:35 PM – 4:40 PM	Chairperson: Josefina Pérez-Arantegui *Introduction to the Session*
4:40 – 5:00 PM	11. Amicone, S., Quinn, P., Radivojević, M.,, Rehren, T. - *Technological Development in Vinča Culture Pottery at the Dawn of the Metal Age*
5:00 – 5:20 PM	12. Holmqvist-Saukkonen, E., Larsson, Å.M., Kriiska, A., Palonen, V., Mizohata, K., Nissinen, T., Oinonen, M., Räisänen, J. - T*racing Grog, Pots and Neolithic Baltoscandian Corded Ware Culture Contacts (SEM-EDS, PIXE)*
5:20 – 5:40 PM	13. Hein, A., Kilikoglou, V. - *Compositional variability of archaeological ceramics in the Eastern Mediterranean and implications for the design of chemical provenance studies*
5:40 – 6:00 PM	14. Braekmans, D., Garnand, B.K., Greene, J.A., Stager, L.E., Degryse, P. - *Provenance of Late Punic and Roman-Byzantine ceramic materials at Carthage (Tunisia). A view from the mercantile harbor and Tophet*

6:00 – 6:20 PM	15. Waksman, Y., Skartsis, S.S., Kontogiannis, N.D., Vaxevanis, G. - *Looking for the Main Production Site of Middle Byzantine Pottery*
6:20 – 6:40 PM	16. Eremin, K., Domoney, K., McWilliams, M., Mason, R., Carey, M., Ferguson, P., Leoni, F. - *Technical Analysis of Safavid Ceramics*
6:40 – 7:00 PM	17. Tite, M., Pradell, T., Molina, G., Domoney, K., Watson, O., Bouquillon, A. - *Revisiting the Beginnings of Tin-opacified Islamic Glazes*
7:00 PM	End of Symposium Day One

Time Tuesday 20 May 2014

8:00-900 AM	*Coffee and Pastries*
9:00 – 10:40 AM	**SESSION *Stone, Plaster and Pigments*** Chairperson: Marc Walton
9:00 – 9:20 AM	18. Claes, P., Ruvalcaba Sil, J.L., Filloy, L., Wong Rueda, M., García Bucio, M.A. - *Non-Destructive Analysis of Olmec Green Stone Figurines and Axes from La Venta's Offering 4*
9:20 – 9:40 AM	19. Tykot, R.H., Freund, K.P., Vianello, A. *Provenance Analysis of 1500 Obsidian Artifacts from 40+ Sites in Sicily (Italy)*
9:40 – 10:00 AM	20. Sternberg, R., Shackley, M.S., Feinberg, J.M., Steffen, A., Freeman, A., Gregovich, A., Hackett, C., Harrison, M., Kim, M., Osborne, Z., Pollen, A., Regier, M., Roth, K., Samuels, R. - *Magnetic and Geochemical Characterization of Georeferenced Obsidian Samples from Four Source Areas in New Mexico*
10:00 – 10:20 AM	21. Beck, L., Rousselière, H., Castaing, J., Duran, A., Lebon, M., Plassard, F. - *First use of portable system coupling X-ray diffraction and X-ray fluorescence for in-situ analysis of prehistoric rock art - Rouffignac cave (France)*
10:20 – 10:40 AM	22. Ribechini, E., Degano, I., Zanaboni, M., Pavan, A., Colombini, M.P., Pérez-Arantegui, J. - *Purple in Sumhuram, Oman (1st-2nd Century AD), Revealed by Mass Spectrometric and Chromatographic Techniques*
10:40-11:20 AM	*Coffee Break*
11:20 AM – 1:20 PM	**SESSION *Ceramics, Glazes, Glass and Vitreous Materials*** Chairperson: Patrick Degryse
11:20 – 11:40 AM	23. Gill, M.S., Rehren, T. - T*echnology and Indigeneity in Mughal Glazed Tile-Work*
11:40AM- 12:00 PM	24. Neff, H., Garfin, T., Burger, P., Niespolo, E. - *Plumbate Ceramic Ecology*
12:00 – 12:20 PM	25. Killick, D., Chiu, S., Sand, C., Dickinson, W.R. - *Paradise for Petrographers: Tracking Movements of Lapita Pottery (1200-900 cal BCE) between New Caledonia, Isle des Pins, the Loyalty Islands and Vanuatu*
12:20 – 12:40 PM	26. Phelps, M., Freestone, I., Gratuze, B. Lankton, J. - *Technological Change and Provenance of Glass in Early Islamic Palestine*
12:40 – 1:00 PM	27. Li, W., Lu, X., Liu, L., Sun, X. - *Origin and Development of Blue-and-White Porcelain in Ancient China*
1:00 – 1:20PM	28. Domoney, K., Shortland, A.J., Kuhn, S., Megens, N. - *XRF Analysis of Vincennes-Sèvres Porcelain: Characterization, Dating and Attribution*
1:20:1:30PM	Presentation of the Next ISA Venue
1:30- 2:25 PM	*Lunch Break*
2:25 – 4:30 PM	**SESSION *Metals and Metallurgical Ceramics*** Convenors: David Killick and David A. Scott
2:25 – 2:30 PM	Chairperson: David Killick *Introduction to the Session*
2:30 – 2:50 PM	29. Radivojević, M., Boscher, L., Timberlake, S., Asmus, B., Radivojević, J., Chen, K., Rehren, Th. - *How To Cook your Met(al): Reconstructing The World's Earliest Metallurgy*
2:50 – 3:10 PM	30. Franke, K.A. *Metal and Elites in Upper Mesopotamia - Uniqueness or Uniformity?*
3:10 – 3:30 PM	31. Bassiakos, Y., Mastrotheodoros, G., Filippaki, L. - *Aspects on the introduction of tin in the Aegean during the 2nd millennium BC*

3:30 – 3:50 PM	32. Perucchetti, L., Bray, P., Pollard, A.M. - *Physical Barriers, Cultural Connections: Ancient Metallurgy Across the Alpine Region*
3:50 – 4:10 PM	33. Le Carlier, C., Le Bannier, J.C., Marcigny, C., Fily, M. - 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 typo-chronology*
4:10 – 4:30 PM	34. Villa, I.M., Cattin, F., Merkl, M.B., Strahm, Ch. - *Elemental and Lead Isotopic Data of Copper Finds from the Singen Cemetery, Germany - a Methodological Approach to Investigate Early Bronze Age Trade Networks*
4:30 - 4:55 PM	*Coffee Break*
4:55 PM – 6:30 PM	**SPECIAL SESSION** ***The transition from the Bronze to the Iron Age*** (4) Convenors: Mark Pollard and Sturt Manning
4:55 – 5:00 PM	Chairperson: Mark Pollard *Introduction to the session*
5:00 – 5:20 PM	35. Manning, S.W. - *Time and context of change at the close of the Late Bronze Age and in the early Iron Age*
5:20 – 5:40 PM	36. Kassianidou, V. - *Copper in the Iron Age*
5:40 – 6:00 PM	37. Knapp, A.B. - *Crisis in Context: The End of the Late Bronze Age in the Eastern Mediterranean*
6:00 – 6:20 PM	*38.* Blomme, A., *Elsen, J., Degryse, P.* - An Isotopic Trip through First Millennium BC Glass History
6:25- 6:30 PM	*Walton, M. Introduction to the keynote*
6:30 – 7:00 PM	**KYENOTE** 39. Ian Freestone, University College London *Small Compositional Groups, Production Events and the Organisation of Production*
7:00 – 9:00 PM	Reception at the Getty Villa **Open to all symposium participants*

Time	Wednesday 21 May 2014
8:00 AM	*Registration and Check-In at California NanoSystems Institute, UCLA Coffee and Pastries*
8:30 – 8:55 AM	Welcoming Remarks and Orientation
8:55 – 10:40 AM	**SESSION & SPECIAL SUB-SESSION** ***Archaeochronometry & New trends in Luminescence Dating*** Convenors: Marco Martini and Edwards Rhodes
8:55 – 9:00 AM	Chairperson: Edward Rhodes *Introduction to the Session*
9:00 – 9:20 AM	40. Ankjærgaard, C.,Kuiper, K.F., Porat, N., Jain, M., Wijbrans, J.R., Wallinga, J. - *Extending the Luminescence Dating Range to the full Quaternary*
9:20 – 9:40 AM	41. Joannes-Boyau, R. - *Recent advances in Geochronology and geochemistry applied to human fossil remains: maximizing the information with minimal damage*
9:40 – 10:00 AM	42. Maniatis, Y., Kotsakis, K. - *New Evidence with Radiocarbon for the Appearance of the Earliest Farmers in the Aegean*
10:00 – 10:20 AM	*43.* Pesce, G.L., *Vecchiattini, R., BALL R.J. - Radiocarbon dating of old plasters and mortars. An overview of the last 5 years application of the "pure lime lumps" technique*
10:20 – 10:40 AM	44. Höflmayer, F., Burke, A.A. - *A New Approach for Combining Historical, Archaeological, and Scientific Chronologies*
10:40 - 11:10 AM	*Coffee Break*
11:10 AM – 1:30 PM	**THEME SESSION** ***Forensic Science Investigations in Art and Archaeology*** Convenor: Ioanna Kakoulli
11:10 – 11:15 AM	Chairperson: Ioanna Kakoulli *Introduction to the session*
11:15 – 11:30 AM	45. Helman-Ważny, A. - *More than meets the eye: Fiber Analysis and Manuscripts from the Silk Roads*
11:30 – 11:45 AM	46. Boehnke, P., Harrison, M. Kakoulli, I. - *Improving lateral resolution of isotopic measurements of ancient glasses using spatially resolved ion beam microanalysis: the LA case*
11:45 AM – 12:00 PM	47. Pernicka, E. - *Testing the authenticity of the Sky Disc of Nebra*
12:00 – 12:15 PM	48. Rose, B. - *Beyond the UNESCO Convention: the Case of the Troy Gold in the Penn Museum*
12:15 – 12:30 PM	*49.* Potts, T. - *Acquiring antiquities for museums: ethics, policy, and analysis*

12:30 – 1:15 PM	50. Panel and open forum: forensic science investigations in art and archaeology
1:15 – 2:30 PM	Lunch Break
2:30 PM – 4:25 PM	**POSTER SESSION II**
4:25 PM – 6:30 PM	**SESSION** ***Human Environment and Bioarchaeology*** Convenor: Henk Kars
4:25 – 4:30 PM	Chairperson: *Introduction to the session*
4:30 – 4:50 PM	51. Evershed, R.P., Salque, M., Cramp, L., Pääkkönen, M., Outram, A. - *Pushing the Limits of Fatty Acid Stable Carbon Isotope Analysis in the Archaeological Record*
4:50 – 5:10 PM	52. Jones, J.R., Nordgren, E., Mulville, J. - *Characterizing changing animal management practices, land use strategies and Palaeoenvironments through time in the North Atlantic Islands: an isotopic approach*
5:10 – 5:30 PM	53. Gerling, C., Pike, A., Heyd, V., Kaiser, E., Parzinger, H., Schier, W. - *Mobility and Diet in the Bronze Age West Eurasian Steppes: A Multi-Isotope Approach*
5:30 – 5:50 PM	54. Correa Ascencio, M., Robertson, I., Cabrera Cortés, O., Cabrera Castro, R., Evershed, R.P. - *Hopanoids as Biomarkers of Pulque in Mesoamerica*
5:50 – 6:10 PM	55. Grupe, G., McGlynn, G.C. - *Transalpine mobility and culture transfer from the Urnfield Culture into Roman times: Isotopic mapping of a Central European Alpine passage*
6:10 – 6:30 PM	56. Cartwright, C. - *Changing Coastal Resource Use in the Bronze and Iron Ages at Ra's al-Hadd, Oman*
6:30 – 6:35 PM	Kakoulli, I. *Introduction to the keynote*
6:35 – 7:05 PM	**KYENOTE** 57. Terry Brown, University of Manchester *The DNA sequencing revolution: new opportunities for biomolecular archaeology*
7:05 – 10:00 PM	Gala Reception and Dinner (UCLA Faculty Center) * Tickets need to be purchased in advance

Time	Thursday 22 May 2014
8:00 AM	Coffee and Pastries in the California NanoSystems Institute lobby, UCLA
9:00 – 10:20 AM	**SESSION** ***Human Environment Interactions and Bio-Materials Bioarchaeology*** Chairperson: Richard Evershed
9:00 – 9:20 AM	58. Photos-Jones, E., Keane, C., Stamatakis, M., Hall, A.J., Leanord, A. - *Medicinal Clays and 'Earths': from geo-archaeological research to microbiological testing*
9:20 – 9:40 AM	59. Rabin, I. - *Integration of advanced analytical techniques in the studies of the Dead Sea Scrolls*
9:40 – 10:00 AM	60. Alexianu, M.T., Asandulesei, A., Tencariu, F-A, Sandu, I, Romanescu, G., Curca, R-G., Asandulesei, M. - *Ethno-archaeology of Salt Supply during the Neolithic and Chalcolithic in the Romanian Carpathians*
10:00 – 10:20 AM	61. Azémard, C., Ménager. M., Vieillescazes, C. - *Identification of Ancient Varnishes: Development of Adapted Methods in GC-MS(/MS)*
10:20 – 10:55 AM	Coffee Break
10:55 AM – 12:40 PM	**SESSION** ***Remote Sensing, Geophysical Prospection and Field Archaeology*** Convenors: Luis Barba and Robert Sternberg
10:55- 11:00 AM	Chairperson: Luis Barba and/or Robert Sternberg *Introduction to the session*
11:00 – 11:20 AM	62. Middleton, W.D., Joyce, A.A., Messinger, D.W., Canham, K., Goman, M., Borejzsa, A., Mueller, R. - *Applications in Landscape Analysis and Cultural Resource Management for Hyperspectral Satellite Imagery*
11:20 – 11:40 AM	63. Argote-Espino, D., Paz-Arellano, P., Tejero-Andrade, A. López-García, P. - *2D-ERT Geophysical Characterization of the Plaza de Santo Domingo, Mexico City*
11:40 AM – 12:00 PM	64. Křivánek, R. - *Different possibilities and combinations of geophysical methods in the research of various types of archaeological sites with changed landscape and land use - case studies from Bohemia, Czech Republic*
12:00 – 12:20 PM	65. Donais, M.K., Duncan, B., Vandenabeele, P., George, D. - *Characterization of Structures at Sant'Ansano Excavation Site in Allerona, Italy using Portable Spectroscopy*

12:20 – 12:40 PM	66. Dirix, K., Rogiers, B., Muchez, P., Degryse, P., Mušič, B., Poblome, J. - *Integrating Multi-Element Geochemical and Magnetic Surveying by Spatial Clustering: the Suburban Sagalassos Case, SW-Turkey*
12:40 – 1:15 PM	**TECHNICAL SESSION** ***ISA 2014 Gold Sponsors***
12:40 – 12:45 PM	Chairperson: Sergey V. Prikhodko *Introduction to the technical session*
12:45 – 1:00 PM	67. Kaiser, B. *Photon Physics Role in Creation, Art and Archaeology*
1:00 – 1:15 PM	68. King, A. *Combined SEM and Raman spectroscopy: a powerful analytical tool for archaeometry*
1:15 – 2:30 PM	*Lunch Break*
2:30 – 4:30 PM	**POSTER SESSION III**
4:30 – 7:00 PM	**SESSION** ***Metals and Metallurgical Ceramics*** Chairperson: David A. Scott
4:30 – 4:50 PM	69. Eley, T., Boscher, L., Georgakopoulou, M. - *Heaps and Heaps of it: Analysis of Kushan-Sassanid Metallurgical Remains from Mes Aynak, Eastern Afghanistan*
4:50 – 5:10 PM	70. Liu, 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., Delqué-Kolic, 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. Fenn, T.R., Ameje, J. Gronenborn, D., Ruiz, J. - Archaeometallurgy of Metal Finds from the Medieval "Royal" Burials of Durbi Takusheyi, Northern Nigeria
5:50 – 6:10 PM	73. Jouttijärvi, A. - Outside the gates - *Metalworking around medieval and post medieval Copenhagen*
6:10 – 6:30 PM	74. Shugar, A., Urban, P., Schortman, E. - *Copper production at El Coyote Honduras: The first evidence for copper smelting in Central America*
6:30 – 6:50 PM	75. Martinón-Torres, M. Uribe, M.A. - *Goldsmiths or Wax Sculptors? Individual Skill and Social Agency in Muisca metalwork (Colombia, AD 600-1800)*
6:50 PM	End of Day

Time	**Friday 23 May 2014**
8:00 AM	*Coffee and Pastries in the CNSI Lobby*
9:00 – 11:20 AM	**SESSION** ***Ceramics, Glazes, Glass and Vitreous Materials*** Chairperson: Hector Neff
9:00 – 9:20 AM	76. Dias, M.I., Prudêncio, M.I., Kasztovszky, Z., Kovács, I., Szokefalvi-Nagy, Z., Flor, P. - *Micro-invasive and non-invasive techniques applied to Italian Renaissance Terracotta Sculptures: Provenance and chronological issues of Della Robbia Collections in Portugal*
9:20 – 9:40 AM	77. Conte, S., Arletti, R., Mermati, F. – *First Archaeometrical Data of Glass from Sarno Necropolis (9th - 6th Century BC)*
9:40 – 10:00 AM	78. Devulder, V., Vanhaecke, F., Shortland, A., Mattingly, D., Degryse, P. - *Boron Isotopic Composition of Roman Natron Glasses to Provenance the Flux Raw Material*
10:00 – 10:20 AM	79. Dussubieux, L., Pryce, T.O. - *Iron Age Glass from Myanmar: Addressing Provenance Issues with Trace Element and Isotopic Compositions*
10:20 – 10:40 AM	80. Fornacelli, C., Bracci, S., Memmi Turbanti, I., Picollo, M., Vilarigues, M., Troeira, M. - *Characterization and contemporary replicae of Art Noveau coloured glass*
10:40 – 11:00 AM	81. Lankton, J.W., Gratuze, B., Cholakova, A., Freestone, I., Phelps, M., Rehren, T. - *Glass Chemical Analysis: Assessing the New Heterarchy*
11:00 – 11:20 AM	82. Gliozzo, E. - *Glass and Diagrams: a Review (Roman and Medieval glasses from the Mediterranean area)*
11:20AM - 12:00 PM	*Coffee Break/Snacks*
12:00 – 1:00 PM	Prizes and Closing Ceremony
1:00 PM	End of the Symposium
1:30 PM	Offsite Excursion 1: *Eames House* Offsite Excursion 2: *Watts Towers*

ISA 2014 LIST OF ORAL ABSTRACTS

Monday

STONE, PLASTER AND PIGMENTS

1. **Full-field X-ray spectroscopy offers new possibilities for the study of paintings**
   Pouyet, E., Cotte, M., Fayard, B., Monico, L., Mass, J., Nuyts, G., Radepont, M., Sciau, P.
2. **Trace Element and Fluid Analyses for Identification of Marbles – Systematic Provenance Analysis of the Imperial Portraits**
   Prochaska, W., Attanasio, D., Bruno, M.
3. **Mural Paintings in Ancient Peru: The Case of Tambo Colorado, Pisco Valley**
   Wright, V., Pacheco, G., Torres, H., Huaman, O., Watanave, A
4. **Identification and Characterization of Painted Wall Plasters and Mortars at Villa Silin, Libya, Using a Range of Analytical Methods: "Part 2"**
   Abd El Salam, S., Maniatis, Y.
5. **Characterization of plasters from different buildings of the Sacred Precinct of Tenochtitlan (Mexico City)**
   Miriello, D., Barca, D., Pecci, A., De Luca, R., Crisci, G.M., López Luján, L., Barba, L.
6. **An archaeometric study of Mortars taken from Rupestrian Churches in Cappadocia (Turkey)**
   Crisci, G.M., La Russa, M.F., Rovella, N., Ruffolo, S.A.,Andaloro, M., Pelosi, C., Pogliani, P.
7. **Validating Roman Descriptions of Harbor Concretes through Fine-Scale Archaeometric Studies**
   Jackson, M.D., Oleson, J.P.
8. **GC/MS, Proteomics and Imaging techniques to reconstruct materials and techniques of the Western and Eastern Buddhas of the Bamiyan valley (Afghanistan)**
   Lluveras-Tenorio, A., Birolo, L., Blaensdorf, C., Bonaduce, I., Cotte, M., Galano, E., Pouyet, E., Colombini, M.P.
9. **Angkorian Stone Materials from 9th century Hariharalaya Workshop and the Temples of Bakong and Preah Kô**
   Douglas, J.G., Carò, F., Polkinghorne, M.
10. **Technical Examination of the Red Queen's Burial Offering of the Maya site of Palenque, Mexico**
    Manrique Ortega, M.D., Ruvalcaba Sil, J.L., Claes, P., García Bucio, M.A., Casanova González, E., Wong Rueda, M., Maynez Robles, M.A., Delgado Robles, A.A., González Cruz, A., Cuevas García, M.

CERAMICS, GLAZES, GLASS AND VITREOUS MATERIALS

11. **Technological Development in Vinča Culture Pottery at the Dawn of the Metal Age**
    Amicone, S., Quinn, P., Radivojević, M.,, Rehren, T.
12. **Tracing Grog, Pots and Neolithic Baltoscandian Corded Ware Culture Contacts (SEM-EDS, PIXE)**
    Holmqvist-Saukkonen, E., Larsson, Å.M., Kriiska, A., Palonen, V., Mizohata, K., Nissinen, T., Oinonen, M., Räisänen, J.
13. **Compositional variability of archaeological ceramics in the Eastern Mediterranean and implications for the design of chemical provenance studies**
    Hein, A., Kilikoglou, V.
14. **Provenance of Late Punic and Roman-Byzantine ceramic materials at Carthage (Tunisia). A view from the mercantileharbor and Tophet**
    Braekmans, D., Garnand, B.K., Greene, J.A., Stager, L.E., Degryse, P.
15. **Looking for the Main Production Site of Middle Byzantine Pottery**
    Waksman, Y., Skartsis, S.S., Kontogiannis, N.D., Vaxevanis, G.
16. **Technical Analysis of Safavid Ceramics**
    Eremin, K., Domoney, K., McWilliams, M., Mason, R., Carey, M., Ferguson, P., Leoni, F.
17. **Revisiting the Beginnings of Tin-opacified Islamic Glazes**
    Tite, M., Pradell, T., Molina, G., Domoney, K., Watson, O., Bouquillon, A.

Tuesday

STONE, PLASTER AND PIGMENTS

18. **Non-Destructive Analysis of Olmec Green Stone Figurines and Axes from La Venta's Offering 4**
    Claes, P., Ruvalcaba Sil, J.L., Filloy, L., Wong Rueda, M., García Bucio, M.A.
19. **Provenance Analysis of 1500 Obsidian Artifacts from 40+ Sites in Sicily (Italy)**
    Tykot, R.H., Freund, K.P., Vianello, A.
20. **Magnetic and Geochemical Characterization of Georeferenced Obsidian Samples from Four Source Areas in New Mexico**
    Sternberg, R., Shackley, M.S., Feinberg, J.M., Steffen, A., Freeman, A., Gregovich, A., Hackett, C., Harrison, M., Kim, M., Osborne, Z., Pollen, A., Regier, M., Roth, K., Samuels, R.
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)**
    Beck, L., Rousselière, H., Castaing, J., Duran, A., Lebon, M., Plassard, F. -
22. **Purple in Sumhuram, Oman (1st-2nd Century AD), Revealed by Mass Spectrometric and Chromatographic**
    Ribechini, E., Degano, I., Zanaboni, M., Pavan, A., Colombini, M.P., Pérez-Arantegui, J.

CERAMICS, GLAZES, GLASS AND VITREOUS MATERIALS

23. **Technology and Indigeneity in Mughal Glazed Tile-Work**
    Gill, M.S., Rehren, T.
24. **Plumbate Ceramic Ecology**
    Neff, H., Garfin, T., Burger, P., Niespolo, E.
25. **Paradise for Petrographers: Tracking Movements of Lapita Pottery (1200-900 cal BCE) between New Caledonia, Isle des Pins, the Loyalty Islands and Vanuatu**
    Killick, D., Chiu, S., Sand, C., Dickinson, W.R.
26. **Technological Change and Provenance of Glass in Early Islamic Palestine**
    Phelps, M., Freestone, I., Gratuze, B. Lankton, J.
27. **Origin and Development of Blue-and-White Porcelain in Ancient China**
    Li, W., Lu, X., Liu, L., Sun, X. -
28. **XRF Analysis of Vincennes-Sèvres Porcelain: Characterization, Dating and Attribution**
    Domoney, K., Shortland, A.J., Kuhn, S., Megens, N.

METALS AND METALLURGICAL CERAMICS

29. **How To Cook your Met(al): Reconstructing The World's Earliest Metallurgy**
    Radivojević, M., Boscher, L., Timberlake, S., Asmus, B., Radivojević, J., Chen, K., Rehren, Th.
30. **Metal and Elites in Upper Mesopotamia - Uniqueness or Uniformity?**
    Franke, K.A. -
31. **Aspects on the introduction of tin in the Aegean during the 2nd millennium BC**
    Bassiakos, Y., Mastrotheodoros, G., Filippaki, L.
32. **Physical Barriers, Cultural Connections: Ancient Metallurgy Across the Alpine Region**
    Perucchetti, L., Bray, P., Pollard, A.M.
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 typo-chronology**
    Le Carlier, C., Le Bannier, J.C., Marcigny, C., Fily, M.
34. **Elemental and Lead Isotopic Data of Copper Finds from the Singen Cemetery, Germany – a Methodological Approach to Investigate Early Bronze Age Trade Networks**
    Villa, I.M., Cattin, F., Merkl, M.B., Strahm, Ch.

FROM THE BRONZE AGE TO THE IRON AGE

35. **Time and context of change at the close of the Late Bronze Age and in the early Iron Age**
Manning, S.W.
36. **Copper in the Iron Age**
Kassianidou, V.
37. **Crisis in Context: The End of the Late Bronze Age in the Eastern Mediterranean**
Knapp, A.B.
38. **An Isotopic Trip through First Millennium BC Glass History**
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39. **Small Compositional Groups, Production Events and the Organisation of Production**
Freestone, Ian University College London

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40. **Extending the Luminescence Dating Range to the full Quaternary**
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41. **Recent advances in Geochronology and geochemistry applied to human fossil remains: maximizing the information with minimal damage**
Joannes-Boyau, R.
42. **New Evidence with Radiocarbon for the Appearance of the Earliest Farmers in the Aegean**
Maniatis, Y., Kotsakis, K.
43. **Radiocarbon dating of old plasters and mortars. An overview of the last 5 years application of the "pure lime lumps" technique**
Pesce, G.L., Vecchiattini, R., Ball, R.J.
44. **A New Approach for Combining Historical, Archaeological, and Scientific Chronologies**
Höflmayer, F., Burke, A.A.

FORENSIC SCIENCE INVESTIGATIONS IN ART AND ARCHAEOLOGY

45. **More than meets the eye: Fiber Analysis and Manuscripts from the Silk Roads**
Helman-Ważny, A.
46. **Improving lateral resolution of isotopic measurements of ancient glasses using spatially resolved ion beam microanalysis: the LA case**
Boehnke, P., Harrison, M. Kakoulli, I.
47. **Testing the authenticity of the Sky Disc of Nebra**
Pernicka, E.
48. **Beyond the UNESCO Convention: the Case of the Troy Gold in the Penn Museum**
Rose, B.
49. **Acquiring antiquities for museums: ethics, policy, and analysis**
Potts, T.
50. **Panel and open forum: forensic science investigations in art and archaeology**

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51. **Pushing the Limits of Fatty Acid Stable Carbon Isotope Analysis in the Archaeological Record**
Evershed, R.P., Salque, M., Cramp, L., Pääkkönen, M., Outram, A.

52. **Characterizing changing animal management practices, land use strategies and Palaeoenvironments through time in the North Atlantic Islands: an isotopic approach**
Jones, J.R., Nordgren, E., Mulville, J.
53. **Mobility and Diet in the Bronze Age West Eurasian Steppes: A Multi-Isotope Approach**
Gerling, C., Pike, A., Heyd, V., Kaiser, E., Parzinger, H., Schier, W.
54. **Hopanoids as Biomarkers of Pulque in Mesoamerica**
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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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56. **Changing Coastal Resource Use in the Bronze and Iron Ages at Ra's al-Hadd, Oman**
Cartwright, C.
57. **The DNA sequencing revolution: new opportunities for biomolecular archaeology**
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HUMAN ENVIRONMENT INTERACTIONS AND BIO-MATERIALS BIOARCHAEOLOGY

58. **Medicinal Clays and 'Earths': from geo-archaeological research to microbiological testing**
Photos-Jones, E., Keane, C., Stamatakis, M., Hall, A.J., Leanord, A.
59. **Integration of advanced analytical techniques in the studies of the Dead Sea Scrolls**
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Middleton, W.D., Joyce, A.A., Messinger, D.W., Canham, K., Goman, M., Borejzsa, A., Mueller, R.
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Kaiser, B.
68. **Cobmbined SEM and Raman spectroscopy: a powerful analytical tool for archaeometry**
King, A.

METALS AND METALLURGICAL CERAMICS

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Eley, T., Boscher, L., Georgakopoulou, M.

70. **Crucible or furnace: a comparative study of silver production traditions in north and south China**
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71. **Iron and the Khmer Empire, Cambodia (9th to 15th c.): first study on the sourcing and dating of iron construction materials of Angkor**
Leroy, S., Hendrickson, M., Delqué-Kolic, E., Vega, E., Dillmann, P.
72. **Archaeometallurgy of Metal Finds from the Medieval "Royal" Burials of Durbi Takusheyi, Northern Nigeria**
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73. **Outside the gates - Metalworking around medieval and post medieval Copenhagen**
Jouttijärvi, A.
74. **Copper production at El Coyote Honduras: The first evidence for copper smelting in Central America**
Shugar, A., Urban, P., Schortman, E.
75. **Goldsmiths or Wax Sculptors? Individual Skill and Social Agency in Muisca metalwork (Colombia, AD 600-1800)**
Martinón-Torres, M. Uribe, M.A.

Friday

CERAMICS, GLAZES, GLASS AND VITREOUS MATERIALS

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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77. **First Archaeometrical Data of Glass from Sarno Necropolis (9th – 6th Century BC)**
Conte, S., Arletti, R., Mermati, F.
78. **Boron Isotopic Composition of Roman Natron Glasses to Provenance the Flux Raw Material**
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79. **Iron Age Glass from Myanmar: Addressing Provenance Issues with Trace Element and Isotopic Compositions**
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80. **Characterization and contemporary replicae of Art Noveau coloured glass**
Fornacelli, C., Bracci, S., Memmi Turbanti, I., Picollo, M., Vilarigues, M., Troeira, M.
81. **Glass Chemical Analysis: Assessing the New Heterarchy**
Lankton, J.W., Gratuze, B., Cholakova, A., Freestone, I., Phelps, M., Rehren, T.
82. **Glass and Diagrams: a Review (Roman and Medieval glasses from the Mediterranean area)**
Gliozzo, E.

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Getty Villa, Monday and Tuesday, May 19-20

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84. **Analysis of Colored Archaeological Fibers from Taira, north of Chile.**
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85. **Investigation study of using Laser-Induced Breakdown Spectroscopy (LIBS) on analysis of Historical Embroideries**
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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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87. **Rock Art at Morro Azul caves in Paraná State, Brazil: an in situ XRF and Raman study**
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91. **Influence of synthesis conditions on growth of Egyptian blue**
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93. **Use-wear Evidence and Functional Information on Lithic Tools at Wulanmulun site, Inner Mongolia, China**
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94. **Characterization of Natural and Artificial Stone Materials from S. Niccolò Archaeological Complex in Montieri (Tuscany, Italy)**
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95. **The use of huntite in the antiquity. A review with respect to ongoing studies in the archaeological site of Hierapolis in Phrygia (Turkey)**
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97. **Non-Destructive Analysis of Green Stone Royal Burial Offerings from the Maya Site of Palenque, Mexico**
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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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99. **Contextualizing Bronze Age Obsidian Use at the 'Ritual Spring' of Mitza Pidighi (Sardinia)**
Kyle P. Freund

100. **Identification of Iron Age Corals Using a Multi-Stage Approach**
Sebastian Fürst, Katharina Müller, Céline Paris, Ludovic Bellot-Gurlet, Marine Gay, Ina Reiche
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103. **Towards portable X-ray spectroscopic imaging of Palaeolithic cave art. Insights into used pigments and wall taphonomy at three Palaeolithic key cave sites**
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Ioannis Grammatikakis, Georgia Anagnostaki
106. **Archaeometric Characterization and First Distribution Study of a Spanish Marble used in Antiquity: The Marble from O Incio**
Anna Gutiérrez Garcia, Hernando Royo Plume, Silvia González Soutelo
107. **Microbiological Deterioration and its Relation in Identification of Reinforcement Material Utilization in Gypsum mortar**
M. A. Hawash & H. A. Mahmoud
108. **Characterisation of ochre pigments from Jawoyn rock art paintings of Arnhem Land, Australia**
A. Hunt, B.H. Stuart, P.S. Thomas, D. James, B. David, J-M. Geneste, J-J. Delannoy
109. **Inorganic fillers used in ancient lacquer wares of Warring Sates to Han Dynasty**
Pujun Jin, Xiaogang Yang, Lajiang Jia, Puheng Nan, Bin Li
110. **First Results of a Systematic Study on the Use of Binding Media for Late Mediaeval and Early Modern Wall Paintings in the Low Countries**
Karin Keutgens, Anna Lluveras-Tenorio, Anna Bergmans, Peter Vandenabeele, Bernard Delmotte, Maria Perla Colombini
111. **Spectral Matching of Pigments for Ancient Artifacts Using Hyperspectral Imaging & Analysis**
Mark Allen Lanoue
112. **Investigation of an Unusual Composite Material Found in a Larnax with Cremated Bones in Royal Tomb II at Vergina**
Y. Maniatis, Th. Arvaniti, T. G. Antikas, L. Wynn-Antikas, S. Orsini, E. Ribechini, M.P. Colombini
113. **Provenance Study of Obsidian Artifacts from the Fowler Museum Collection (UCLA) using a Handheld X-ray Fluorescence Spectrometer**
Kristine Martirosyan-Olshansky, Christian Fischer, Wendy Teeter
114. **Metal Leaf Decorations in Post-Byzantine Devotional Panel Paintings from Greece**
George Mastrotheodoros , Konstantinos G. Beltsios, Yannis Bassiakos
115. **Archaeometric Methods Applied to the Conservation and Study of the Site Named 'Altar of Mictlantecuhtli.' A proposal**
Ana Bertha Miramontes Mercado, Fernando Godos González.
116. **Geochemistry of Jadeitites to Link Maya Artifacts and Geologic Sources in Guatemala**
Elizabeth Niespolo, Hector Neff, Gregory Holk, & Brigitte Kovacevich
117. **Illuminated Manuscripts from Turfan: Tracing back Silk Road Glamour by Analysis of Pigments**
Renate Nöller

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118. **Obsidian Economy In Neolithic Corsica: Insights From The Phase III Level Of Renaghju**
Marie Orange, François-Xavier Le Bourdonnec, André D'Anna, Ludovic Bellot-Gurlet, Anja Scheffers, Gérard Poupeau, Carlo Lugliè, Renaud Joannes-Boyau
119. **Importations 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**
Josefina Pérez-Arantegui, Andrea Gil, Lourdes Ventolá, Marius Vendrell, José Antonio Mínguez
120. **Catching Neolithic Humans Red-Handed: the Procurement of Colouring Materials in N.-W. Mediterranean Neolithic**
Jean Victor Pradeau1,Didier Binder, Chrystèle Vérati, Jean-Marc Lardeaux, Ludovic Bellot-Gurlet, Paolo Piccardo, Stéphan Dubernet, Yannick Lefrais, Martine Regert
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"**
Michela Ricca, Mauro Francesco La Russa, Silvestro Antonio Ruffolo, Donatella Barca, Barbara Davidde, Gino Mirocle Crisci
122. **Material Analysis on 17th century Armenian Wall Painting in New Julfa-Isfahan**
A. Sasani, F. C. Petrucci, C. Vaccaro, A. Murray
123. **Elemental and Isotopic Variability in Mogollon-Datil Province Obsidian, Western New Mexico**
M. Steven Shackley
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.W. Arthur, Matthew Curtis, Mauro Coltorti, Pierluigi Pieruccini, Sean Stretton
127. **Marble Sculptures in Algeria: From Local Sources or Elsewhere?**
Robert H. Tykot, Jessica A. Morgan, John J. Herrmann, Jr., Annew ies 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 Nubian Wall-Painting: A Reconstruction of the Past through the Painting Materials and Techniques**
Dobrochna Zielińska, 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**
C. R. Appoloni, R. A. Ikeoka, O. H. Marcori, F. Lopes, M. A. Rizzutto, J. F. Curado, R. B. Scorzelli, P. Munayco and A. M. Bandeira
133. **A Study of Bronze Age Pottery from Al-Khidr Site, Kuwait: Chemical and Petrographic Characterization**
Hasan Ashkanani, Robert H. Tykot, Mary Ownby
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 Vanhaecke, 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 Sherds: Multi-period Pottery Classificationwith the p-XRF, from the excavations at Stromboli-San Vincenzo, Italy**
Valentina Cannavò, Effie Photos-Jones, Sara Tiziana Levi, Daniele Brunelli, Maria Clara Martinelli, Erica Camurri, Pamela Fragnoli, Giacomo Lomarco, 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 Chatr Aryamontri, Gregory A. Pope, Laying Wu
143. **Investigation on the Effects of Drying Time and Age of Glaze on a Macrocrystalline 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**
Ilaria Cianchetta, Karen Trentelman, Jeff Maish, Marc Sebastian Walton
145. **Characterization of Costa Rican Archaeological Ceramics from the Formative Period: Preliminary Electrochemical Studies**
Gerardine Conejo Barboza, Jean Sanabria Chinchilla, Francisco Corrales Ulloa, 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 Qizlar Qal'eh (North-Eastern Iran)**
Maria Daghmehchi, Jebrael Nokandeh,Bahman Firoozmandi Shirejini
148. **Copper and Antimony isotopic analysis via multi-collector ICP-mass spectrometry for provenancing ancient glass**
Patrick Degryse, Lara Lobo, Domingo Gimeno, Andrew Shortland, Katherine Eremin, Frank Vanhaecke
149. **Two pre-Columbian Pottery Productions of the Peruvian North Coast: An Archaeometrical Approach to Understand 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)**
Kaatje De Langhe, Bart Vekemans, Wim De Clercq, Peter Vandenabeele, Laszlo Vincze
151. **An Application of Geological Survey and Ceramic Compositional Studies for Tracing Provenance and Probing Manufacture Practices during Pre-History in Alentejo (Portugal)**
M. I. Dias, 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 Ganio, Veerle Devulder, Frank Vanhaecke, Domingo Gimeno, Olivier Bonnerot, Patrick Degryse, Marc Walton
154. **The archaeological site of Luni: first archaeometrical results on the glass findings**
Monica Ganio, Kris Latruwe, Frank Vanhaecke, Patrick Degryse, Marc Walton

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 Corsica. Insights of a Mycenaean influence?**
Eleonora Canobbio, Ludovic Bellot-Gurlet, Céline Paris, Joseph Césari, Franck Léandri, Céline Léandri, Kewin Peche-Quilichini
156. **The Technology of Late Bronze Age/Early Iron Age Glass in the Mediterranean: Analytical Studies of Vitreous Materials from Lofkënd**
Vanessa Muros, Nikolaos Zacharias, John K. Papadopoulos
157. **Not first but fast: on the Bronze-Iron Age transition in mainland Southeast Asia**
T. O. Pryce
158. **Beads Culture of Early Myanmar, Doorway to Southeast Asia**
Terence Tan

METALS AND METALLURGICAL CERAMICS

159. **Persian Crucible Steel Production: Chāhak Tradition**
Rahil Alipour, Thilo Rehren
160. **Tracking Technological Change in High Resolution: an XRF Study of Iron Age Copper Smelting in the Southern Levant**
Erez Ben-Yosef, Thomas E. Levy
161. **Experimental and Analytical Investigation of Black Bronze Alloys**
Agnese Benzonelli, Ian Freestone, Marcos Martinón-Torres
162. **An Unusual Example of Gold Cloisonné from Central Anatolia**
Alice Boccia Paterakis, Sachihiro Omura, Ellen van Bork
163. **Analytical Study of Andean Precolumbian Metallurgy by Energy Dispersive X-Ray Fluorescence**
Jorge A. Bravo, Mirian E. Mejia, Mercedes Delgado, Alejandro L. Trujillo
164. **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, Danièle Perrey, Maitena Sohn, Igor M. Villa, Alain Villes
165. **Low Tin Bronze Corrosion by Hydrosulfide (HS-) and Sulfide (S2-) Ions**
Michelle Chan, Alexandra Capek, Simon J. Garrett
166. **Gold in Palaepaphos (Cyprus): A Study of Artifacts from the Early Iron Age Necropolis of Skales using Portable X-Ray Fluorescence Spectrometry (pXRF)**
Andreas Charalambous, Vasiliki Kassianidou, George Papasavvas
167. **Evidence of arsenical copper smelting of Bronze Age China: a preliminary study of slag discovered at the Laoniupo Site, Central Shaanxi**
Kunlong Chen, Yanxiang Li, Lianjian Yue
168. **New Insights to the Early 19th-Century Naval Technology: Metallurgical Examination of the Cargo of a British Transport Lost Off Catalonia Coast, Spain**
Nicolás Ciarlo

169. **Breaking Fad: Pushing the Boundaries of Metallurgical Communities at The Cenote Sagradro**
Bryan Cockrell, José Luis Ruvalcaba Sil, Edith Ortiz Díaz
170. **Thracian Silver Artifacts from Romanian and USA Museums - the Same Provenance Workshop**
Bogdan Constantinescu
171. **Neutron diffraction characterization of pre-Roman coinage from northern Italy: silver debasement and relationships within different emissions**
J. Corsi, C. Ricci, A. Scherillo, A. Re, A. Lo Giudice, F. Grazzi, F. Barello
172. **Comparison Between Quantitative (ICP-OES) and Qualitative (pXRF) Data of Iron Slag from Sagalassos (SW-Turkey)**
Kim Eekelers, Rebecca Scott, Patrick Degryse, Phillipe Muchez
173. **Methodological Development for the Decomposition of Ancient Iron Slags for ICP-OES Analysis**
Kim Eekelers, Elvira Vassilieva, Phillipe Muchez, Patrick Degryse
174. **Mill scale on historic wrought iron: characterisation and impact on corrosion behaviour**
Nicola Emmerson, Eric Nordgren, David Watkinson
175. **From sculptures to foundries: elemental compositional analysis to trace modern bronzes provenance**
Monica Ganio, Francesca Casadio, Katherine Faber, Anne Leonard, Johanna Salvant, Marc Walton
176. **Gilded and Silvered Artefacts from Medieval Tuscia (Italy): Materials and Technological Features**
Mainardo Gaudenzi Asinelli, Marcos Martinón-Torres
177. **In the middle of it all: metallurgy in Early Bronze Age Palamari (Skyros island, Aegean)**
Myrto Georgakopoulou, Stamatis Bonatsos, Yannis Bassiakos
178. **On the Distribution of European Copper Artifacts in Northeastern North America**
R.G.V. Hancock, J.-F. Moreou, K . Lulichelaki, W. Foxa
179. **The Importance of Kestel in Anatolian Metal Supply**
Philly Howarth, Mark Pollard, Peter Bray
180. **Exploitation of Manganese-Rich 'Ore' to Smelt Iron in Mwenge, Western Uganda**
Louise Iles
181. **The metallographic and lead isotopic research on several bronze weapons corresponding to origination of Qin Dynasty**
Lajiang Jia, Pujun Jin, Congcang Zhao, Xue Lin, Xiaogang Yang, Puheng Nan
182. **Combine XRD, Metallography and RadiographyAnalysis of Metal and Corrosion Products for Luristan Bronzes, Iran**
Zahra Karamad, Zahra Nikoei

SESSION II
CNSI at UCLA, Wednesday to Thursday, May 21-22

ARCHAEO-CHRONOMETRY

183. **The Aegean Early Bronze Age, Tracing the Absolute Timeframe - Looking for Boundaries**
Theodora Arvaniti, Yannis Maniatis
184. **Embracing In-Homogeneity in Archaeomagnetism: Implications for Sampling and Analysis**
Eric Blinman, J. Royce Cox.
185. **Dating results of new palaeoenvironmental studies conducted in South Peloponnesus, Greece**
John Christodoulakis, Yannis Bassiakos, Evangellos Tsakalos, Maria Kazantzaki
186. **Back to Basics: Understanding the Major Factors Affecting Absorbed Organic Residue Preservation in Archaeological Ceramics**
Marisol Correa Ascencio, Richard P. Evershed

187. **The Rectorate Building of the University of Cagliari (18th century): metrologicalchronological and materical analysis of masonries**
Caterina Giannattasio, Silvana Maria Grillo
188. **Rehydroxylation Dating of Pre-Hispanic and Colonial Fired-Clay Artifacts from Aguascalientes, Mexico**
Becket Lailson, Jose R. Alvarez, Jorge Balmaseda, Ana M. Pelz, Nicolás Caretta, Niklas Schulze, Marisol Martínez, Eli Puch
189. **Comparative Study of Two Estruscan Bucchero Amphoras**
Elena Minina, A. Mazina, S. Sokolov
190. **Putting a Puzzle Together: A Roman Bronze Lamp from Kavastu (Estonia)**
Ester Oras, Thomas Higham, Ian D. Bull, Lucy Cramp
191. **Radiocarbon Dating of Pacific Island Wooden Figures: Multiple Analyses Produce Better Age Determinations**
Christine A. Prior
192. **Reexamining the Archaeology of the Colorado Plateau (USA) Using Radiocarbon Dating of Collected Wood**
Dana Drake Rosenstein, Ronald H. Towner, Gregory W.H. Hodgins and Jeffrey S. Dean
193. **The First Experience of Comparative Radiocarbon Dating of Archaeological Monuments of Late Bronze Age Southern Transurals**
I.A.Shuteleva, T.A.Leonova
194. **Dating of Submerged Landscapes by Electron Spin Resonance**
Anne R. Skinner, Justin K. Dix, Edward Cho, Fraser Sturt, Justin P. Mangope, Bonnie A. B. Blackwell
195. **Geochronology of the Royal Tomb at Ulaankhermiin Shoroon Bumbagar, Mongolia**
S. Solongo, A.Ochir, S.Tengis, K.Fitzsimmons
196. **Luminescence Dating for Artefacts and for Field Studies: Alterations, Variations and the Context**
N. Zacharias
197. **Quaternary Palaeoenvironmental Reconstruction of the Coastal Zone of North Evoikos Gulf (Greece) based on the use of Luminescence Dating Techniques**
Maria Kazantzaki, Yannis Bassiakos, Theodora Rondoyanni, Evangelos Tsakalos, John Christodoulakis
198. **Change in Production and Distribution Pattern of Olivine-Tempered Ceramics Using OSL Dating**
Sachiko Sakai
199. **Unraveling the Palaeoenvironmental Framework of Southeast Cyprus over the Late Quaternary - Luminescence Geochronology and Quartz Grains-Shape Examination**
Evangelos Tsakalos, Yannis Bassiakos, Maria Kazantzaki, John Christodoulakis

FORENSIC SCIENCE INVESTIGATIONS IN ART AND ARCHAEOLOGY

200. **Epifanio Garay Between the Truth and the Oral Tradition: A Spectroscopic Micro-Raman Study**
Diego Badillo, Wolfram Baumann
201. **Rapid Identification of a Blood Encrustation on an African Ritual Mask by DART-MS**
Daniel Fraser, Cathy Selvius DeRoo, Robert Cody, Sylvia Torres, Ruth Ann Armitage
202. **The use of enzyme-linked immunosorbant assay and mass spectrometry for the characterization of binding media in Egyptian Romano portraits**
Takashi Nakazawa, Yoko Taniguchi, Kazuki Kawahara, Shunsuke Fukakusa, Joy Mazurek, Marie Svoboda, Jeffrey Maish
203. **Analysis of an Egyptian Sarcophagus Fragment**
Colleen O'Shea, Aaron Shugar, Lucy Skinner
204. **Mayans Did Not Just Drink Chocolate?**
Shawn Owens, Marshall Ligare, Mattanjah S. de Vries, Stuart Tyson Smith, Anabel Ford
205. **Quantitative Elemental Analysis of Historical Soil through XRF, AAS, ICP-OES and EDX**
Capri Price, Natasja Swartz, Doug Wilson, Tami L.Clare
206. **Application of VPSEM-μRS for SERS analysis of archaeological textiles**
Diana C. Rambaldi, Sergey V. Prikhodko, Vanessa Muros, Elizabeth Burr, and Ioanna Kakoulli

207. **Getting to the Root of It: Analysis of Human Skeletal Remains from the New Haven Green**
Yukiko Tonoike, Nicholas F. Bellantoni, Gary P. Aronsen, Gerald J. Conlogue, John Krigbaum, Lars Fehren-Schmitz, Natalie A. Pellatier, Robert Lombardo, Kylie Williamson, Judith A. Schiff, Frank Hole
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 Karul, Songül Alpaslan-Roodenberg, Ron Pinhasi, Malcolm Lillie
213. **The use of strontium isotope data from human dental enamel as prima facie evidence for evaluating human provenience and mobility.**
James H. Burton
214. **Thermal degradation chemistry of archaeological pine pitch: alone and mixed with beeswax**
Maria Perla Colombini, Celia Duce, Andreas Kurzweil, Sibilla Orsini, Erika Ribechini, Alessio Spepi, Maria Rosaria Tinè
215. **Biochemical Indicators of Diet in a Late Muisca Settlement in the Northern Andes: Stable Isotopes and Trace Elements**
M. E. Delgado Burbano, C. H. Langebaek, L. Aristizabal, R. H. Tykot, L. Johnson
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 Lugliè, 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, Jaibir Singh Pharswan
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.**
Rafael R. Galindo, Brian Castro, Cesar Sierra, Helen H. Henderson
219. **Migration or not? Diet evidence of stable isotope analysis of human and animal from the Qinglongquan site, China**
Yi Guo, Yilu Fan, Yaowu Hu, Junying Zhu, Changsui Wang, Benjiamin Fuller, Michael P. Richards
220. **The Holy Wells of Scotland: a geo-hydro-archaeological approach to their study**
Alan J Hall , Alex Alexander, Alan Stroud, Effie Photos-Jones
221. **How to fit vegetation in a box? Building a palaeobotanical and chemical database for the project "Exsudarch".**
Auréade Henry, Claire Delhon, Arnauld Jouvenez, Antoine Pasqualini, Maxime Rageot, Martine Regert
222. **Anthraquinone Dye Colorants in Red Fibers from the Seip Mound, Ohio**
Kathryn Jakes, Ruth Ann Armitage, Calvin Day
223. **Paleodiet and Society in Medieval Rural Communities from Basque Country (Spain)**
Carmine Lubritto, Maite Iris García-Collado, Carmina Sirignano, Paola Ricci, Simona Altieri, Juan Antonio Quirós Castillo

224. **Climate driven dietary and agricultural change in the late Eneolithic/early Bronze Age Ukrainian Steppe recorded in organic residues in ceramic vessels**
Simona Mileto, Richard P. Evershed, Elke Kaiser, Yuri Rassamakin, Wolfram Schier
225. **Was the Climate Too Harsh for the Late Neolithic Farmers of Finland? Tracing Foraging-Farming through Organic Residues in Pottery**
Mirva Pääkkönen, Richard Evershed, Henrik Asplund
226. **Diagnosis of the Conservation State of a Granitic Outcrop with Rock Art.**
S. Pozo, L. García, F. Carrera, T. Rivas
227. **Characterizing organic micro-residues by non- or micro-destructive method: new trends in mass spectrometry (DART TOF) combined with organic and inorganic analysis**
M. Rageot, X. Fernandez, J-J. Filippi, L. Bellot-Gurlet, A.S. Le Hô, K. Pêche-Quilichini, M. Regert
228. **The POMEDOR Project: People, Pottery and Food in the medieval Eastern Mediterranean**
S.Y. Waksman, A. Pecci, R.S. Gabrieli, E.J. Stern, J. Vroom and the POMEDOR collaboration
229. **The Study of Hyaena Coprolites from a Paleolithic Site of Central China**
Wenjuan Wang, Guoding Song, Zhanyang Li, YanWu
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 (Alvaiázere, Portugal): Preliminary Results**
Anna J. Waterman, Robert H. Tykot, Alexandra Figueiredo
231. **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
232. **Reconstructing Diet in Neolithic Greece using Stable Isotopes from Lipid Residues in Pottery**
Helen Whelton, Mélanie Roffet-Salque, Kostas Kotsakis, Dushka Urem-Kotsou, Richard P. Evershed1
233. **The relationship between archaeological site distribution and shoreline changes of Taiwan**
Hsiao-chin Yang, Wen-shan Chen
234. **MRI and NMR-MOUSE study of reindeer skin tanning processes**
Lizheng Zhu, Andy Ilott, Torunn Klokkernes, Cindie Kehlet, Eleonora Delfederico, Alexej Jerschow

REMOTE SENSING AND GEOPHYSICAL PROSPECTION AND FIELD ARCHAEOLOGY

235. **Subsurface Survey and Spatial Analysis on Chalcolithic Settlements From Eastern Romania**
Andrei Asandulesei, Ionuț Cristi Nicu, Radu Balaur, Stefan Caliniuc, Vasile Cotiuga, Cristian-Constantin Stoleriu, Oana Mihaela Stoleriu
236. **Geophysical studies of ancient tumulus in Azapa Valley, Arica, Chile**
Luis Barba, Ivan Muñoz, Agustín Ortiz, Jorge Blancas
237. **Geophysical studies for the location of a mammoth remains in Mexico City**
Luis Barba, Agustín Ortiz, Jorge Blancas, Joaquín Arroyo
238. **Preliminary conservation issues study of unearthed marble ruins in the Plutonium of Hierapolis (Denizli, Turkey)**
F. D'Andria, S. Bracci, P. Caggia, E. Cantisani, T. Ismaelli, C. Riminesi, B. Sacchi, G. Scardozzi, S. Vettori
239. **Wireless Environmental Monitoring Devices for Historical Collections and Cultural Heritage Sites**
Alexandra Jeberien, Susanne Litty
240. **Photogrametry and Visualization of the Viminacium**
Miomir Korać, Snežana Golubović, Željko Jovanović
241. **Roman Legionary fort Viminacium – Multidisciplinary Research**
Miomir Korać, Nemanja Mrđić
242. **Contribution of new geophysical measurement of previously excavated Neolithic roundel area near Bylany.**
Roman Křivánek
243. **Mapping of Indus-Saraswati Civilization (Using Geographical Information System)**
Kulbhushan Mishra, Sudesh Nangia
244. **Elucidation of the degradation mechanisms in archaeological birch bark**

Sibilla Orsini, Erika Ribechini, Francesca Modugno, Johanna Klügh, Maria Perla Colombini

245. **Application of REMPI Laser Mass Spectrometry to Cultural Heritage**
Shawn Owens, Jacob Berenbeim, Mattanjah S de Vries, Stuart Tyson-Smith, Anabel Ford

246. **The examination of dynamics of oak wood degradation process in the wet peat and lake water conditions**
Jeanette Lucejko, Magdalena Zborowska, Leszek Babiński, Bogusława Waliszewska, Francesca Modugno, Diego Tamburini, Maria Perla Colombini

OTHER

247. **The Red and The Gray: Ochre Pigments and Iron Ores from Twin Rivers Kopje, Zambia**
Andrew M. Zipkin, Alison S. Brooks, John M. Hanchar, Kathy Shick, Nicholas P. Toth

248. **Petrological- chemical investigations for characterization of marble stones discovered in south Konar-Sandal (Jiroft, Iran)**
Mohammad Amin Emami, Parvin Soleimani

249. **Study on the Smelting and Casting Technology of Copper and Copper Alloy: Wares from Central Plains in the Early Bronze Age of China**
Yu Liu, Jianli Chen, Hong Xu, Nu He, Chunqing Zhao

SESSION III
CNSI at UCLA, Thursday to Friday, May 22-23

CERAMICS, GLAZES, GLASS AND VITREOUS MATERIALS

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

251. **Clays, Kilns and Ceramic Productions in Northern Apulia**
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1. Full-field X-ray spectroscopy offers new possibilities for the study of paintings

E.Pouyet[1], M.Cotte[1,2], B. Fayard[1,3], L. Monico[4,5], J.Mass[6], G. Nuyts[4], M. Radepont, P.Sciau[7]

1 *European Synchrotron Radiation Facility, ESRF, 6, rue Jules Horowitz, F-38000 Grenoble, France*
2 *L.A.M.S., CNRS UMR8220, 3, rue Galilée, F-94200 Ivry-Sur-Seine, France*
3 *Laboratoire de Physique des Solides, UMR 8602 CNRS, Paris, France*
4 *Antwerp University, Chemistry Department, Groenenborgerlaan 171, B-2020 Antwerp, Belgium*
5 *CNR-ISTM, c/o Chemistry Department, Perugia University, via Elce di Sotto 8, I-06123 Perugia, Italy*
6 *Scientific Research and Analysis Laboratory, Winterthur Museum, Winterthur, Delaware 19735, USA*
7 *Groupe nMat, CEMES-CNRS, 29 rue Jeanne Marvig, BP 94347, 31055 Toulouse Cedex 4, France*

The complex, layered, and heterogeneous structure of painting materials complicates their chemical characterization. Consequently, chemical-imaging techniques, combining microscopy and spectroscopy, are well suited to obtain full 2D characterization of paint fragments. Both composition and spatial organization of the multilayered complex mixtures constitutive of paintings are probed. Within the last decades synchrotron radiation (SR)-based micro-imaging techniques have been used to an increasing extent for the analysis of painting fragments. Based on a highly bright and collimated source, they offer high spatial resolution combined with very low detection limits. Among the various techniques available, X-ray absorption spectroscopy (XAS) is largely applied to understand chemical processes taking place both during the creation and the degradation of the artwork, since both processes are usually governed by oxidation-reduction reactions [1]. Based on this statement, the 2D full-field XANES set-up recently developed at ID21, ESRF, combining XAS with full-field X-ray microscopy was applied to study ancient artistic materials. Basically, a set of radiographies are acquired over millimetric field of view (up to 2mm2) with sub-micron resolution (down to 0.9 µm2), while scanning the energy of the incoming pencil beam around the absorption edge of the element of interest. Millions XAS spectra are thus acquired within minutes [2]. This technique is therefore very well suited for the 2D study of multilayered and heterogeneous samples such as artistic materials.

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 studying 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.

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

Walter Prochaska[1], Donato Attanasio[2], and Matthias Bruno[3]

1. *Department of Applied Geological Sciences and Geophysics, University of Leoben, A-8700 Austria*
2. *Istituto di Struttura della Materia del CNR, Monterotondo Stazione 00016 Rome, Italy*
3. *Via dei Vascellari 34, 00153, Roma, Italy*

Since the pioneering work of Craig and Craig in 1972 the stable isotope investigation of white marbles became the most important technique in the investigation of marble provenance. Consequently, an enormous amount of data on the isotopic composition of marbles from quarries and artifacts is available until now entailing however confusing overlaps of the corresponding compositional fields.
The evident demand for further characteristic variables led us to extend the database with further analytical data and analyzed a set of trace elements of the marbles. We focused on the ions substituting Ca^{2+} in the lattice site of the carbonate minerals (Mg, Fe, Mn, and Sr) which show a more consistent distribution and show much less scattering than elements bound to trace minerals.
Searching for more selective parameters for the characterization of ancient marbles we extended the databank with the results from the chemical analysis of microinclusions which are present in all marbles. These inclusions are extracted from the marbles and analyzed by different analytical methods. Since metamorphism homogenizes the fluid phase of a marble on a regional scale, a reliable result will be achieved, even when using small samples. Until now results of some 2000 quarry samples from all classical marble locations are available.
The discovery of the quarries Göktepe of Aphrodisias contributed essentially to the knowledge of the marble used in ancient Roman times throughout the whole empire. The production of fine-grained white marble of highest quality used exclusively for portraits is attested from the mid of the first century AD until advanced late antiquity.
The macroscopic features of the Göktepe marble are very similar to other high quality marbles used in antiquity, so we looked for particular analytical characteristics for unambiguous archaeometrical identification. Trace element contents, namely low Fe and unusual and homogenous high Sr numbers, discriminate the Göktepe marbles perfectly against all other prominent high-quality, fine-grained marbles.

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 Lychnites (21%), followed by Carrara with 10%.

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

Véronique Wright[1], Gianella Pacheco[2], Henry Torres[3], Oliver Huaman[4], and Aldo Watanave[5].

1. *Ministère des Affaires Étrangères, Institut Français d'Études Andines, UMIFRE 17 - CNRS MAE USR3337; Projet de Recherche Tambo Colorado, Lima Peru.*
2. *Projet de Recherche Tambo Colorado, Lima Peru.*
3. *Projet de Recherche Tambo Colorado, Lima Peru.*
4. *Projet de Recherche Tambo Colorado, Lima Peru.*
5. *Programa Arqueológico San José de Moro, Laboratorio de Arqueologia, Pontificia Universidad Católica del Perú, Lima Peru.*

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 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 transdisciplinary 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 painting technology developed by Inca artisans and artists who made these murals. To achieve these objectives we have done archaeometric studies on the painted surfaces *in situ* and in the laboratory, according to an experimental protocol with observation techniques (optical and electron microscopies), colorimetry, elemental analysis (XRF) and structural analysis (X-ray diffraction, Raman and Infrared spectra) [3]. Furthermore, to investigate the origin of the painting materials it was studied geological areas that were possibly used as quarries for making the pigments of the site.

The first results obtained allow us not only to reconstruct the operational chain followed to elaborate the murals, (since the pigments extraction to the making of the murals) but also allow us to consider and develop a suitable surfaces conservation plan.

Finally, to compare these analyses with the research developed about pre-Hispanic Peruvian civilizations of the north coast [4] [5] [6] to contextualize this Inca complex in a wider space-time context, providing new information to the understanding and development of this unique artistic expression in Peru.

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

Safaa Abd El Salam[1] and Yannis Maniatis[2]

1. *Faculty of Fine Arts, Department of Painting, University of Alexandria, Egypt.*
2. *Laboratory of Archaeometry, Institute of Materials Science, National Centre for Scientific Research "Demokritos", Greece*

Following the research that has been carried out on 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:

-OP: Optical microscopy for the initial examination of polished cross-sections to identify the structure and microstratigraphy 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, nitrites and nitrates.

-SM: 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 EDXA: 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, bath rooms had a different mixture compared to each other.

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

D. Miriello[1], D. Barca[1], A. Pecci[1], R. De Luca[1], G. M. Crisci[1], L. López Luján[2] and L. Barba[3]

1. *Dipartimento di Biologia, Ecologia e Scienze della Terra (DiBEST), Università della Calabria, Arcavacata di Rende (CS), Italy.*
2. *Museo Templo Mayor, Instituto Nacional de Antropologia e Historia (INAH), Guatemala 60, Centro 06060, México, D.F.; Institut d'études avancées de Paris, Paris, France.*
3. *Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México (UNAM), México. D.F.*

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, three 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 aims to provide information on the raw materials, their provenience, 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 replastering practice in the same constructive phases.

Changes in the different 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 lumps 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 plasters of the analyzed buildings 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)

G.M. Crisci[1], M.F. La Russa[1], N.Rovella1, S.A. Ruffolo[1], M. Andaloro[2], C.Pelosi[2], P.Pogliani[2]

1 *D.B.E.S.T, Università della Calabria, Arcavacata di Rende (CS), Italia.*
2 *Dipartimento di Scienze dei Beni Culturali (DISBEC),Università della Tuscia, Viterbo, Italia.*

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 Nevşehir district, especially in the areas near Göreme and Ürgüp, an important part of Turkey's heritage due to its historical past.

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 Miocene-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 Tokalı church (10th century) in the Open Air Museum of Göreme, the most famous rupestrian sites, and in the four layers of the palimpsest painting of the Forty Martyrs church (from 6th to 13th centuries) in Şahinefendi.

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

Marie D. Jackson[1], and John P. Oleson[2]

1. *UC Berkeley, Department of Civil & Environmental Engineering, Berkeley, CA, USA.*
2. *University of Victoria, Victoria, BC, Canada.*

Roman seawater harbor installations in the Bay of Pozzuoli near Naples were “made possible by the natural qualities of the local sand (ámmos), 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 construction technology and material provenance of the maritime structures. ICP-MS analyses of presumably immobile trace elements in pumice clasts, Y, Zr, Nb, La, Yb, Ta, Th, confirm the provenance of ash from “the vicinity of Baiae” in the Campi Flegrei volcanic district (Vitruvius, de Architectura 2.6.1). NEXAFS spectra determined through Soft X-ray Transmission Microscopy reveal the bonding environments of Al3+ and Si4+ in crystalline Al-tobermorite and calcium-alumina-silicate-hydrate (C-A-S-H) binder, and inform the long term stability of piers built in the sea so that “neither the force of the waves, nor the effect of the [sea]water can dissolve them” (Vitruvius, de Architectura 2.6.1), even after 2000 years in the aggressive maritime environment. An adiabatic thermal model of the Baianus Sinus breakwater computes maximum temperatures of 75–95 ºC produced by heat evolved through hydration of quicklime and C-A-S-H cementitious binder, using the lime (calx), pumiceous volcanic ash (pulvis), and tuff (tofus) concrete mix described by Vitruvius, which “seethes with the latent heat in the substances, vehemently causes them to combine into a unified mass and gain solidity quickly” (de Architectura 2.6.4). X-ray microdiffraction studies with synchroton radiation reveal Al-tobermorite in vesicles of the pumiceous ash pozzolan, and validate the cementitious properties of “the powdery earth of Puteoli (Puteolanus pulvis) [which] becomes rock if it touches water (Seneca, Questions about Nature 3.20.3). These rocks are the lithified tuff deposits along the shoreline of Pozzuoli Bay. Romans apparently used this geologic analog as a conceptual basis for the cohesion of the seawater concretes: “For who could marvel enough that on the hills of Puteoli there exists a dust (pulvis) … that, as soon as it comes into contact with the waves of the sea and is submerged, becomes a single stone mass, impregnable to the waves and every day stronger” (Pliny, Natural History 35.166). The pyroclastic rock–lime–seawater concrete developed by republican era engineers has great relevance to the production of highly resilient and environmentally sustainable concretes two millenia 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 Bamiyan valley (Afghanistan)

Anna Lluveras-Tenorio[1], Leila Birolo[2], Catharina Blaensdorf[3], Ilaria Bonaduce[1], Marine Cotte[5], Eugenio Galano[2], Emeline Pouyet[5], Maria Perla Colombini[1]

1. *Dipartimento di Chimica e Chimica Industriale, Università di Pisa, via Risorgimento 35, 56126 Pisa, Italy.*
2. *Dipartimento di Scienze Chimiche, Università di Napoli Federico II, Complesso Universitario Monte S.Angelo, 80126, Napoli, Italy.*
3. *Technische Universitaet Muenchen, Chair of Restoration, Art Technology and Conservation Science, Oettingenstrasse 15, 80538 Munich, Germany.*
4. *European Synchrotron Radiation Facility, 6 rue Jules Horowitz, F-38000 Grenoble (France).*

This work describes the results obtained from the characterisation 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 carved from the rocks, but the 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.

Polarised 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 microsamples. 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 arisen. A database of paint materials compatible with materials available in the area 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 Bamiyan.

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

Janet G. Douglas[1], Federico Carò[2] and Martin Polkinghorne[3]

1. *Department of Conservation and Scientific Research, Freer and Sackler Galleries, Smithsonian Institution, Washington, DC, USA.*
2. *Department of Scientific Research, Metropolitan Museum of Art, New York, NY, USA.*
3. *Department of Asian Studies, The University of Sydney, Sydney, Australia.*

In the 1990s two large unfinished stone triads that included Śiva and two consorts (Umagaṇgapatiśvara) 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 Hariharālaya 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 Hariharālaya workshop was recently completed [1], and here we report on further research into the role of the Hariharālaya 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 Hariharālaya sculpture 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 are 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 “Triassic 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 Kô need to be careful considered. It seems unlikely that the freestanding sculptures found at the Bakong and Preah Kô temples were created in the Preah Kô 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.

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

M.D. Manrique Ortega[1], J.L. Ruvalcaba Sil[1], P. Claes1, M.A. García Bucio[1], E. Casanova González[1], M. Wong Rueda[1], M.A. Maynez Robles[1], A.A. Delgado Robles[1], A. González Cruz[2], M. Cuevas García[3].

1. *Instituto de Física, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica s/n, Ciudad Universitaria, Mexico DF 04510, Mexico.*
   e-mail: sil@fisica.unam.mx
2. *Centro INAH Chiapas, Instituto Nacional de Antropología e Historia, Calzada de los hombres ilustres s/n, Zona Centro. CP 29000, Tuxtla Gutiérrez, Chiapas, Mexico.*
3. *Dirección de Registro Público de Monumentos y Zonas Arqueológicas. Instituto Nacional de Antropología e Historia. Av. Victoria 110, Copilco El Bajo, Mexico DF 04510, Mexico.*

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’inich Janaab Pakal, called Tz’akbu 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 headdress, 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 royal 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 mineral 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 sclera of the eyes is white jadeite and the pupils fit the jet-black amber mineral signature. In contrast, most of the Maya masks, the sclera 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 to those used for other ruler of the site, including her king K’inich Janaab Pakal.
This research has been supported by the projects CONACyT Mexico 131944 MOVIL II, PAPIIT UNAM IN402813 ANDREAH II and ICyTDF PICCO10-57.

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

Amicone Silvia[1], Quinn Patrick[1], Radivojević Miljana[1], Rehren Thilo[2]

1. *Institute of Archaeology, University College London, London, United Kingdom.*
2. *UCL Qatar, Hamad bin Khalifa University, Doha, Qatar.*

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 in order to characterise the raw materials and processes employed in Neolithic/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 XRPD 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)

Elisabeth Holmqvist-Saukkonen[1], Åsa M. Larsson[2], Aivar Kriiska[3], Vesa Palonen[4], Kenichiro Mizohata[4], Tuomas Nissinen[4], Markku Oinonen[5], and Jyrki Räisänen[4]

1. *Archaeology, Department of Philosophy, History, Culture and Art Studies, University of Helsinki, Finland*
2. *Societas Archaeologica Upsaliensis, Uppsala, Sweden*
3. *Department of Archaeology, University of Tartu, Estonia*
4. *Department of Physics, University of Helsinki, Finland*
5. *Finnish Museum of Natural History, University of Helsinki, Finland*

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-breading, 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 the style and shape of the beakers differ to a notable degree 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

Institute of Materials Science, N.C.S.R. "Demokritos", 15310 Athens, Greece.

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 'provenience 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 reported showing that specific accessory minerals, not homogeneously 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 craftspeople 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 subgroup 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.

Dennis Braekmans[1,2], Brien K. Garnand[3], Joseph A. Greene[3], Lawrence E. Stager[3], Patrick Degryse[4]

1. *Laboratory for Ceramic Studies, Faculty of Archaeology, Leiden University, Leiden, The Netherlands.*
2. *Materials in Art and Archaeology, Material Science and Engineering, Delft University of Technology, Delft, The Netherlands.*
3. *Semitic Museum, Harvard University, Cambridge, MA, USA.*
4. *Centre for Archaeological Sciences, Division of Geology, KU Leuven, Leuven, Belgium.*

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 typo-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

S.Y. Waksman[1], S.S. Skartsis[2], N.D. Kontogiannis[2] and G. Vaxevanis[2]

1. *Laboratoire de Céramologie, CNRS UMR5138 Archéométrie et archéologie, Lyon, France.*
2. *23rd Ephorate of Byzantine Antiquities, Chalkida, Greece.*

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" includes 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 / Kadikalesi. 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[1] 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 #228).

16. Technical Analysis of Safavid Ceramics

Katherine Eremin[1], Kelly Domoney[2] Mary McWilliams[1], Robert Mason[5], Moya Carey[3], Patricia Ferguson[3], Francesca Leoni[4]

1. *Harvard Art Museums, Cambridge, USA.*
2. *Cranfield University, Shrivenham,UK.*
3. *Victoria & Albert Museum, London, UK.*
4. *Ashmolean Museum, Oxford, UK.*
5. *Royal Ontario Museum, Canada.*

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 Iranian 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 Turkish 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.

106 Iranian ceramics from the 15th to 19th centuries in the collections of the Harvard Art Museums, the Ashmolean Museum and the Victoria & Albert Museum were analyzed using non-destructive x-ray florescence (XRF). Where possible, the study focused on objects with known dates and/or places of manufacture. Barium was found in 35 out of 39 underglazed blue and white ceramics attributed to the period from 1600 to 1675 but was not detected in any earlier or later Iranian ceramics. Where present, barium occurred in both the ceramic body and the glaze and the levels showed no relationship to the decoration. Barium was detected in objects attributed to both Mashhad and Kirman but not in those attributed to Isfahan, (attributions being based on petrographic and/or art historical grounds). No barium was present in any monochrome or luster ceramics from the 17th century.

The results suggests use of a distinct material for the majority of underglaze decorated ceramics from the first three-quarters of the 17th century in 2 of the 3 known manufacturing sites. One possibility is the use of a barium-containing glass frit for both the stonepaste and the glaze. Whilst published data for contemporaneous European glass shows this does not include barium, there is no analytical data for the glass produced within Iran at this period. The next phase of the project will concentrate on the identification and analysis of such material.

17. Revisiting the Beginnings of Tin-opacified Islamic Glazes

Michael Tite[1], Trinitat Pradell[2], Gloria Molina[2], Kelly Domoney[3], Oliver Watson[4], and Anne Bouquillon[5]

1. *Research Laboratory for Archaeology and the History of Art, Dyson Perrins Building, South Parks Road, Oxford OX1 3QY, UK.*
2. *Departament de Fisica i Enginyeria Nuclear, UPC, Campus Baix Llobregat, 08860 Castelldefels, Spain.*
3. *Department of Materials and Medical Sciences, Center for Archaeological and Forensic Analysis, Cranfield University, Shrivenham, Wiltshire SN6 8LA, UK.*
4. *Khalili Research Centre for the Art and Material Culture of the Middle East, 3, St John Street, Oxford, OX1 2LG, UK 5C2RMF, Palais du Louvre, 14, quai François Mitterrand, 75001 Paris, France.*

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. From here, the tradition spread to Mesopotamia where it provided the context for the emergence of the cobalt blue and lustre decorated pottery, now with a white glaze inspired by Chinese imports.

Using a combination of SEM analysis of polished cross-sections, and surface analysis using both hand-held XRF and (PIXE), Coptic Glazed Ware from Egypt, Yellow Glazed Ware from Syria, and comparable glazed wares from Samarra, Kish and Susa have been analysed. The results show that, in all cases, lead stannate was used to produce the opaque yellow decoration and that tin oxide was used on the rare occasions where opaque white decoration was employed. The use of tin-based opacifiers in Egypt and Syria in the 8th century AD can be explained in terms of technological transfer from Byzantine glassmakers, who were themselves using tin-based opacifiers following the switch from the use of antimony-based opacifiers (lead antimonate and calcium antimonate) by Roman glassmaker around the 4th century AD. In contrast, the sudden emergence of tin-opacified glazes in Abbasid Iraq in the 9th century AD might be best explained by the spread of the yellow glaze family technology, given the greater distance from Byzantium.

The compositions of the different lead-tin-silica mixtures used in the production of the yellow, green and white glazes will be discussed in terms of the conversion of lead stannate to tin oxide during the glaze firing, and the role of the high lead oxide content (approximately 60 wt% PbO) of the yellow glazes in this context. The extent to which lead 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

Pieterjan Claes[1], José Luis Ruvalcaba Sil[1], Laura Filloy[2], Malinalli Wong Rueda[1], Ma. Angélica García Bucio[1]

1. *Departamento de Física Experimental, Instituto de Física, Universidad Nacional Autónoma de México, Mexico DF, Mexico.*
2. *Museo Nacional de Antropología, Instituto Nacional de Antropología e Historia, Mexico DF, Mexico.*

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 out 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 Tenochtitlán, 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 Mezcalapa 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 selection 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 ANDREAH II and ICyTDF PICCO10-57.

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

Robert H. Tykot[1], Kyle P. Freund[2], Andrea Vianello[3]

1. *Department of Anthropology, University of South Florida, Tampa, FL 33620 USA.*
2. *Department of Anthropology, McMaster University, Hamilton, Ontario, Canada L8S 4L9.*
3. *Oxford University, England, OX1 2JD, United Kingdom.*

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-SD 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 subsources on each, including Gabellotto and Canneto 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, Marsala, Tindari, and on Lipari. The pXRF settings were 40 kV, 11 uA, 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

Rob Sternberg[1], M. Steven Shackley[2], Joshua M. Feinberg[3], Anastasia Steffen[4,5], Alexandra Freeman[6], Andrew Gregovich[6], Caroline Hackett[7], Michael Harrison[8], Michaela Kim[9], Zachary Osborne[10], Audrianna Pollen[11], Margo Regier[12], Karen Roth[13], and Ryan Samuels[1]

1. *Department of Earth and Environment, Franklin & Marshall College, Lancaster, PA, USA.*
2. *Geoarchaeological XRF Laboratory, Albuquerque, NM, USA.*
3. *Institute for Rock Magnetism, University of Minnesota, Minneapolis, MN, USA.*
4. *Valles Caldera Trust, Jemez Springs, NM, USA.*
5. *Department of Anthropology, University of New Mexico, Albuquerque, NM, USA.*
6. *Department of Geology, Colorado College, Colorado Springs, CO, USA.*
7. *Department of Geosciences, Smith College, Northampton, MA, USA.*
8. *Department of Geological and Environmental Sciences, California State University, Chico, CA, USA.*
9. *Department of Geology, Mount Holyoke College, South Hadley, MA, USA.*
10. *Department of Geology, St. Norbert College, De Pere, WI, USA.*
11. *Department of Geology, Occidental College, Los Angeles, CA, USA.*
12. *Department of Geology, Beloit College, Beloit, WI, USA.*
13. *Department of Geology, Washington and Lee University, Lexington, VA, USA.*

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 provenance 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)

L. Beck[1,2], H. Rousselière[2,3], J. Castaing[2,3], A. Duran[2], M. Lebon[2,4], F. Plassard[4]

1. *CEA, DEN, Service de Recherches de Métallurgie Physique, Laboratoire JANNUS, 91191 Gif-sur-Yvette, France.*
2. *C2RMF - UMR171 CNRS, Centre de Recherche et de Restauration des Musées de France, Palais du Louvre, Porte des Lions, 14 quai François Mitterrand, 75001 Paris, France.*
3. *Laboratoire d'archéologie moléculaire et structurale (UMR 8220 CNRS-UPMC), Université Pierre et Marie Curie, 94200 Ivry, France.*
4. *Muséum National d'Histoire Naturelle, Département de Préhistoire, UMR 7194, 1 rue René Panhard, 75013 Paris, France.*
3. *S.A.R.L. Grotte de Rouffignac, 24580 Rouffignac-Saint-Cernin, France and UMR 5199 PACEA- Institut de Préhistoire et de Géologie du Quaternaire. Université Bordeaux 1.*

Study of prehistoric art is playing a major role in our knowledge of the human evolution. In the past decades, the characterisation 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 (mammoths, ibex, rhino) are composed of manganese oxides. Two crystalline forms identified by XRD are present: pyrolusite (MnO2) and romanechite (Ba2Mn5O10).
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 homogenous group; the mammoths and bison of the Great Ceiling as well as the rhinoceros 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 rhinoceros of the Breuil gallery have a chemical composition very similar to the animals of the Great Ceiling except the ibex which different in term of style and composition.

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

Erika Ribechini[1], Ilaria Degano[1], Marco Zanaboni[1], Alexia Pavan[2], Maria Perla Colombini[1], Josefina Pérez-Arantegui[3]

1. *Dipartimento di Chimica e Chimica Industriale, Università di Pisa, 56126 Pisa, Italy.*
2. *Dipartimento di Scienze Storiche del Mondo Antico, Università di Pisa, 56126 Pisa, Italy.*
3. *Instituto Universitario de investigación en Ciencias Ambientales de Aragón (IUCA), Universidad de Zaragoza, 50009 Zaragoza, Spain.*

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.

Avanzini - 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 demonstrated to be a valuable 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'-dibromoindirubin, 6- and 6'-monobromoindirubin, 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

Maninder Singh Gill[1] and Thilo Rehren[1]

1. *UCL Qatar, P.O. Box 25256, Georgetown Building, Hamad bin Khalifa University, Doha, Qatar.*

In sixteenth and seventeenth century Mughal (1526-1857 CE) northern India, two styles of tile-work were employed in the embellishment of buildings, at Delhi and Punjab, distinguishable from each other in their mode of application and to some extent in their physical characteristics. While recent studies have brought forth technological similarities between the Punjab and central/western Asian tiles, notably in their plant-ash glaze compositions, very little 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 stonepaste comprising quartz-rich bodies with interparticle 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 their Punjab counterparts. 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 1.5-2:1 serves as an additional characteristic marker for tiles from this region. The clustered distribution of lead stannate particles in yellow and green glazes 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 Jalesar 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 stonepaste ceramics.

24. Plumbate Ceramic Ecology

Hector Neff[1], Timothy Garfin[2], Paul Burger[1], Elizabeth Niespolo[3]

1. *Institute for Integrative Research in Materials, Environments, and Societies, and Department of Anthropology, California State University Long Beach, California, USA.*
2. *Institute for Integrative Research in Materials, Environments, and Societies, and Department of Anthropology, California State University Long Beach and Department of Anthropology, California State University Northridge, California, USA.*
3. *Department of Geological Sciences, California State University Long Beach, California, USA.*

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 slip clays. 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 reports the result 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

David Killick[1], Scarlett Chiu[2], Christophe Sand[3], and William R. Dickinson[4]

1. *School of Anthropology, University of Arizona, Tucson, Arizona, USA .*
2. *Academia Sinica, Taipei, Taiwan.*
3. *Institute of Archaeology of New Caledonia and the Pacific, Noumea, New Caledonia.*
4. *School of Geosciences, University of Arizona, Tucson, Arizona, USA.*

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 minerals concentrated 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 sherd 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 Isle des Pins and the Loyalty Islands were made on New Caledonia. A few vessels from Efate Island in Vanuatu contain metamorphic index minerals that can only have originated in New Caledonia.

Reference

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26. Technological Change and Provenance of Glass in Early Islamic Palestine

Matt Phelps[1], Ian Freestone[1], Bernard Gratuze[2] and James Lankton[3]

1. *UCL Institute of Archaeology, London, UK.*
2. *IRAMAT-CEB, UMR 5060, CNRS/Univ. Orleans, Orleans, France.*
3. *UCL Qatar, Doha, Qatar.*

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; Ahihud, Ramla, Sepphoris and Bet Shean. The glass samples, most of which are from well-dated vessels, date from the 6/7th to 12th centuries. Analysis was performed using LA-ICP-MS, allowing quantification of 57 elements, including majors, the 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 Gratuze 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 types1 & 2 from Raqqa, Syria. 7 further samples are similar to colourless glass from Nishapur, Iran analysed by Brill. However, the lack of comparison trace element data for Raqqa and Nishapur 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

Weidong Li[1], Xiaoke Lu[1], Lanhua Liu[2], Xinmin Sun[3]

1. *Shanghai institute of ceramics, Chinese Academy of Sciences, Shanghai, China*
2. *Chinese academy of cultural heritage, Beijing, China*
3. *Cultural relics and archaeology institute of henan province, Zhengzhou, China*

A large amount of evidence has shown that blue-and-white porcelain was successfully produced as early as the Tang Dynasty (618-907 A.D.) 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 field emission transmission electron microscope equipped with EDS. 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 and glaze recipes, improvement of firing technologies, and unremitting practices. Until the late Tang dynasty, blue-and-white porcelain came into being based on the mature technology of white porcelain production. The body and glaze compositions of blue-and-white shards are close to the white porcelain of late Tang. The type of cobalt pigment used is similar to the pigment used for the upper-glaze 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

Kelly Domoney[1], Andrew Shortland[1], Sebastian Kuhn[2] and Nette Megens[2]

1. *Cranfield Forensic Institute, Cranfield University, Shrivenham, UK.*
2. *European Ceramics and Glass Department, Bonhams, London, UK.*

During the second half of the 18th century, Vincennes-Sèvres soft-paste porcelain dominated the European ceramic market in the manufacture of 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, and several private 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 1749 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(al): Reconstructing The World's Earliest Metallurgy

Radivojević, M.[1,2], Boscher, L.[3], Timberlake[5,4], Asmus, B.[5], Radivojević, J.[6], Chen, K.[7] and Rehren, Th[3]

1. *UCL Institute of Archaeology, London, United Kingdom*
2. *Centre for Research in Archaeological Materials, Faculty of Philosophy, Belgrade, Serbia.*
3. *UCL Qatar, Doha, Qatar.*
4. *University of Cambridge, Cambridge, United Kingdom.*
5. *Laboratory for Archaeometallurgy, Freiburg, Germany.*
6. *Institute of Molecular Genetics and Genetic Engineering, University of Belgrade, Serbia.*
7. *Institute of Historical Metallurgy and Materials, University of Science and Technology Beijing, China.*

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 recipe 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 small quantity of debris stands in stark contrast to the vast number of metal artefacts produced at the time, and very little, if anything, can be said about the field conditions of metal production, such as type of smelting installations, air supply, or fuel.

It is generally understood that the Chalcolithic metal production debris was neglected in archaeological excavations in the past; also, it is argued that such process would have left only ephemeral evidence behind. Our 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 Ždrelo 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

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

Kristina A. Franke[1]

1. *Institute of Archaeology, UCL London, UK.*

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 EPAM/WDS 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 understand 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 Bassiakos, George Mastrotheodoros and Liana Filippaki

Lab. of Archaeometry, Institute of Advanced Materials, Physicochemical Processes, Nanotechnology and Microsystems, N.C.S.R. "Demokritos", Athens, Greece.w

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 Chrysokamino, or in crucibles, during the entire 3rd millennium, based on indigenous copper and arsenic sources.

In a previous paper we (Bassiakos, Tselios 2012) have argued that the cessation of the flourishing 3rd millennium centers, that had exploited local copper-ore sources, was owed to exhaustion of the available secondary cupriferous 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 artifacts 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 Skyros/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-impurities 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

Y. Bassiakos and T. Tselios, 2012, "On the cessation of the local copper production in the Aegean in the second millennium BC" in: V. Kassianidou and G. Papasavvas, eds, Eastern Mediterranean Metallurgy and Metalwork in the Second Millennium BC, 151-161, Oxbow Books, Oxford.

32. Physical Barriers, Cultural Connections: Ancient Metallurgy Across the Alpine Region

L. Perucchetti[1], P. Bray[2], A.M. Pollard[3]

1. *Research Laboratory for Archaeology and the History of Art, University of Oxford, Oxford, U.K.*
2. *Research Laboratory for Archaeology and the History of Art, University of Oxford, Oxford, U.K.*
3. *Research Laboratory for Archaeology and the History of Art, University of Oxford, Oxford, U.K.*

The interest of scholars in the ancient metallurgy in the Alpine region has a long 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 the more 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 (3200-2200 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.
- Speculate about 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 a North-South pattern, had an East-West pattern. The first production of bronze objects, as well, was uneven in the Alps, but affected the Western part first. The movements of metal have been statistically demonstrated to be strongly influenced by the river systems, as different types of metal were related to different rivers. Geostatistical analysis on the metal groups of the Early Bronze Age allowed us to create maps that shown a clear pattern of recycling, with a peak of arsenic corresponding to the known metal sources and a constant, gradual decrease according to distance from them.
To conclude, this study has allowed us to have a more holistic idea of the ancient metallurgy in the Alpine area, focusing not only on the spatial distribution of metal, but also investigating the movement of metal, both in terms of means of transport, emphasising the importance of rivers, and in terms of human activity, that is to say giving evidence of metal recycling.

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 typo-chronology

Cécile Le Carlier[1]; Jean Christophe Le Bannier[1], Cyril Marcigny[2], Muriel Fily[3]

1. *Laboratoire Archéosciences - UMR6566-CReAAH (Centre de Recherche en Archéologie, Archéosciences et Histoire) CNRS; bat 24-25, Campus de Beaulieu, 35042 Rennes Cedex, France, cecile.lecarlier@univ-rennes1.fr*
2. *INRAP - UMR6566-CReAAH - France.*
3. *Service Archéologique Départemental du Finistère - France.*

Since a few years now, we have witnessed a real revival concerning the interest on chemical analyzes of copper-based objects of the Bronze Age of Western Europe atlantic coasts. 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 several 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 analyzes 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 analyzes 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 analyzes 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 be 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 analyzes, 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

I. M. Villa[1,2], F. Cattin[3], M. B. Merkl[4], Ch. Strahm[5]

1. *Universität Bern, Institut für Geologie, Baltzerstrasse 3, 3012 Bern, Switzerland.*
2. *Università di Milano Bicocca, Centro Universitario Datazioni e Archeometria, 20126 Milano, Italy.*
3. *Université de Bourgogne, Laboratoire ArTeHiS, UMR 6298, 6 Bd Gabriel, 21000 Dijon, France.*
4. *Landesamt für Denkmalpflege, Berliner Straße 12, 73712 Esslingen, Germany.*
5. *Universität Freiburg, Institut für Archäologische Wissenschaften, 79089 Freiburg, Germany.*

We report a trace element - Pb isotope 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 coeval copper types? (i) is it 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. Co/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 predicted by geochemical arguments on the Brixlegg mining area. Brixlegg 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". Archaeological information limits the scope to Central European sources. LIA would require a diverse supply network from many mining localities, including possibly Brittany. 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

Sturt W. Manning

Department of Classics and Cornell Institute of Archaeology and Material Studies, Cornell University Ithaca NY 14853-3201, USA sm456@cornell.edu

The precision and accuracy with which actors, events and forces can, or cannot, be tied together determines

the type of history which can be written, and whether we can move from a longue durée impersonal scale to a specific, agent-centered, nexus. Increasingly, the claim is made of high-resolution data, both in terms of dating and climate/environment. For example, terminal destructions and cultural collapse in the northern Levant have been stated to be dated as narrowly as 1192-1190BC. But what real temporal resolution do we currently have both on the archaeology and the climate of the period from the close of the Late Bronze Age LBA) through the early Iron Age (IA)? This paper will explore and seek to quantify these issues, both overall and via a few cases, and consider the likely nature of a best current assessment. It will then consider what history is possible, exploring the remarkably confident recent statement of Broodbank, in his The Making of the Middle Sea (2013), who simply states of the LBA-IA transformation that “climate played no significant part”.

36. Copper in the Iron Age

Vasiliki Kassianidou

Archaeological Research Unit, University of Cyprus, P.O. Box 20537 Nicosia, Cyprus CY1678

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 it is therefore readily available. But to achieve the same or greater hardness than bronze, iron first must be turned into steel through a multi-stepped process. Furthermore, because of its high melting-point (1583o C), it could not be melted and cast in molds. Thus, its use was restricted to objects that could be forged. Finally, iron’s vulnerability to corrosion rendered it a base metal. Therefore iron, could not altogether substitute for copper and its alloys.
The metal was used for weapons and tools but even in this case not exclusively. The archaeological record shows that weapons and armor both for men and for animals were still made of bronze. Consider the amount of bronze needed to manufacture a warship (where the wooden planks where secured with copper alloy nails) and to furnish it with a ram which weighed as much as 500 kg (at least the example found in Athlit, Israel). Bronze of course continued to be used to manufacture vessels and works of high craftsmanship, as well as a great variety of other objects. This is fully supported by the numerous references, in Neo-Assyrian and Neo-Babylonian texts, to copper- and bronze-smiths, as well as to statues, bas-reliefs, plates, bowls, basins, cauldrons, weapons, etc., made of copper. Clearly, then, copper did not cease to be a strategic material during the Iron Age; in fact, it remained a valuable 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 in 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.

37. Crisis in Context: The End of the Late Bronze Age in the Eastern Mediterranean

A. Bernard Knapp

Department of Archaeology, University of Glasgow, Glasgow G12 8QQ UK e-mail: bernard.knapp@glasgow.ac.uk

Explanations for the Late Bronze Age crisis and collapse in the eastern Mediterranean are numerous and seem to change along with changing times: migrations and their aftermath; predations by external forces (the Sea Peoples); political struggles within the dominant polities or system collapse amongst them; inequalities between centres and peripheries; climatic change and/or natural disasters; the coming Age of Iron. There has never been nor should we expect that there ever will be any coherent, overarching explanation to account for all the changes within and beyond the eastern Mediterranean, some of which occurred at different times from the mid-late 13th through the 12th centuries BC. The ambiguity of the evidence — material, textual, climatic, chronological — makes it difficult to sort out what was cause, and what was result. Can we identify the agents or protagonists of the crisis and related events? How valid are recent explanations that focus on climate or chronology in helping us to understand better the onset or outcome of the crisis? This paper reviews the current state of the archaeological and historical evidence, and considers the coherence of climatic explanations, in the attempt to place the crisis, if such it was, in context.

38. An Isotopic Trip through First Millennium BC Glass History

Annelore Blomme1, Jan Elsen1 and Patrick Degryse1

1. *Division of Geology, Department of Earth and Environmental Sciences, KU Leuven, Celestijnenlaan 200E, B-3001 Leuven, Belgium.*

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 project focuses on using isotope 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 centre(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

Ian Freestone

Institute of Archaeology, University College London, 31-34 Gordon Square, London WC1H 0PY

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

C. Ankjærgaard1, K.F. Kuiper2, N. Porat3, M. Jain4, J.R. Wijbrans2, and Jakob Wallinga1

1. *Soil Geography and Landscape group, Wageningen University, Netherlands.*
2. *Department of Earth Sciences, Vrije Universiteit Amsterdam, Netherlands.*
3. *Luminescence Dating Laboratory, Geological Survey of Israel, Jerusalem, Israel.*
4. *Centre for Nuclear Technologies, DTU Nutech, 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 extending 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 Steinitz, 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 Israelian sites, we will discuss the feasibility of extending luminescence dating to cover the full Quaternary using VSL methods.

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This work is financed by Technology Foundation STW (STW.10502) and NWO VENI.

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

Renaud Joannes-Boyau1

1. *Southern Cross GeoScience, Southern Cross University, Lismore, NSW, Australia.*

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 (Grün 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-ICPMS, offers to investigate at a micro scale not only the U-uptake history crucial for ESR dating (Grun et al., 2008b), but also insight into migration and diet pattern 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 Ba 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

Yannis Maniatis1, Kostas Kotsakis2

1. *Laboratory of Archaeometry, Materials Science Sector, NCSR "Demokritos", 153 10 Aghia Paraskevi, Attiki, Greece.*
2. *Department of Archaeology and History, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece.*

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 inland) 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 (6600/6400 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 way of life in many geographical parts 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

PESCE Giovanni L.1, VECCHIATTINI R.2 and BALL R. J.1

1. *Department of Architecture and Civil Engineering of the University of Bath, Bath, United Kingdom.*
2. *Faculty of Engineering, Polytechnic School of the University of Genoa, Genoa, Italy.*

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 archaeometric 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

Felix Höflmayer[1], Aaron A. Burke[2]

1. *University of Chicago, The Oriental Institute, Chicago, IL, USA.*
2. *University of California, Los Angeles, Near Eastern Languages and Cultures, Los Angeles, CA, USA.*

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.
Past major projects like ARCANE (Associated Regional Chronologies of the Ancient Near East) or SCIEM 2000 (Synchronization 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-Thyssen 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 (CINEMA) 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

Agnieszka Helman-Ważny

Centre for the Study of Manuscript Cultures, University of Hamburg, Germany and College of Science, LTRR, University of Arizona, Tucson, USA

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 reveals 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 (BSL). 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 has aimed to explore the 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 if artwork is a copy 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

Patrick Boehnke[1], Mark Harrison[1] and Ioanna Kakoulli[2,3]

1. *Department of Earth, Planetary, and Space Sciences, University of California, Los Angeles, 595 Charles Young Drive East, Box 951567, Los Angeles, CA 90095-1567, United States.*
2. *Department of Materials Science and Engineering, University of California, Los Angeles, 410 Westwood Plaza, 3111 Engineering V, Los Angeles, CA 90095-1595, United States.*
3. *UCLA/Getty Conservation Program, Cotsen Institute of Archaeology, University of California, Los Angeles, 308 Charles E. Young Drive North A210 Fowler Building/Box 951510, Los Angeles, CA 90095-1510, United States.*

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 ETP 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 concentration. 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. 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/Sr 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.

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47. Testing the authenticity of the Sky Disc of Nebra

Ernst Pernicka[1]

1. *Curt-Engelhorn Zentrum Archäometrie, Mannheim, Germany, and Institute of Geosciences, University of Heidelberg, Germany.*

Early in the year 2002 a sensational find was rescued from the antiques 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 inlays. 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 of the damages induced by the looters were used as evidence to disprove allegations of a modern production during the law suit [3]. Even archaeoastronomic considerations are consistent with a Bronze Age date of the Sky Disc [4], which is now beyond doubt.

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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 gold prompted the Penn Museum curators to advocate for the adoption of a new resolution (“The Pennsylvania Declaration”) wherein the museum pledged not to purchase any antiquities without a known archaeological provenance and evidence of legal export.
There were no repatriation claims on the Troy Gold for the next 45 years. In 2009, however, new scientific tests on the gold raised the possibility that the assemblage might have been plundered from a site in or near Troy, and Turkey subsequently filed a repatriation claim. The result was that the gold traveled to Turkey on indefinite loan in exchange for pledges of archaeological cooperation and long-term loans from Turkey to Penn.
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[1]

1. *The J. Paul Getty Museum , 1200 Getty Center Drive, Suite 1000, Los Angeles, CA 90049-1687*

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.

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

Richard P. Evershed[1], Melanie Salque[1], Lucy Cramp[1,2], Mirva Pääkkönen[3], Alan Outram[4]

1. Organic Geochemistry Unit, University of Bristol, Bristol, United Kingdom.
2. Department of Archaeology and Anthropolgy, University of Bristol, Bristol, United Kingdom.
3. Archaeology, University of Turku, Turku, Finland.
4. Department of Archaeology, University of Exeter, Exeter, United Kingdom.

The past 3 decades have seen major developments in the application of analytical chemical approaches to the investigation of organic residues preserved at a wide variety of locations at archaeological sites. ‘Cooking’ vessels in particular have been shown to be a remarkable sink of lipids derived from the processing of a wide range of natural products, especially foodstuffs. Such residues provide information relating to the specific functions of vessels but, perhaps more significantly, to the wider aspects of hunting and agricultural practices adopted by the communities who used the vessels. In this respect food residues surviving in pottery vessels are highly complementary to other dietary and subsistence indicators, particularly ecofactual remains.
Although the major components detected in archaeological pottery, i.e. C16:0 and C18:0 n-alkanoic acids and other acyl lipids, are rather non-specific biomarkers the diagnostic of molecular structure is strengthened synergistically by making links to their stable isotopic compositions. Hence, the presentation will discuss the use of gas chromatography-combustion-isotope ratio mass spectrometry in the investigation of the major class of organic residue observed in prehistoric pottery, namely the fatty acid components of degraded acyl lipids.
Up to now the compound-specific stable carbon isotope analysis of fatty acids has been used mainly to study the exploitation of the major domesticated animals, namely, cattle, sheep/goats, pigs and, to a lesser extent, horse. Since interest in the compound-specific stable isotope approach is increasing we felt it timely to explore the potential for expanding the use of δ13C values of C16:0 and C18:0 alkanoic acids for an increased range of hunted and domestic species. The δ13C values obtained from a wide range of different modern species, including marine and freshwater aquatic organisms and terrestrial animals, will

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.

52. Characterizing changing animal management practices, land use strategies and Palaeoenvironments through time in the North Atlantic Islands: an isotopic approach.

Jennifer Rose Jones[1], Eric Nordgren[1], and Jacqui Mulville[1]

1. *School of History, Archaeology and Religion, Cardiff University, Cardiff University, John Percival Building, Colum Drive, Cardiff, Wales, United Kingdom, CF10 3EU.*

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. Bulk Carbon (C12:C13) and Nitrogen (N14:N15) isotopic analysis of faunal remains was used to explore past animal diets, providing insights into animal management strategies used within different time periods in the islands. A total of 622 wild and domestic fauna were sampled, from the islands of Orkney and the Western Isles to explore palaeoenvironmental differences in C13 and N15 and to characterize faunal diets through time.

This isotopic research demonstrated distinct and intriguing trends in animal management practices throughout time. During the Neolithic period in Orkney, sheep were being grazed on the shore front, possibly as a method of providing fodder during the harsher winter months. Bronze Age animal management indicates that domestic animals were being foddered in various locations across the landscape, indicative of more localized or even household management practices. Within the Iron Age Broch of Dun Vulan several pigs were being foddered on fish. Fish consumption is also observed within the human isotopic values observed at the site. Later the arrival of the Vikings to the islands marks a dramatic change in the economic practices undertaken. Isotopic evidence supports the hypothesis that manuring is practiced in both island groups. At this time cattle and sheep are no longer foddered on the shorefront resources, indicating that these populations had an enhanced capability of overwintering stock without having to rely on marginal pastures. Detailed sampling of fauna for bulk collagen isotopic analysis of Carbon and Nitrogen can revolutionize our understanding of changes in animal management, economic practices, and can even provide insights into wider social behavior within archaeological populations.

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

Claudia Gerling[1], Alistair Pike[3], Volker Heyd[4], Elke Kaiser[1], Hermann Parzinger[5], Wolfram Schier[1]

1. *Excellence Cluster Topoi, Institute of Prehistoric Archaeology, Free University Berlin, Germany.*
2. *Integrative Prehistory and Archaeological Science, University of Basel, Switzerland.*
3. *Faculty of Humanities, University of Southampton, UK.*
4. *Department of Archaeology and Anthropology, University of Bristol, UK.*
5. *Stiftung Preußischer Kulturbesitz, Berlin, Germany.*

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 palaeodiet 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 (87Sr/86Sr, δ18O, δ15N, δ13C) 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 specimens 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 regions 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. Here we will 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. Hopanoids as Biomarkers of Pulque in Mesoamerica

Marisol Correa Ascencio[1], Ian Robertson[2], Oralia Cabrera Cortés[3], Rubén Cabrera Castro[4] and Richard P. Evershed[1]

1. *Organic Geochemistry Unit, School of Chemistry, University of Bristol, Cantock's Close, Bristol, BS8 1TS, UK.*
2. *Department of Anthropology, Stanford University 450 Serra Mall, Stanford, California, CA 94305-2034, U.S.A..*
3. *School of Human Evolution and Social Change, Arizona State University, Arizona, 85287-20402, U.S.A..*
4. *Zona Arqueológica de Teotihuacan, Instituto Nacional de Antropología e Historia, Teotihuacan, Mexico.*

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 Teotihuacan people 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/vitamin 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 Zymommonas 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 (30 mg g-1 dry wt) 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 191) only these resin-containing vessels were found to contain characteristic hopane distributions. The detection of such bacteriaohopanoids 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

Gisela Grupe[1,2], George C. McGlynn[2]

1. *Dept Biology I, Anthropology, Ludwig-Maximilians-University Munich, Biocenter, Grosshaderner Str. 2, 82152 Martinsried, Germany. G.Grupe@lrz.uni-muenchen.de*
2. *Bavarian State Collection for Anthropology and Palaeoanatomy, Karolinenplatz 2a, 80333 Munich, Germany. gc.mcglynn@extern.lrz-muenchen.de*

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 the overall redundancy of geologically and ecologically defined isotopic ratios. Mainly based on archaeological animal bone and teeth, a local isotopic fingerprint consisting of 5 isotopic ratios (ð18O, 87Sr/86Sr, 208Pb/204Pb, 207Pb/204Pb, 206Pb/204Pb) is established and defined by application of new data mining methods. In a second step, a similarity search is conducted in the form of e.g. "Given an animal bone x, find all skeletal finds from one species with similar isotopic fingerprints within a radius of y km, which are of the same archaeological age". Reconstruction of past human mobility within this project is based on the systematic investigation of cremated remains, an often neglected bioarchaeological substrate. The establishment and precision of the isotopic fingerprint as applied to the cremated material will be scaled down to four isotopic ratios (Sr and Pb only), since ð18O is not stable at high temperatures [1]. All sample analyses are accompanied by both experimental and empirical mineralogical/crystallographical controls to validate the isotopic data.

The ultimate goal of this collaboration of geologists, mineralogists, archaeozoologists, anthropologists, and computer scientists is the integration of the data into a freely accessible data bank, and the establishment of a catalogue of criteria for validating stable isotope analysis of the mineral fraction of cremated and non-cremated skeletal finds. Respective criteria currently available are still a matter of debate (e.g. [2, 3, 4]). The first data sets have been generated and will be presented.

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

Caroline R. Cartwright[1]

1. *Research Laboratory, Department of Conservation and Scientific Research, British Museum, London WC1B 3DG, United Kingdom.*

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 [1]. The scientific analyses of charcoal, fish, molluscan, turtle and mammal remains from recent excavations (February 2013) of Iron Age contexts beneath a fort in the town itself have provided significant new evidence of increasing aridity and declining mangrove habitats, thus augmenting the results of previous excavations [2]. The pronounced onset of more arid conditions during the Iron Age, coupled with the impoverishment of Avicennia marina mangrove resources, had important repercussions on the life and seasonal subsistence patterns of the people at Ra's al-Hadd, their plants and animals. Strategically located at the easternmost tip of Arabia for sea-borne trade in the Gulf, and to and from India, such major environmental changes were likely to have impacted on more than just the local population. The February 2014 season of excavations at Ra's al-Hadd promises to shed further light on the reasons for the apparent hiatus of occupation at the Ra's al-Hadd fort after the Iron Age, and resumption of use from the 17th century onwards, with renewed evidence of Indian Ocean trade links.

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KEYNOTE PRESENTATION

57. The DNA sequencing revolution: new opportunities for biomolecular archaeology

Terry Brown

Manchester Interdisciplinary Biocentre, Faculty of Life Sciences, University of Manchester, Manchester M1 7DN, UK

It is 30 years since the first report of ancient DNA (aDNA) in a quagga skin and 25 years since the discovery of aDNA in preserved bones. During the intervening years, aDNA research has progressed through an over-ambitious phase during 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 in occurs. Today, contamination is still a major issue when human remains are studied, but 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 now 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.

58. Medicinal Clays and 'Earths': from geo-archaeological research to microbiological testing

Effie Photos-Jones[1,3], Chloe Keane[2], Michael Stamatakis[4], Alan J Hall[3], Alistair Leanord[2]

1. *Analytical Services for Art and Archaeology, Glasgow, UK.*
2. *Microbiology Department, Southern General Hospital, Glasgow, UK.*
3. *Archaeology, School of Humanities, University of Glasgow, UK.*
4. *Geology Department, National and Kapodistian University of Athens, Athens, Greece.*

Medicinal clays are currently the focus of extensive research on account of the emerging awareness of their antibacterial properties. The property of an inorganic substance or clay mineral to act as an antibacterial or antifungal agent lies less on its composition and more on the mechanism of reaction of the clay (and other minerals within) with the cell wall. In that respect conventional chemical and mineralogical analysis is not the definitive technique for medicinal clay characterization, only the preliminary phase of the investigation.

This paper focuses on a specific type of medicinal clays, the

Earths of the Aegean, mentioned extensively in Greek and Latin texts by Dioscorides, Pliny and Galen. Not all earths have 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 efficacy.

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-archeological 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 statistically important bactericide effect on two strands of gram positive and gram negative bacterial strains. The elucidation of the mechanism underlying drug-cell reactions is beyond the scope of archaeometric research. But the 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

Ira Rabin[1,2]

1. *BAM Federal Institute for Materials Research and Testing, Division 4.5, Berlin, Germany.*
2. *Centre for the Study of Manuscript Cultures CSMC, Hamburg, Germany.*

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, PMMA, 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

Marius Tiberiu Alexianu[1], Andrei Asandulesei[2], Felix-Adrian Tencariu[2], Ion Sandu[3], Gheorghe Romanescu[4], Roxana-Gabriela Curca[5], Mihaela Asandulesei[5]

1. *"Alexandru Ioan Cuza" University, Interdisciplinary Research Platform-Arheoinvest, Ethno-Archaeology section, Iasi, Romania.*
2. *"Alexandru Ioan Cuza" University, Interdisciplinary Research Department-Field Science, Iasi, Romania.*
3. *"Alexandru Ioan Cuza" University, The Interdisciplinary Laboratory of Scientific Investigation and Conservation of Cultural Heritage Assets, Iasi, Romania.*
4. *"Alexandru Ioan Cuza" University, Faculty of Geography and Geology, Department of Geography, Iasi, Romania.*
5. *"Alexandru Ioan Cuza" University, Faculty of History, Iasi, Romania.*

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 plead 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 ethnological 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).

On the basis of the GIS analyses, in direct relation with the existence of salt water springs and their confirmed exploitation by the prehistoric communities, we determined variable diachronic density and, more poignant, the dynamics of human habitation from the aforementioned periods, in the eastern part of Romania, an area which during the Neolithic and Chalcolithic witnessed the development of several civilisations representative for the entire European prehistory. The results enable us to assert that the necessity to cover the requirements of salt, a mineral indispensable to human life, of the agricultural communities, particularly of those found in tepid areas, constitute one of the factors that must be taken into consideration when attempting to explain the demographic expansion that occurred during the Neo-Eneolithic era, as particularly exemplified by the notable Cucuteni culture.

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

Clara Azémard[1], Matthieu Ménager[1] and Catherine Vieillescazes[1]

1. *Avignon Université, Equipe Ingénierie de la Restauration des Patrimoines Naturel et Culturel, Institut Méditerranéen de Biologie et d'Ecologie (IMBE), UMR CNRS 7263 - IRD 237, Avignon, France.*

Resins were used since ancient times for different purposes: incense, balms, religious symbolism, or varnishes. Those varnishes are made by dissolving the natural resin into alcohol, oil or turpentine spirit. Through times the materials undergo different photochemical processes, 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 recipe used by the old masters various analytical techniques can be used. We focused our researches 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 varnishes.

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 with a special attention to the botanical origin. Once the varnishes elaborated, they were irradiated under artificial sunlight and analyzed

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, oleanenes 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.
Fresh resins undergo different reaction during photoaging mostly oxidations and reticulation leading to polymerization. This study also contributed to highlight the degradation of the principal markers and the apparition of various hydroxylated di- or tri-terpenes. Those compounds seem to be the good degradation markers in order to identify the resins in complex matrix.
The results after artificial aging were confronted to the analyses of various ancient varnishes sampled on different artworks (ex-votos, Boyerman's painting) during their restoration in specialized workshops. It is possible to create a data base from our experiments that will help the identification of ancient resins

62. Applications in Landscape Analysis and Cultural Resource Management for Hyperspectral Satellite Imagery

William D. Middleton[1], Arthur A. Joyce[2], David W. Messinger[3], Kelly Canham[3], Michelle Goman[4], Aleksander Borejzsa[5], and Raymond Mueller[6]

1. *Department of Sociology and Anthropology, Rochester Institute of Technology.*
2. *Department of Anthropology, University of Colorado-Boulder*
3. *Center for Imaging Science, Rochester Institute of Technology.*
4. *Department of Geography and Global Studies, Sonoma State University.*
5. *Department of Anthropology, Universidad Autonoma de San Luis Potosi.*
6. *Department of Environmental Sciences, Richard Stockton College of New Jersey.*

Hyperspectral Satellite Imagery (HSI) from the Hyperion Imaging Spectrometer aboard the Earth Observing One Satellite provides abundant spectral reflectance data over large areas. These data lend themselves to a wide variety of applications in the study of contemporary landscapes, ranging from the analysis of landscape diversity, the classification of reflectance spectra into archaeologically and biologically meaningful taxa, the extraction of abundance spectra for the identification of specific materials, to the calculation of spectral indices for the measurement of material properties. Over the past several years we have been using HSI as part of an interdisciplinary project that also includes Geoarchaeology, Paleobotany, Isotope Geochemistry, Ecology, and Archaeology in the study of the ecology of complex societies in Prehispanic Oaxaca, Mexico. Oaxaca has a deep history of human occupation, beginning with the Paleoindian period, that includes the rise and fall of one of the first state-level societies in ancient Mesoamerica, the Zapotec state (ca. 250 BC-AD 800). Throughout the Prehispanic past human behavior has both been shaped by, and has impacted the local environment. We present here two of the applications of HSI that we have developed as part of this project: the measurement of potential agricultural productivity of the prehispanic landscape, and the assessment of the impact of urban sprawl on cultural resources.
The Central Valleys of Oaxaca have a pronounced wet-season/dry-season cycle in which most of the annual rainfall of 700 mm falls between May and September. As a result, most of the arable land away from the river flood plains can only be cultivated during the wet season. Using the Normalized Difference Water Index (NDWI), which measures water in plant tissue, we can compare dry season, during which there is sufficient water to support agriculture only along the river floodplains, and the dry season, when large areas of piedmont can support agriculture. The NDWI allows us to calculate the actual area over which agriculture can be supported throughout the year, and from that, estimate past potential agricultural productivity.
In the late 1970s and early 1980s, a full-coverage regional survey identified over 3,000 Prehispanic archaeological sites in the Central Valleys of Oaxaca. All of these sites were mapped on air photos, and their significant data recorded. In the three decades since the survey, the population of the Central Valleys, and Oaxaca city in particular, has skyrocketed and urban and industrial sprawl has impacted many archaeological sites. Using an ACE target detection algorithm, we are able to identify and measure areas of human habitation and construction in the contemporary landscape. We can then compare these images to digitized versions of the original survey air photos, and identify sites that have been impacted by urban sprawl and calculate the extent of the damage to cultural resources.

63. 2D-ERT Geophysical Characterization of the Plaza de Santo Domingo, Mexico City.

Denisse Argote-Espino[1], Pedro Paz-Arellano[2], Andrés Tejero-Andrade[3] and Pedro López-García[4]

1. *Subdireccion de Laboratorios y Apoyo Academico, Instituto Nacional de Antropologia e Historia, Mexico City, Mexico.*
2. *Coordinacion Nacional de Monumentos Historicos, Instituto Nacional de Antropologia e Historia, Mexico City, Mexico.*
3. *Facultad de Ingenieria, Universidad Nacional Autonoma de Mexico, Mexico City, Mexico.*
4. *Posgrado de Arqueologia, Escuela Nacional de Antropologia e Historia, Mexico 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 Mexica 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.

64. Different possibilities and combinations of geophysical methods in the research of various types of archaeological sites with changed landscape and land use – case studies from Bohemia, Czech Republic

Roman Křivánek

Institute of Archaeology of the Academy of Sciences of the Czech Republic, Prague, v.v.i., Dept. of Landscape archaeology and archaeobiology, Letenská 4, 118 01 Prague 1, Czech Republic

Geophysical methods and their different techniques have been intensively applied in Bohemia for various needs of archaeology or protection of archaeo-monuments for more than last two decades. The most common was combination of geophysical measurements with other non-destructive method, but also its integration as a part of archaeological researches and various projects. In more recent years, geophysical methods are used in monitoring of the state of subsurface preservation or planned new research of sites with significant and long-term threat by various changes in the landscape and origin terrain.
In terms of Central European archeology we have to count in the most of land definitely with multiple and repeated landscape changes. Many prehistoric or medieval sites were covered by new layers of settlements, other destroyed by afforestation, irrigation, agriculture, communications, continuous changing of cadastral systems, linear trenches etc. Possibilities of geophysical surveys on changed or disturbed terrains of archaeological sites were generally considered to be very limited. But at a suitable combination of geophysical methods we can provide a range of new information and their results may substantially complement.
Case studies from Bohemian sites represent different examples of efficient combination of geophysical methods during monitoring various archaeological situations. Combination of magnetometric and resistivity measurements of destroyed elevation of vanished afforested burial mound from the late Hallstatt period (approx. 500 BC) near Rovná contributed to effective management of archaeological excavation. Due to combination of 3 geophysical methods near Neumětely there was localized origin ground plan entirely extinct medieval stronghold (14th/15th century AD) in place of the extinct island (peninsula today) on the banks of the pond. Complex geophysical survey (3 methods) of abandoned Breda castle gardens near Lemberk (from the 2nd half 17th century to 2nd world war) helped to identify defunct castle park road systems, flower beds

and water distribution between the fountains in condition of destroyed garden and modern greenhouse destruction. Examples of presented results confirm the fact that application of some geophysical methods in conditions of changed terrains of sites may be successful. Few satisfactory use of one specific geophysical method does not mean that the subsurface situations had to be completely destroyed or we can´t identify them by different geophysical (or another) non-destructive method. Success of measurement, however, will always depend on conditions of survey as well as the extent and thickness of the disturbed situations and physical properties of archaeological relics still preserved in situ.

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

Mary Kate Donais[1], Bradley Duncan[2], Peter Vandenabeele[3], and David George[4]

1. *Department of Chemistry, Saint Anselm College, Manchester, New Hampshire, USA.*
2. *Department of Chemistry, University of Massachusetts, Amherst, Massachusetts, USA.*
3. *Department of Archaeology, Ghent University, Ghent, Belgium.*
4. *Department of Classics, Saint Anselm College, Manchester, New Hampshire, USA.*

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 Cavita, are directed by David George and Claudio Bizzarri under the auspices of the Soprintendenza per I Beni Archeologici dell'Umbria and the Parco Archeologico e Ambientale dell'Orvientano.

Two apsidal structures, part of the collapsed church of Sant'Ansano, were the focus of these initial spectroscopic measurements at the site. Systematic analyses of the mortars on the eastern apse utilizing portable x-ray fluorescence (XRF) spectrometry were conducted to better understand its construction. Eighteen analysis locations were examined in duplicate, some corresponding to mortar in the upper brick construction areas and others to the mortar in the lower stone construction areas, using a 40 kV excitation, 8.0 μA tube current, and a filter composed of 0.001-in Ti and 0.12-in. Al. A fully cross-validated principal component analysis (PCA) of the spectral data with centering and no weighting was performed. The PCA model accounted for 91% of the data variance. Scores plot results showed significant overlap of the brick and stone mortars, thus indicating that the lower and upper mortars on the apse did not exhibit different elemental compositions and were therefore likely to be of the same construction period.

Additional XRF data at twelve analysis locations also were acquired for the adjacent western apse using the same instrument conditions noted for the first study. A fully cross-validated PCA of the eastern and western apse spectral data with centering and no weighting was performed. The PCA model accounted for 93% of the data variance. Scores plot results showed significant overlap of the western apse and eastern apse data, again indicating that apse structures did not exhibit different elemental compositions and were thus likely constructed at approximately the same time. In contrast, comparisons of the Sant'Ansano mortars to mortars from the Coriglia site a tower in Monterubiaglio exhibited differences and data clustering when examined statistically.

Lastly, a partially intact fresco was located in the eastern apse. Portable XRF and portable Raman spectroscopy data were collected at various points on the fresco for pigment identification. The Raman spectrometer was equipped with two lasers, a red diode laser (785 nm) and a green Nd:YAG laser (532 nm). Preliminary data analysis of the pink, yellow, red, and dark red pigments indicate the presence of ochre. The dark green and light green pigments both had significant levels of copper present but have yet to be identified definitively.

Portable spectroscopy continues to be a valuable tool in archaeological field work as demonstrated by these two different applications for construction material analysis and pigment identification.

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

K. Dirix[1], B. Rogiers[1,2], P. Muchez[1], P. Degryse[1], B. Mušič[3] and J. Poblome[4]

1. *Department of Earth and Environmental Sciences, University of Leuven, Celestijnenlaan 200E, 3001 Heverlee, Belgium.*
2. *Institute for Environment, Health and Safety, Belgian Nuclear Research Centre (SCK•CEN), Boeretang 200, 2400 Mol, Belgium.*
3. *Department of Archaeology, University of Ljubljana, Aškerčeva 2, 1000 Ljubljana, Slovenia.*
4. *Sagalassos Archaeological Research Project, University of Leuven, Blijde Inkomststraat 21 - box 3314, 3000 Leuven, Belgium.*

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 dimensions of the dataset, resulting in clusters that are not only statistically, but also spatially homogeneous. The same algorithm was applied to the chemical dataset. Comparison of the resulting chemical and magnetic clusters reveals that an area characterised by a very low variogram-range is spatially associated with a chemical cluster rich in Cu, K, P, Pb and Zn. This is interpreted as the accumulation and decomposition of occupational debris. Increased Al, As and Ba concentrations helped interpreting cluster 3 with low average magnetic response as a region where limestone bedrock is located close to the surface. Finally, a cluster of enhanced magnetization and high range and sill was shown to partly overlap with two clusters of soils with elevated levels of Co, Cr, Mg, Mn, Ni, (Fe) and Ti, V, (Fe) respectively, indicating the presence of two different types of mafic to ultramafic ophiolitic bedrock near the surface.

This study illustrates that contiguity constrained clustering is a promising data analysis technique for geochemical and magnetic survey data, as the spatial dimension of the multivariate datasets is included in the algorithm. In addition, this research confirms that multi-element geochemistry has potential as an archaeological survey technique, because it offers direct information on bedrock characteristics or ancient human disturbance. In this way, it adds an extra dimension to the interpretation of geophysical survey data. It is shown that soil chemical data are particularly valuable in distinguishing and interpreting anthropogenic and natural impacts creating geophysical anomalies.

67. Photon Physics Role in Creation, Art and Archaeology

B. Kaiser,

The world of art and archaeology involves light or as scientist would have it photons at every turn. And it involves them at every level. So it goes to reason that it is vital that those are involved in these fields and indeed in life itself would benefit greatly if they knew more about the fundamentals of photons and how to best use them in their investigations..

Photons are used in most forms of elemental and molecular analysis, as well as the creation and destruction of many things. This short presentation will shed new light on one's understanding how one uses these flitting little packets of electromagnetic energy in everyday scientific investigations and many other adventures relative to one's existence in the dimension we are currently trapped in.

What is a photon?

- Discrete packets of electromagnetic radiation
- Force carriers
- Sometimes they exhibit the characteristics of a wave, sometimes the characteristics of a particle
- Have no mass
- Have electromagnetic energy
- Have momentum
- Free space always at the speed of light, c
- They have no length in the direction they travel
- Are slowed down when moving through matter, or

absorbed completely
- Define the dimension of time

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

Andrew King

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 particles, 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 archaeomtety, giving an insight into the power that these two instruments can provide in identifying elemental and chemical species at the same time.

69. Heaps and Heaps of it: Analysis of Kushan-Sassanid Metallurgical Remains from Mes Aynak, Eastern Afghanistan

Tom Eley[1], Loïc Boscher[2], Myrto Georgakopoulou[2]

1. *Archaeological Consultant for the Ministry of Mines of the Islamic Republic of Afghanistan on the Mes Aynak Archaeological Project (MAAP).*
2. *UCL, Doha Qatar.*

It is commonly understood that Afghanistan has played a significant role in the development of metallurgy as a source rich in both copper and tin throughout the Bronze Age and beyond. Despite this, and largely due to political instability, very little archaeometallurgical studies have been undertaken in the region, which has resulted in a critical knowledge gap (Berthoud et al. 1977; Pigott 1999). The announcement in 2007 that the world's second largest copper deposit, Mes Aynak, in the Islamic Republic of Afghanistan's Logar Province, was to be developed has offered us a rare opportunity to record and analyse some of the archaeometallurgical remains from the area. Initial results have so far revealed that exploitation of the copper deposits of Mes Aynak appear to date mainly to the Kushan-Sassanid period (1st to 7th centuries AD), although it is likely that earlier phases are present in deeper, as of yet unexcavated, strata.
This project focuses on the chemical analysis of some samples of the production remains uncovered 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 productions of the time. Initial results show that the technology employed revolved around exploitation of bornite and chalcopyrite from dolomitized marble host rock in a two-step matte smelting process. Interestingly, and in contrast to 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.

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70. **Crucible or Furnace** — A comparative study of silver production traditions in north and south China

Siran Liu[1]; Thilo Rehren[2]; Dashu Qin[3]; Jianli Chen[3]

1. *UCL Institute of Archaeology.*
2. *UCL Qatar.*
3. *School of Archaeology and Museology, Peking University.*

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, gift-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 for 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 ISA2014, 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 Mengshan, 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

Stéphanie Leroy[1], Mitch Hendrickson[2], Emmanuelle Delqué-Kolic[3], Enrique Vega[1], Philippe Dillmann[1]

1. *Laboratoire Archéomatériaux et Prévision de l'Altération: IRAMAT LMC CNRS & SIS2M LAPA CEA/CNRS, CEA Saclay, France.*
2. *Department of Anthropology, University of Illinois at Chicago, United States.*
3. *Laboratoire de Mesure du Carbone 14, LMC14, CEA Saclay, France.*

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 unrecognised in 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 (SI) 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 (MEB, LA-IPC-MS, ICP-MS) on a specific set of ores, slag samples and architectural crampons and tools from three temples within Angkor, we examined the geochemical variability of potential sources and SI of crampons 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

Thomas R. Fenn[1,2], James Ameje[3], Detlef Gronenborn[4], and Joaquin Ruiz[5]

1. *School of Anthropology, The University of Arizona, Tucson, AZ 85721, USA.*
2. *The Council on Archaeological Studies, Yale University, New Haven, CT 06520, USA.*
3. *National Commission for Museums and Monuments, Abuja, Nigeria.*
4. *Römisch-Germanisches Zentralmuseum (RGZM), 55116 Mainz, Germany.*
5. *Department of Geosciences, The University of Arizona, Tucson, AZ 85721, USA.*

Durbi Takusheyi is a burial site composed of at least eight mounds located between the modern towns of Katsina and Daura in northern Nigeria. Excavation blocks from three mounds, retained after the 1992 campaign, were stored in the Jos Museum, Nigeria, for further analyses. In 2007 the Römisch-Germanisches Zentralmuseum (RGZM) and the National Commission for Museums and Monuments in Nigeria (NCMM) started a project with the objective of completely restoring and analyzing the excavated artifacts. The remains of the 1992 excavation from burial mounds 4, 5 and 7 included single interments in the center of each mound, all three with various burial goods produced from inorganic (metal, glass, stone, cowries) and organic material (cloth, wood, hides). Many artifacts are of regional provenance but some were also imported from distant regions of the Islamic world. Following the currently available radiocarbon measurements, one group of the burials would date to the earlier 14th century AD, and judging from typology and art history another burial dates to the later 15th/early 16th centuries. The site thus covers a crucial phase in history during which the Hausa city states emerged, indicating shifting contacts to the Mediterranean and to the Middle East.

The current paper presents results of analyses on many of the non-ferrous metal objects recovered during the RGZM restoration. These comprise objects made of copper and copper-based alloys, as well as of silver. The objects range from bracelets/anklets of various forms and manufacturing techniques and leg guards, to bowls, buckets, ingots, and finery such as beads, pins, and forks. Manufacturing techniques and metal types illustrate a mix of imported finished and unfinished objects with locally manufactured and/or modified objects. Chemical composition and lead isotopic analysis results show that metals from Africa as well as further abroad, such as Iran, comprise the bulk of the metal raw materials. Multiple source regions supplied metals/objects for consumption in the Durbi Takusheyi burials. These results provide additional evidence on the late medieval contacts between sub-Saharan West Africa and the greater Islamic world.

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

Arne Jouttijärvi

Heimdal-archaeometry, Skovledet 30, 2830 Virum, Denmark

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 amterial 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 smiting of imported bloom iron was predominant. Only very few traces of secondary smithing 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 smiting while secondary smiting 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

Aaron Shugar[1], Patricia Urban[2], Edward Schortman[2]

1. *Art Conservation Department, Suny - Buffalo State, Buffalo, NY 14222.*
2. *Department of Anthropology, Kenyon College, Gambier, OH 43022.*

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 buddle 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 Blackiston 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 Muisca metalwork (Colombia, AD 600-1800)

Marcos Martinón-Torres[1] and María Alicia Uribe[2]

1. *UCL Institute of Archaeology, London, United Kingdom.*
2. *Museo del Oro, Banco de la República, Bogotá, Colombia.*

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. While technically interesting, these studies yield relatively little information about the societies who made and used those artefacts – at best, archaeometallurgical studies present gross generalisations. Only a closer integration of technical and contextual data can 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 Muisca – 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, metallography, 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 archaeometallurgical studies in other areas, we highlight the implications 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 gold figurines 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 Muisca 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 Muisca 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

M.I. Dias[1], M.I. Prudêncio1, Zsolt Kasztovszky[2], Imre Kovács[3], Zoltán Szőkefalvi-Na[3] and P. Flor[4]

1. *Centro de Ciências e Tecnologias Nucleares – C2TN. Campus Tecnológico e Nuclear. Instituto Superior Técnico, Polo de Loures. Estrada Nacional 10 (km 139.7). 2695-066 Bobadela, Loures, Portugal.*
2. *Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary.*
3. *Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary.*
4. *Universidade Aberta, Rua da Escola Politécnica, 147, 1269-001 Lisboa / Instituto de História da Arte da Faculdade de Ciências Sociais e Humanas da Universidade Nova de Lisboa, Av. de Berna 26c, 1069-061 Lisboa. Portugal.*

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/HIS/HEC/116742/2010) and a CHARISMA project at BNC (BRR-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 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 homogeneity 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, PGAA, 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 - carbonate rich of marine origin
(negative Ce anomaly) – marly clays, and firing temperatures around 900°C with the main mineralogical associaction: 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.

77. First Archaeometrical Data of Glass From Sarno Necropolis (9th - 6th CENTURY BC)

S. Conte[1], R. Arletti[2], F. Mermati[3]

1. *University of Modena and Reggio Emilia, Department of Chemical and Geological Sciences, Modena, Italy.*
2. *University of Torino, Department of Earth Sciences, Torino, Italy.*
3. *University Federico II di Napoli, Department of Humanistic Study, Napoli, Italy.*

The archaeometrical data on a set of 35 glass beads coming from two ancient necropolis, 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] underlined 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 (<0.1%) 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, as 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 ~ 0.40%). The trace elements analysis show that the plant ash and the natron samples (excluding the cobalt blue and the iron 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.

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

Veerle Devulder[1,2], Frank Vanhaecke[2], Andrew Shortland[3], David Mattingly[4] and Patrick Degryse[1]

1. *Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Leuven, Belgium.*
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 the 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 Nd 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 Sb 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 provenance this 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 δ11B 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 δ11B. The Wadi Natrun salts analysed, perfectly fit a model in which the δ11B of the glasses is somewhat lower compared to the natron source due to the input of low δ11B of the sand. The samples from Lake Pikrolimni in Greece show too low δ11B values to be used in glass making according to this model.

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

Laure Dussubieux[1] and Thomas Oliver Pryce[2]

1. *Elemental Analysis Facility, The Field Museum, Chicago, USA.*
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 heavily on 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 sodium – 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 glass 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 area. 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 isotope 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

Cristina Fornacelli[1,3], Susanna Bracci[2], Isabella Memmi Turbanti[3], Marcello Picollo[4], Márcia Vilarigues[5,6], Magda Troeira[6]

1. *Department of Earth Science, University of Pisa, Italy .*
2. *Institute for Conservation and Valorization of Cultural Heritage (ICVBC), National Council of Research (CNR), Sesto Fiorentino, Florence, Italy.*
3. *Department of Physical sciences, Earth and environment, University of Siena, Italy.*
4. *Institute of Applied Physics "Nello Carrara", National Research Council (IFAC-CNR), Sesto Fiorentino, Florence, Italy.*
5. *Department of Conservation and Restauration, Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus Caparica, 2829-516 Caparica, Portugal.*
6. *VICARTE, Research Unit "Glass and Ceramics for the Art", Faculdade de Ciências e Tecnologia, Universidade Nova de Lisboa, Campus Caparica, 2829-516 Caparica, Portugal.*

Currently the importance 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 chromophores and raw materials even though the complexity of interpreting the results and the lack of references necessitate a preliminary phase of testing on standard and reference samples.

In this study a collection of colored 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 analyzed 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 alkali) and different amounts of chromophores. For cobalt colored glasses 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/sulfide and cadmium/selenium ratios.

The cobalt blue 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 the glasses colored by CdS and Se is still in progress, and the results will be available soon.

81. Glass Chemical Analysis: Assessing the New Heterarchy

James W. Lankton[1], Bernard Gratuze[2], Anastasia Cholakova[3], Ian Freestone[3], Matthew Phelps[3] and Thilo Rehren[1]

1. *UCL Qatar, Doha, Qatar.*
2. *Institut de Recherche sur les Archéomatériaux, CNRS, Centre Ernest Babelon, Orleans, France.*
3. *UCL Institute of Archaeology, London, UK.*

The forty issues of the Journal of Archaeological Science published between November 2005 and February 2009 contained 9 articles reporting glass chemical compositional analyses, using a total of five different techniques. SEM-EDS (four studies) was the most common, followed closely by XRF, EPMA and ICP-AES (three studies each), then LA-ICP-MS with one. For the five years from November 2010 through February 2014, the number of articles including glass analyses had increased to thirty. In addition, the number of different techniques more than doubled to eleven, with EPMA, ten studies, now the most common, and LA-ICP-MS, nine studies, a close second.

This marked increase in the publication of glass compositional data, accompanied by the use of an increasing number of techniques, presents both opportunity and danger to scholars interested in the outcomes of glass analytical studies. While many authors provide data for their chosen techniques applied to standard glasses, the important issue of comparability of data from different techniques has received surprisingly little attention. For the two techniques of EPMA and LA-ICP-MS, we will present comparison data from the Wolfson Archaeological Science Laboratories at the UCL Institute of Archaeology (EPMA) and the Institut de Recherche sur les Archéomatériaux, CNRS, Orléans (LA-ICP-MS) for repeat measurements of standard glass Corning A, as well as comparison data for several series of Roman and Islamic glasses analysed by both techniques.

We evaluated the parameters of trueness, RSD (relative standard deviation) and estimated total uncertainty for the Corning A analyses, finding that trueness was similar for the two techniques, particularly for oxides present above 1000 ppm. On the other hand, RSD for LA-ICP-MS analyses of SiO2, Na2O, K2O, CaO and Al2O3 was about twice that for EPMA, similar for most other oxides down to 5000 ppm, then generally lower for oxides below 5000 ppm. Estimated total uncertainty followed a similar pattern.

The calculated percent difference for the EPMA and LA-ICP-MS measurements of our Roman and Islamic samples

was consistent with the Corning A results. For major elements, the results for the two techniques were within twenty relative percent when above 5000 ppm, with increased variation at lower values, particularly for K2O. Minor oxides were similar by both techniques to the 1000 ppm level, although a few high EPMA values corresponded to much lower LA-ICP-MS measurements. Relative overestimation by EPMA became more important below 500 ppm, and particularly below 300 ppm, with some variation by oxide studied. We believe that comparison studies such as these form an essential complement to the multiplicity of techniques now used for glass chemical analysis, allowing individuals and institutions to make informed choices regarding the techniques best suited to answer the archaeological questions most important for their overall research agendas.

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.*

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.

STONE, PLASTER and PiGMENTS

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

Mona Abdel-Ghani[1*], Fatma S. Madkour[2]

1. *Department of Conservation, Faculty of Archaeology, Cairo University, Giza, 12613, Egypt.*
   Email: mabdelghani2001@yahoo.com.
2. *Department of Conservation, Faculty of Fine Arts, Minia, University, Minia, Egypt,*
   Email: fatma_madkour@yahoo.com.

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 three 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 Aguayo[1], Marcela Sepúlveda[2], Patricio De Souza[3], Celine Paris[4] and Ludovic Bellot-Gurlet[4].

1. *Laboratorio de Espectroscopía Vibracional, Facultad de Ciencias, Universidad de Chile, Santiago, Chile.*
2. *Laboratorio de Análisis e Investigaciones Arqueométricas (LAIA), Depto de Antropología, Universidad de Tarapacá, Arica, Chile.*
3. *Programa de Doctorado en Antropología Universidad Católica del Norte- Universidad de Tarapacá, Arica, Chile.*
4. *Laboratoire de Dynamique, Interactions et Réactivité (LADIR), UMR 7075 UPMC/CNRS, Université Pierre et Marie Curie, Paris, France.*

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 multianalytical 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 through 10X and 50X objectives. When the sample is dry it can be used without further preparation for non-destructive RS and IR analyses. RS spectra were obtained using various excitation wavelengths (λ) at 458 nm (Horiba LabRAM HR800) and 633 nm (LabRAM Infinity). The IR spectrum was obtained using a Bruker Equinox 55 instrument. A single reflection attenuated total reflectance (ATR) germanium tip of a diameter of 100 µm was used to perform the measurements by contact with the sample.

With OM fiber diameters ranging from 35 to 62 µm were observed. In the case of blue and bluish green samples the color is due to blue agglomerates deposited on the fiber. The fibers present discontinuous medullas from 1/3 to 2/3 the size of the fiber diameter. Protein detected by ATR-IR measurements allow confirming that fibers are from animal origin, and due to their microscopic characteristics it is highly probable that the animal is the alpaca (Vicugna pacos). The blue agglomerates were identified as indigo in 2 samples [1]. The dye was identified in both cases by RS and in the blue sample was observed even by ATR-IR. It was observed that the RS spectrum with λ=458 nm show less fluorescence than that obtained with λ=633 nm. Further analyses to complete the characterization of dyeing techniques of this Formative context burial are currently performed.

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Acknowledgements

T Aguayo acknowledges the funding from CONICYT (21110352), FONDECYT (1110106) and from the French Embassy in Chile.
M Sepúlveda acknowledges the project Mecesup UTA0801 and Convenio de Desempeño Universidad de Tarapacá-MINEDUC

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

Harby E. Ahmed[1,2], Yuan Liu1, Matthieu Baudelet[1], Martin Richardson[1]

1) *The Collage of Optics & Photonics, University of Central Florida, USA.*
2) *Department of Conservation, The Collage of Archaeology, Cairo University, Egypt.*
   harbyezzeldeen@yahoo.com

Embroideries were one of the most sumptuous kinds of textiles produced in the world. In the present work, we studied the using of laser induced breakdown spectrometry (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 60mm). The spectrometer (Acton 2300i Acton 2300i, 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 39 mJ were studied.

The morphology of the surface of metal threads was investigated before and after LIBS analysis. Furthermore elementals composition was confirmed of the metal fibers by Scanning Electron Microscope (SEM) with energy-dispersive X-ray analyzer (EDX) –ULTRA 55, ZEISS). The investigation of the metal thread surface using Scanning Electron Microscopy (SEM) shows that all the metal thread is the typical structure of historical metal threads, which consists of metal strips wound around a fibrous core of cotton fiber.

The results from LIBS spectra of sample are in agreement with the results obtained by EDX analysis. The LIBS spectra show that the main elements of the metal thread are Copper (Cu), Silver (Ag), Gold (Au). In addition some elements such as Aluminum (Al), Magnesium (Mg), Calcium (Ca), and Sodium (Na) were also found in the metal threads of sample. The study suggests that the metal threads are Cu-Ag-Au alloy. This study presents clear statements of the effect of different LIBS shots with different pules energy on the metal threads. The metals threads were exposed to 1, 5, 10, 20, 30, 40, 50 and 80 laser shots at a single location on the sample with laser pulse energies set at 5, 10, 20, and 30 mJ. This study presents clear statements of the effect of different LIBS shots with different pules energy on the metal threads by using SEM images.

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.

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

Aloise Piergiorgio[1], Ruffolo Silvestro Antonio[1], La Russa Mauro Francesco[1], Belfiore Cristina Maria[1,2], Barca Donatella[1], Gino Mirocle Crisci[1]

1. *Dipartimento di Biologia, Ecologia e Scienze della Terra (DiBEST), Università della Calabria, Via Pietro Bucci, 87036 Arcavacata di Rende, CS.*
2. *Dipartimento di Scienze Biologiche, Geologiche e Ambientali - Sezione di Scienze della Terra, Corso Italia 57, 95129 Catania.*

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 Iulius are submerged after bradyseism events, started from IVth century AD. Several architectural structures are still preserved into the submerged environment, such as: luxurious maritime 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 Protiro.
A multianalytical 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 cocciopesto and marble fragments.

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

C.R. Appoloni[1], C.I. Parellada[2], F.L. Melquiades[3], E.I. Jussiani[1], F.C. Pereira[2] and F. Lopes[1]

1. *Departamento de Física, CCE, Universidade Estadual de Londrina, CEP 86055-990, Caixa Postal 6001, Londrina, Paraná, Brasil. appoloni@uel.br*
2. *Museu Paranaense, Setor de Arqueologia, Rua Kellers 289, CEP 80410-100, Curitiba, Paraná, Brasil.*
3. *Departamento de Física, Universidade Estadual do Centro Oeste, CEP 85015-430, Caixa Postal 3010, Guarapuava, Paraná, Brasil.*

Until recently, the pictograph pigments 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. The paintings occur along the length of 200m, between 0.3 to 4m height, central point E 577.073 e N 7.327.349 UTM SAD 69 coordinates. This area, with two caves and a big rock shelter had three different occupations, the oldest one is related to “Umbu” hunters and gatherers, from to 10,000 to 3,000 years BP. The two more recent are related to the Itararé-Taquara farmers and ceramists of Jê linguistic family, from 4,000 to 500 years BP. Rock art of this site are over sandstones and diamictites of Itararé Group, and belong to Planalto tradition, which are common in this region. The paintings of Morro Azul present figures in red and black, almost always with animals, fantastic human representations, barred lines, dots, semicircles, emblematic figures and lattice motifs. Also different styles of paintings can be observed. Rock art paintings regions were analyzed employing two portable systems: a Raman spectrometer operating at 785 nm, 120 mW and 8 cm-1 resolution, which spectral range from 200 to 2000 cm-1; an EDXRF equipment employing a 4mW X-ray tube with Ag filter and target, a Si PIN diode detector (149eV FWHM for the 5.9keV line) and a special designed mechanical system for the detector and X-ray tube positioning, which enables angular and XYZ movements of the excitation-detection system respect to the measurement area. Elements from Ca to Pb were measured. X-Ray Fluorescence spectra were analyzed using the AXIL-WinQXAS software. PCA and HCA analysis were performed with both Raman and PXRF spectra for grouping analysis. The rock base and red and black pigments were studied. By PXRF it was determined Fe as key element for the red pigment. Raman spectra of the red pigment showed hematite lines 292, 407 and 608 cm-1. Black pigment presented Mn as key element and more organic matter than the red one. PCA made a good discrimination of the red pigments, from the two black ones and from the rock without pigmentation.

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

Lydia Avlonitou[1]

1. *University Paris Ouest-Nanterre, UMR 7041 - Archéologies et Sciences de l’Antiquité, Maison d’Archéologie et d’Ethnologie René Ginouvès, 21 Allée de l’Université, 92023 Nanterre CEDEX, France.*

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 NARNIA ITN*, an integrating approach to the study of the painted decoration of the tombs, combining archaeological and archaeometrical 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 tomb types and represent as more regions as possible. They vary in terms of decoration themes and they are located in archaeological sites near seven major cities of Macedonia such as Thessaloniki, Amphipolis and Makrygialos.
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. The blue is almost always the Egyptian Blue, used alone or over a black background to achieve the desired optical effect. Mixed with yellow ochre or a ferrous red creates respectively vivid greens and violets. Green earths are also 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

*NARNIA (New Archaeological Research Network for Integrating Approaches to ancient material studies) ITN (Initial Training Network) Project
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.

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

S. Bracci[1], M. Barucci[2], R. Fontana[2], M. Marongiu[3], E. Pampaloni[2], C. Riminesi[1], J. Striova[2]

1. *Institute for the Conservation and Valorization of Cultural Heritage/CNR, Sesto Fiorentino (FI), Italy.*
2. *National Institute of Optics/CNR, Firenze, Italy.*
3. *Casa Buonarroti, Firenze, Italy*

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), Fiber Optic Reflectance Spectroscopy (FORS), Fourier Transform Infrared Spectroscopy (FT-IR), and X-Ray Fluorescence (XRF). The restricted material palette and the materials' low concentrations present in drawings make the physicochemical 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 providing essential information to historical and archaeometric research without taking any samples.
For MSR a scanning instrument with single point measurements of reflectance was used to collect 30 spatially registered images at different wavelengths (400-2500 nm). The possibility to operate a multispectral imaging proved convenient over the wide-band method. For example, the minimum optical density of iron-gall ink above 1000 nm allowed probing the underlying layers at higher wavelengths revealing often the preparation in carbon-based black not visible to the naked eye. The false color representation of the data (digital combination of infrared at 1300 nm with visible green and blue channels) proved very valuable and enabled quite straightforward mapping of areas realized in iron-gall ink.
As analytical methods XRF, FORS, and FTIR spectra on single spot, for respectively elemental and molecular information, were acquired in the areas of interest identified by means of multispectral images.
Selected Michelangelo's drawings, representing geometrical complex architectural designs with multi-layer structure aimed at rendering them three-dimensional, were examined. Our scope was to probe these layers in order to verify the presence of hidden features and to map the distribution and composition of dark washes and highlights. The multi-disciplinary approach provided some key elements for gaining a further insight into the 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 covering some pentimenti, outlining particular areas, and preparing the paper before drawing.

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

Roberto Bugini[1], Cristina Corti[2], Luisa Folli[1], Laura Rampazzi[2]

1. *CNR-Ist. Conservazione e Valorizzazione Beni Culturali, Milano, Italy.*
2. *Università dell'Insubria, Dipartimento Scienza e Alta Tecnologia, Como, Italy.*

A particular kind of plaster containing clay was identified in a Roman republican Sanctuary (first century B.C.E., first half) unearthed in 1992 near the Flavian Capitolium of Brixia (today Brescia). The plaster was examined by different analytical methods in order to detect each component: X-ray diffraction, Optical microscopy on thin section, Scanning electron microscopy, Infrared spectroscopy. The plaster shows two superimposed coats. (i) A render coat (about 20 mm thick) containing a lime binder and a sandy aggregate (size 0.1-4.0 mm) made of limestone, dolomite, chert, metamorphic rock, with addition of crushed brick. (ii) A finish coat containing a binder, with "decussate" texture, made of a mix of lime and clay minerals (illite) together with grains of dolomite, quartz, metamorphic rock (size 0.1-0.8 mm) as natural inclusion or added temper. The finish coat shows different colour and thickness: a sample (US 592), situated near the vault of the Sanctuary western cell, shows uniform thickness (1.2 mm) with 2.5GY 7/2 as Munsell Notation; another one (US 1437), coming from the rubble, shows uneven thickness (0.8 - 4.0 mm) and 5GY 6/1 as Munsell Notation. The presence of organic matter was detected in many samples, but the amount was too low for a reliable identification. In some cases the finish coat supports a greenish painted layer (0.15 mm tick - M.N. 10YR 7/2) with a pigment made of rounded grains of Glauconite and Celadonite (size 0.02 mm) and angular crystals of Cuprorivaite (size 0.01 mm).
The Latin Authors, as Vitruvius (De Architectura) or Pliny (Naturalis Historia), used different terms (argilla, creta, lutum) to describe a clay component of plaster. 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 replacement of the powdered marble.
Other clay-based plasters were found in some archaeological sites of Lombardy (Calvatone Bedriacum, domus Labirinto - Scavo sud, Saggio Beta 96; Milan, domus via Correnti 24 - US 219), but they were joined to the use of reed in wall construction as reported by Vitruvius (De Arch. 7.3.11).

91. Influence of synthesis conditions on growth of Egyptian blue

Manuela Catalano[1], Andrea Bloise[1], Domenico Miriello[1], Safaa Abd El Salam[2], Gino Mirocle Crisci[1]

1. *Department of Biology, Ecology and Earth Sciences, University of Calabria, Ponte P. Bucci, 87036, Arcavacata di Rende (CS), Italy.*
2. *Department of Painting Conservation of Mural Painting, University of Alexandria, Abd El Salam Aref, Mazloom Station, 108, Alexandria, Egypt.*

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 are calcium-copper silicate crystals (i.e. cuprorivaite, $CaCuSi_4O_{10}$) 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, trydimite) and copper oxide as impurities. The synthesis of this pigment "caeruleum", described by Vitruvius in De Architectura in the first century BC, was performed by heating at 830-1050 ºC a mixture constituted by siliceous sand (angular quartz pebbles or rounded quartz sand), lime (limestone, shell, calcareous sand) copper compounds (malachite, cuprite, bronze) and a flux (natron, plant ash). The mixture constituent EB shows a wide variety of possible sources of materials and temperature of formation. As regards preparation of EB, not all these sources of materials and temperatures have been investigated in previous studies, so that the question on which synthesis variables control the formation and 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 CM- 2600d under 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. cuprorivaite) occur at 900 °C for reaction times of 24 hours.

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

G. Cavallo[1,3], C. Lumia[2] and M. P. Riccardi[3]

1. *University of Applied Sciences of Southern Switzerland, DACD, IMC, Canobbio, Switzerland*
2. *University of Applied Sciences of Southern Switzerland, DACD, Canobbio, Switzerland*
3. *University of Pavia, Dept. of Earth Sciences, Pavia, Italy*

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 façade 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 the distinction 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, textural 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. A Mg-lime was used as binder and aggregates are represented by siliceous 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 examination but it cannot be considered exhaustive. In this case, it helped to understand the composition and the technology of the renders, the provenance of the sands (gneiss, amphibolites and peridotites of the Pre-Permian crystalline basement of the Southern Alps) and binder (the closest formations are the Triassic Lucomagno cariata dolomite and Campolungo dolomite); in addition, groups were established on the basis of the proportion of the mixes.

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

Hong Chen[1], Yamei Hou[2], Zemeng Yang[3], Ziming Zhen[3], Huiru Lian[1], Yang Liu[3]

1. *Department of Cultural Heritage and Museology, Zhejiang University, Hangzhou, China.*
2. *Key Laboratory of Vertebrate Evolution and Human Origin of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing, China.*
3. *Ordos Antiquity & Archaeology Institution, Ordos, China.*

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 for20% 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)

Nicoletta Chiarelli[1], Domenico Miriello[2], Andrea Scala[1], Giovanna Bianchi[3], Jacopo Bruttini[3], Giuseppe Fichera[3], Marco Giamello[1], Isabella Turbanti Memmi[1]

1. *Department of Physical Sciences, Earth and Environment, University of Siena.*
2. *Department of Biology, Ecology and Earth Sciences, University of Calabria, Italy.*
3. *Department of Historical Sciences and Cultural Heritage, University of Siena, Italy.*

S. Niccolò archaeological site is situated on the north-east side of Montieri Hill (Southern Tuscany), in an ancient mining district. Ruins of the medieval ecclesiastical complex were discovered during recent excavations and consist 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-micaceous sandstone was utilized for the foundation walls of the complex, while the outer walls are mainly constituted by marly limestone and calcareous tufa ashlars. 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, metallurgic slags and crushed ceramic fragments (cocciopesto) were also identified. In the majority of samples the binder is weakly hydraulic and it shows a moderate hydraulicity in the samples containing slags or cocciopesto.
The archaeological and archaeometric 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 metallurgic 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 metallurgic 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 huntite in the antiquity. A review with respect to ongoing studies in the archaeological site of Hierapolis in Phrygia (Turkey)

F. D'Andria[1], S. Bracci[2], E. Cantisani[2],T. Ismaelli[3], C. Riminesi[2], B. Sacchi[2], G. Scardozzi[3], S. Vettori[2]

1. *Department of Cultural Heritage/University of Salento, Lecce, Italy. Director of the Italian Archaeological Mission in Hierapolis of Phrygia.*
2. *Institute for the Conservation and Valorization of Cultural Heritage/CNR, Sesto Fiorentino (FI), Italy.*
3. *Institute for Archaeological and Monumental Heritage/CNR, Lecce, Italy.*

Huntite, $CaMg_3(CO_3)_4$, 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, dewelyte deposits (Faust 1953) or simply in dolomites (Skinner 1958), or in serpentinized 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 (Thrailkill 1965);
3) as early diagenetic products of Mg-rich solutions in pore waters of supratidalevaporitic environment (Kinsman

1967) 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 Procchio (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 white 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 its chemical composition. 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 through the Second Intermediate Period and in the New Kingdom through to the Third Intermediate Period. It was used less frequently during the Late, Ptolemaic, and Roman Periods. Since the late 1980s, naturally occurring mixtures of hydromagnesite and huntite have found important industrial use. Their endothermic decomposition over a temperature range similar to that of commonly used polymers and their release of water and carbon dioxide, has led to such mixtures being successfully used as fire or flames retardant additive materials (Atay&Celik 2010 and 2012; Hollingbery& Hull 2010). At present, the commercially used deposits are located in Greece and Turkey. In particular, Turkey has millions of tons of reserves. There have been more than five active quarries operating in Denizli region since the beginning of 1990s.
In the archaeological site of Hierapolis in Phrygia (Pamukkale, Denizli Province, south-western Turkey) the huntite mineral has been found around the iron pin used to connect the head, now lost, to a marble half-bust of a small statue, found during the 2013 campaign. The bust probably depicts a female figure or goddess, with long hair, chiton and himation over the head. During the antiquity the upper part with the head and the bust were restored after a break, using an iron pin coated by huntite. The marble bust has been discovered in the Ploutonion, the sanctuary of Hades, god of the Underworld, that was the most famous sacred place in Hierapolis, described by ancient Greek and Roman authors (Strabo and Cicero), who visited this important pilgrimage centre.
The authors suppose the identification of a new use of this material in antiquity. 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 Çürüksu River (ancient Lykos), where the ancient city lies. But the main quarrying district of this mineral in south-western Turkey is in the Acıpayam 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 whose harbors the 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”.

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

Daniel F., Mounier A., Lefrais Y.

Institut de Recherche sur les Archéomatériaux (IRAMAT), UMR CNRS 5060
Centre de Recherche en Physique Appliquée à l’Archéologie (CRPAA) Université Bordeaux 3
Maison de l’archéologie, Esplanade des Antilles 33607 Pessac, France

The paintings (15th century), situated in the last floor of a medieval house (Belves Castle), today transformed into attic, represent an important exemple 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].
These murals paintings were the object of a study on the question 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 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 spectrum references. An ACP analysis gives a spectral signature of these paintings and the mapping of the pigments allows to highlight the original paintings and the previous restorations.

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Keywords: *Hyper spectral imaging, pigments, mural paintings.*

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

A.A. Delgado Robles[1], M.D. Manrique Ortega[1], P. Claes[1], E. Casanova González[1,2], J.L. Ruvalcaba Sil[1], M. Maynez Rojas[1], M. Cuevas García[3]

1. *Instituto de Física, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica s/n, Ciudad Universitaria, Mexico DF 04510, Mexico. e-mail: sil@fisica.unam.mx*
2. *Centro de Investigaciones en Corrosión, Universidad Autónoma de Campeche, Av. Agustín Melgar s/n entre Calle 20 y Juan de la Barrera. Col. Buenavista, San Francisco de Campeche, CP 24039, Campeche, Mexico.*
3. *Dirección de Registro Público de Monumentos y Zonas Arqueológicas. Instituto Nacional de Antropología e Historia. Av. Victoria 110, Copilco El Bajo, Mexico DF 04510, Mexico.*

Mesoamerican 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 found which fired people's imagination ever since its discovery. Because of this variety and historical importance, we analyzed the 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, omphacite, amazonite, 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.
This research has been supported by the projects CONACyT Mexico 131944 MOVIL II, PAPIIT UNAM IN402813 ANDREAH II and ICyTDF PICCO10-57.

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

FENG Nan[1], WANGHuizhen[2] ZHU Hong[3]

1. *Research Center for Chinese Frontier Archaeology, Jilin University, ChangChun City, Jilin Province, China.*
2. *School of Cultural Heritage, Northwest University, Xi'an City, Shanxi Province, China.*
3. *Research Center for Chinese Frontier Archaeology, Jilin University, ChangChun City, Jilin Province, China.*

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 dispersion X-ray analysis(EDX), conventional X-ray diffraction(XRD) have been used for assessing weathering and bideterioration 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 destory the stone. In order to prevent and control the serious biological weathering, for the first time, we collected 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 by in situ scanning electron microscopy and classical cultivation studies. Analyses revealed complex fungal communities, which include Penicillium cyclopium, Curvularia lunata, Penicilliumimplication, Phycomycetes, the lichen is Xanthoparmelia mexicana (Gyeln) 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 Pidighi (Sardinia)

Kyle P. Freund[1,2]

1. *Department of Anthropology, McMaster University, Hamilton, Ontario, Canada.*
2. *McMaster Archaeological XRF Lab, McMaster University, Hamilton, Ontario, Canada.*

This study focuses on obsidian consumption at the 'ritual spring' of Mitza Pidighi in west-central Sardinia, Italy. The site dates to late Nuragic I to Nuragic III phases of the Bronze Age (ca. 1350-850 B.C.) and is found just east of a contemporaneous residential village. Mitza Pidighi 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 Pidighi, of which approximately 78% was obsidian and the remaining material black/gray rhyolites. 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 EDXRF 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 indicates that people were physically knapping obsidian near the well to create expedient flake tools and non-prismatic blades. While differences do exist between the reduction sequences seen at Mitza Pidighi 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 Pidighi and in understanding the role of obsidian use outside of domestic contexts.

100. Identification of Iron Age Corals Using a Multi-Stage Approach

Sebastian Fürst[1], Katharina Müller[2], Céline Paris[3], Ludovic Bellot-Gurlet[3], Marine Gay[2] and Ina Reiche[2]

1. *Institute for Pre- and Protohistory/Johannes Gutenberg University Mainz, Germany.*
2. *Laboratoire d'Archéologie Moléculaire et Structurale (LAMS), UMR 8220 CNRS/Université Pierre et Marie Curie/ Paris 6, Ivry-sur-Seine, France.*
3. *Laboratoire de Dynamique, Interactions et Réactivité (LADIR), UMR 7075 CNRS/Université Pierre et Marie Curie/ Paris 6, Paris, France.*

During the Iron Age, red corals (Corallium rubrum) were the most frequent imported object type from the Mediterranean area into the Celtic world. The density and the distinct patterns of their distribution are perfectly suited for the study of intra-European cultural contacts and trade relations due to their long-term importation.
Despite the 130-year-old history of research on prehistoric corals, there have been hardly any extensive studies. One reason for this limited interest is that corals lose their intense red colour and shiny surface structure due to poorly understood ageing processes. Hence, other light-coloured materials such as bone, ivory, chalk or shells, which were also used to decorate jewellery, are often mistaken for corals.
We propose a multi-stage approach to identify red corals and light bio-minerals with emphasis on digital microscopy and mobile Raman spectroscopy. This setup is portable and can therefore be used directly in the museums, allowing a very efficient work flow thanks to a high identification rate while saving time.
Our work has shown that the easiest way to identify red coral is the proof of organic pigment residues, which are still visible in Raman spectra of optically already completely faded artifacts. Low laser excitation wavelengths like 532 nm are ideally suited for detecting organic pigments, while higher wavelengths are rather sensitive to calcium

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 unique verrucae 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 "critical 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

Alessa A. Gambardella[1], Catherine M. Schmidt Patterson[1], Marc S. Walton[2], and Samuel M. Webb[3]

1. *Getty Conservation Institute, Los Angeles, CA, USA.*
2. *Northwestern University/Art Institute of Chicago Center for Scientific Studies in the Arts (NU-ACCESS), Evanston, IL, USA.*
3. *Stanford Synchrotron Radiation Laboratory (SSRL), Menlo Park, CA, USA.*

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 material 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)8Al6Si6O24(SO4,S,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 ultramarine pigments from many origins including Afghanistan, Russia, and Chile—as a potential means for identifying a geological fingerprint. 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.

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

Gianluca Gariani[1], Debora Angelici[1,2,3], Alessandro Lo Giudice[1,2], Alessandro Re[1,2], Alessandro Borghi[3], Thomas Calligaro[4], Silvia Calusi[5,6], Lorenzo Mariano Gallo[7], Nicla Gelli[5], Lorenzo Giuntini[5,6], Maria Cristina Guidotti[8], Claire Pacheco[4], Giovanni Pratesi[9], Chiara Ricci[1], Francesco Taccetti[5], Gloria Vaggelli[10]

1. *Dipartimento di Fisica - Università di Torino, Italy*
2. *Istituto Nazionale di Fisica Nucleare - Sezione di Torino, Italy.*
3. *Dipartimento di Scienze della Terra - Università di Torino, Italy.*
4. *Centre de Recherche et de Restauration des Musées de France, Palais du Louvre, Paris, France.*
5. *Istituto Nazionale di Fisica Nucleare - Sezione di Firenze, Italy.*
6. *Dipartimento di Fisica - Università di Firenze, Italy.*
7. *Museo Regionale di Scienze Naturali - Torino, Italy.*
8. *Museo Egizio di Firenze, Italy.*
9. *Dipartimento di Scienze della Terra e Museo di Storia Naturale - Università di Firenze, Italy.*
10. *CNR - Isitituto Geoscienze e Georisorse - Unità Operativa di Torino, Italy.*

Lapis lazuli is a blue semi-precious stone used for more than 7000 years for carving decorative objects and jewels. The value and rareness of this gem 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 minero-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 Baikal 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 µXray-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)[4] and µXray-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 Medicea di pietre lavorate") [4], the Egyptian Museum of Firenze (New Kingdom amulets and pendants) and the Regional Museum of Natural Science of Torino (some polished items of the 19th century "Collezioni Sabaude"). 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.

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

Marine Gay[1], Katharina Müller[1], Frédéric Plassard[2], Jean-Jacques Cleyet-Merle[3], Pablo Arias[4], David Strivay[5], Catherine Defeyt[5] and Ina Reiche[1]

1. *Laboratoire d'Archéologie Moléculaire et Structurale, UMR 8220 CNRS - Université Pierre et Marie Curie, Paris, France.*
2. *S.A.R.L. Grotte de Rouffignac, France.*
3. *Musée National de Préhistoire, Les Eyzies-de-Tayac, France.*
4. *Instituto Internacional de Investigaciones Prehistóricas de Cantabria, Universidad de Cantabria, Santander, Spain.*
5. *Centre Européen d'Archéométrie, University of Liège, Belgium.*

Palaeolithic cave art has taken a more and more important 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 over time. However, the on-site geo-physico-chemical study of archaeological record stays difficult and the conservation of its integrity imposes restrictions. Taking benefit of recent analytical developments in the X-ray field, new perspectives of acquiring statistically relevant data for archaeological 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, difficult 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 has been demonstrated for three major cave sites featuring Palaeolithic art: Font-de-Gaume and Rouffignac cave in Dordogne (France) and La Garma 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 in a same cave, giving more detailed insights into its 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 65 Great Ceiling figures whereas a unique pigment mixture has been used for the drawing of the Ten Mammoths Frieze. Further information has been obtained on the taphonomic wall processes.
The spectroscopic study of these cave art illustrate the strong potential of such combined in situ and non-invasive analyses to better characterize the prehistoric figures in their cave environment and in a wider perspective to better understand the symbolic practices of past societies, appreciate possible cultural changes and relationships within the Franco-Cantabrian region.

104. Biodegradation of frescoes in the “Beata Vergine del Pilone” Sanctuary, Polonghera (Italy)

Roberto Giustetto[1], Dario Gonella[2], Valeria Bianciotto[3], Erica Lumini[3], Samuele Voyron[3], Emanuele Costa[1], Eliano Diana[4] and Sonia Conte[5]

1. Department of Earth Sciences, University of Turin, via Valperga Caluso 35, 10125 Torino (Italy).
2. Gonella Dario Restauri, via G. Priotti 115, 12035 Racconigi, Cuneo (Italy).
3. Department of Life Sciences and Systems Biology, University of Turin, viale P.A. Mattioli 25, 10125 Torino (Italy).
4. Department of Chemistry, University of Turin, via P. Giuria 7, 10125 Torino (Italy).
5. Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Via S. Eufemia, 41121 Modena.

When Conservation scientists casted a glance at the frescoes decorating the cupola of the ‘Beata Vergine del Pilone’ Sanctuary in Polonghera, near Cuneo (Italy), they scarcely could believe their eyes. Those paintings, dating back to the 18th Century, looked as if an unknown vandal purposely covered the skin of most religious characters with brown paint. A couple of cherubs even reminded of the exhortation in the famous “Angelitos Negros” song: “Painter, born in my land… though the Virgin may be white, paint me some little black angels, for they go to heaven too, as all good black people do.”
This transfiguring effect was the result of a bio-chemical deterioration due to the growth of a viscous, brownish biofilm selectively covering those frescoes areas painted in pink. To study this phenomenon, a multi-disciplinary approach was adopted including both minero-chemical methods and DNA-sequencing techniques. The former allowed to characterize those materials used by the original artist(s) as well as the components responsible for their chemical deterioration, together with the by-products of microbial activity; the latter brought to identify those microbial species responsible for the sequential colonization steps.
Water played a key-role in both chemical and biological aspects. Dampness percolating from outside, due to cracks in the cupola walls or capillarity, brought pollutants such as H2S and SO2 on the frescoes surface thus triggering formation of gypsum-sulphurous crusts. This fact, coupled to the particular composition of these frescoes pinkish pigments – a mixture of Cinnabar (HgS) and Zinc White (ZnO2) – caused significant S concentrations to occur in selected areas which, in presence of catalysts (i.e. Zn and other metals), favoured colonization of a first-generation sulphate-cycling bacteria. The dead bodies of these bacteria and abundant moisture, in turn, supplied those nutrients necessary to allow the settlement of a second-generation microbial community, represented by scavenger bacteria and saprophyte fungi. These late colonizers were responsible for the biofilm development, selectively covering the flesh-coloured areas.
These frescoes suffered therefore both an aesthetic and a structural damage, the first related to the biofilm growth and the second to pigments alteration caused by mobilization of certain elements recycled in the by-products of microbial activity (i.e. sulphates).
The performed survey paved way for a restoration intervention, achieved by delicately dry-cleaning the frescoes surface and applying a proper biocide which allowed the effective biofilm extirpation while possibly preserving the vividness of the residual pigmented layers

105. New Evidence About the Use of Ophiolites in the Minoan Architecture. The Investigation of the Excavated Duct in the “High Priest’s House”, a Peripheral Monument of the Palace of Knossos.

Grammatikakis Ioannis[1], Anagnostaki Georgia[2].

1. *Conservation Scientist, 23rd Ephorate of Prehistoric and Classical Antiquities, Hellenic Ministry of Culture, Heraklion, Crete, Greece. Department of Chemistry, University of Crete, Heraklion, Crete, Greece.*
2. *Archaeologist, 23rd Ephorate of Prehistoric and Classical Antiquities, Hellenic Ministry of Culture, Heraklion, Crete, Greece.*

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 (selenite) elements 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 excavation of the monument in 1931. The preliminary results of the investigation for the determination of the material of the drain revealed the presence of Chrisotile a characteristic mineral of the family of Ophiolites. 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 quaries as well as the ophiolite – bearing mélange on the Island of Crete, excluded several outcrops. Further analysis of samples from most of the ophiolite 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

Gutiérrez Garcia-M., Anna[1], Royo Plumed, Hernando[2] and González Soutelo, Silvia[3]

1. *Institut de Recherche sur les ArchéoMATériaux (IRAMAT), Centre de Recherche en Physique Appliquée à l’Archéologie (CRP2A), CNRS-Université de Bordeaux 3, Bordeaux/Pessac, France. Email: anna.gutierrez@u-bordeaux3.fr*
2. *Unitat d’Estudis Arqueomètrics, Institut Català d’Arqueologia Clàssica (ICAC), Tarragona, Spain. Email: hroyo@icac.cat*
3. *Departamento de Historia, Arte e Xeografía, Universidade de Vigo, Vigo, Spain. Email: silviatui2004@yahoo.es*

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 its presence 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 outcropping marble varieties as the first and basic step to correctly differentiate from other Spanish or even Mediterranean marbles.
Petrography, cathodoluminiscence CL and, in some cases, IRMS for C-O isotopic determination were applied and enabled to distinguish at least three significant varieties: a) a poorly crystalline 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 white marble with thin, 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) confirm 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 essential basis upon which pursue further research.

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

M. A. Hawash[1] & H. A.mahmoud[2]

1. *Dpt. Conservation, Faculty of Archaeology- Cairo University, Giza, Egypt.*
2. *Dpt. Conservation, Faculty of Archaeology- Cairo University, Giza, Egypt.*

Gypsum plasters as decorative material in the archaeological 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 Gawish in Al Mahala Al Kaubra, Egypt. by using different analysis, XRF to estimate the components of reinforcement material after burning compared with common fiber used as reinforcement material like linen, hay. and investigations, LM- SEM 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 emphasis 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. Aspergillusniger, Aspergillusflavus, Trichodermaviride, Alternariasolaui, Botrodiplodia sp., Penicillium sp., were the detection fungi and Xanthomonasalbilineans bacteria.

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

A. Hunt[1], B.H. Stuart[1], P.S. Thomas[1], D. James[2], B. David[2], J-M. Geneste[3] and J-J. Delannoy[4]

1. *School of Chemistry and Forensic Science, University of Technology Sydney, Australia.*
2. *School of Geography and Environmental Science, Monash University, Melbourne, Australia.*
3. *Centre National de Préhistoire, Université de Bordeaux 1, Périgueux, France.*
4. *Laboratoire EDYTEM, Université de Savoie/CNRS, Le Bourget du lac, France.*

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 reds to yellows, 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 determined using optical microscopy: red, purple, yellow, white, black, orange and brown. Along with optical microscopy, scanning electron microscopy – energy dispersive spectroscopy has been used to characterise the nature and distribution of the elemental composition of the pigments. X-ray fluorescence techniques are also used to determine complimentary 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 compliment 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.

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109. Inorganic fillers used in ancient lacquer wares of Warring Sates to Han Dynasty

Pujun JIN[1], Xiaogang Yang[2], Lajiang Jia[3], Puheng Nan[4], Bin Li[5]

1. *School of Materials Science and Engineering, Shaanxi Normal University, Xi'an, China.*
2. *Chongqing Cultural Heritage Research Institute, Chongqing, China.*
3. *Northwest University, Xi'an, China.*
4. *Shanxi Provincial Institute of Archaeology, Taiyuan, China*
5. *Emperor Qinshihuang's mausoleum Site Musuem, Xi'an, China.*

The remains of Chinese lacquer artifact were found as early as the Neolithic early stage, such as famous red lacquer bowl in Hemudu site, and lacquer bow in Kuahuqiao site. In ancient China, lacquer manufacture shows a continual development which remain alive now and deeply influence that in other parts of world. Warring Sates to Han Dynasty is an innovative stage of lacquering technology when a giant amount of various exquisite lacquers were mainly produced by government agencies. As a matter of fact, the lacquer film has a complicated component makeup that is usually a complex composition by lacquer, organic and inorganic material. This paper aimed to introduce hierarchical structure of lacquer film and inorganic material used as pigments and fillers, which were analyzed by microtomy, optical microscopy (OM), X-ray diffraction (XRD), scanning electron microscopy/energy dispersive X-ray spectrometer (SEM/EDS) and Raman spectroscopy (RS). The results showed that cross-sections of lacquer film demonstrated multilayer structures including Qihui layer (a layer mixed by lacquer and various plaster), undercoat layer (or finishing coat) and colored paint layer. As for pigment and fillers, cinnabar (HgS) was used as red pigment, covelline (CuS) as dark blue color, orpiment (As_2S_3) as yellow pigment. Bone ash [$Ca_5(PO_4)_3(OH)$], albite ($NaAlSi_3O_8$) and quartz (SiO_2) were added in lacquer plaster layers. In case of Jiuliandu site of Warring States,

the basal structure of lacquer film already were elected and different size particles were use 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 Mediaeval and Early Modern Wall Paintings in the Low Countries

Karin Keutgens[1,2], Anna Lluveras-Tenorio[3], Anna Bergmans[4], Peter Vandenabeele[2], Bernard Delmotte[4] and Maria Perla Colombini[3]

1. *Viering bvba, Lier, Belgium.*
2. *Ghent University, Department of Archaeology, Ghent, Belgium.*
3. *University of Pisa, Department of Chemistry and Industrial Chemistry, Pisa, Italy.*
4. *Ghent University, Department of Art History, Ghent, Belgium.*
5. *B.J.Delmotte bvba, Antwerp, Belgium.*

Late mediaeval and early modern wall paintings in the Low Countries mainly are executed using a secco painting techniques. Hitherto little is known about which specific binding media have been used. Entries to the investigation of original execution techniques generally are the study of archival source material and the material-technical survey and analysis of the paintings themselves.
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 studies of cross-sections and on gas chromatography/mass spectrometry (GC/MS) analysis of separated paint layers. As binders of a secco wall paintings can be singular or complex mixtures of organic (and inorganic) materials, the GC/MS analytical procedure applied is based on a multistep chemical sample pretreatment that allows the identification of lipids, waxes, proteins, polysaccharides and resinous materials in the same micro-sample. It is the first time that this analytical procedure is systematically conducted on wall paintings samples from the Low Countries.
Besides presenting the first instrumental analysis results, the paper will discuss sampling conditions, analysis possibilities and choices and in site interpretation. Moreover comparison between the results from analytical data and technical instructions found in archival sources concerning the execution of wall paintings in the Low Countries, will be provided. Finally, the contribution will shortly deal with conservation problems and how knowledge of original binding media could contribute to define more durable and case-specific conservation advices and practices for wall paintings.

111. Spectral Matching of Pigments for Ancient Artifacts Using Hyperspectral Imaging & Analysis

Mark Allen Lanoue[1]

1. *PhiLumina, LLC (Gulfport, MS, USA), The Hyperspectral Imaging Foundation.*

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 data (We have used a NASA Award winning system from PhiLumina, 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 PhiLumina 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

Y. Maniatis[1], Th. Arvaniti[1], T. G. Antikas[2], L. Wynn-Antikas[2], S. Orsini[3], E. Ribechini[3], M.P. Colombini[3].

1. *Laboratory of Archaeometry, materials Science Sector, NCSR "Demokritos", 153 10 Aghia Paraskevi Attiki, Greece.*
2. *Anthropological Research Team, Vergina Excavations, Aristotle University, Department of History and Archaeology, Thessaloniki, Greece.*
3. *Department of Chemistry and Industrial Chemistry, University of Pisa, I-56126 Pisa, Italy.*

During the recent anthropological study of the cremated bones of the male found in the main chamber of Tomb II in the Great Tumulus of Vergina (ancient Aegae), small fragments of an unusual material was noticed among the fragments of the cremated bones kept in a golden larnax and thought to belong to King Philip of Macedon. Remains of this material were also found adhered on several bone fragments.
A systematic scientific investigation is under way in order to characterize its nature, origin, relation to the bones and purpose of being in the larnax. The techniques used were non-invasive or minimally invasive requiring minute amounts of sample. These were: Optical Microscopy, SEM examination and analysis at low vacuum, FTIR spectroscopy, GC/MS spectrometry and pyrolysis GC/MS on a selected fragment for identification of the possible organic content. The first results have indicated that this unusual material consists of a multi-layered structure containing 4 to 5 layers of different thickness and composition. Namely, a thin purple layer, a pure white layer, a second purple layer, a beige layer, and finally a third purple layer. However this sequence is not the same in all fragments; sometimes a layer is missing or an extra layer may be present. Analysis proved that the basic material involved is the mineral huntite [CaMg3(CO3)4] containing inclusions of hydromagnesite [Mg5(CO3)4(OH)2•4(H2O)]. This is a pure white mineral and one of its very rare worldwide deposits is located in the Kozani district of northern Greece, some 40 km away from Aegae. The white layers of the multi-structured material consist of pure huntite, the beige layers of huntite plus an amount of clay, and the purple layers either of Tyrian purple with some clay or Tyrian purple with huntite. The microstructure of the layers containing huntite is enigmatically cellular but no plant or animal fibers are observed. The organic analysis showed the presence of proteinaceous material in all layers, beeswax and pine resin in the beige layer, and plant fibers in the final purple layer.
It is a first time such material in composition and structure is identified in association with either cremated or inhumed ancient bones hence its nature and origins are quite puzzling. Is it an object, an embalming material, or an accidental attachment to the bones? Further research is underway.

113. Provenance Study of Obsidian Artifacts from the Fowler Museum Collection (UCLA) using a Handheld X-ray Fluorescence Spectrometer

Kristine Martirosyan-Olshansky[1], Christian Fischer[1] and Wendy Teeter[2]

1. *Cotsen Institute of Archaeology, UCLA, Los Angeles.*
2. *Fowler Museum, UCLA, Los Angeles.*

Over 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; Ambroz 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 pXRF), 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

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 concentrations 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.

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

George Mastrotheodoros[1,2], Konstantinos G. Beltsios[1] and Yannis Bassiakos[2]

1. *Materials Science and Engineering Dept., University of Ioannina, Ioannina, Greece.*
2. *Institute of Advanced Materials, Physicochemical Processes, Nanotechnology and Microsystems, NCSR 'Demokritos', Aghia Paraskevi, Athens, Greece.*

Metal-leaf decoration plays an essential role in the context of Eastern Orthodox 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 gilding') or by employing drying oil based mordants ('mordant gilding'). 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 gilding' technique while the highlights are made by employing various versions of the 'mordant gilding' method.

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

Ana Bertha Miramontes Mercado[1], Fernando Godos González[2]

1. *Instituto Nacional de Antropología e Historia (INAH). Proyecto de Conservación del Altar del Mictlantecuhtli/ Coordinación Nacional de Conservación del Patrimonio Cultural (CNCPC-INAH)/Centro INAH Veracruz, ciudad de México-Veracruz, México.*
2. *INAH. Proyecto de Conservación del Altar del Mictlantecuhtli/CNCPC-INAH/Centro INAH Veracruz, ciudad de México-Veracruz, México.*

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 pictorical 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 archaeometric 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 electromagnetic 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

Elizabeth Niespolo[1], Hector Neff[2], Gregory Holk[3], & Brigitte Kovacevich[4]

1. *Department of Geological Sciences, California State University, Long Beach.*
2. *Department of Anthropology, California State University, Long Beach.*
3. *Department of Geological Sciences, California State University, Long Beach.*
4. *Department of Anthropology, Southern Methodist University.*

The only known jadeitite source region in Central America lies along the Motagua River in Guatemala, divided by the Motagua Fault into two source regions. Jadeitite from north of the Motagua Fault Zone (MFZ) differs petrologically from that found south of the MFZ; thin 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 jadeites by approximately 0.5-4‰ with a window of overlap between 8.6-9.1‰, while δ18O 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 homogeneous 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, omphacite, 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 Cancuén workshop may represent a link between the Motagua 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

Renate Nöller

Division 4.5 Analysis of Artefacts and Cultural Assets, Federal Institute for Materials Research and Testing (BAM), Berlin, Germany

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 the cultural diversity of people who travelled along trade roads between East and West. The composition of inks used for writing and painting have been determined by analysis. Quite a few fragments show elaborate manufactures for highlighting text on one and painting colorful pictures on the other side of a paper. In order to clarify the cultural background of this high level standard, similar materials and techniques used for preparation are compared.
The analysis is conducted on site using non-destructive methods. It encompasses visible spectroscopy (VIS) for primary characterization of inks and pigments, mobile X-Ray Fluorescence spectroscopy (ARTAX/TRACER) for elemental analysis, and FTIR (EXOScan) to determine chemical composition.
The black ink of the chosen manuscript fragments has a common feature, as it is identified as carbon ink enriched with copper as trace element. Furthermore a special preparation with a white colored surface under black letters is observed on papers written in Tocharic and Soghdian language. The priming is identified as gypsum [Fig. 1]. On the back side of some of these documents remains of paintings show a rich palette of colors. The pigments identified are red lead and cinnabar, blue and green indigo, green malachite, yellow orpiment and gold.

To establish a group of similarly produced documents, some additional manuscripts were selected. The fragments from Qoco with Buddhist texts in Soghdian and Manichaean and an Indian Pustaka book format represent the same kind of support prepared for writing and for colorful painting on the back side. Thus analyses of the material should give information to clarify a common provenance.
The manuscript fragments are mostly prepared with a whitish surface, variable in thickness but also in material. Concerning the pigments used- apart from common ones the most interesting for tracing back a tradition of manufacture resulted to be orpiment and gold, applied interchangeably on all illuminated fragments. They have also been detected onSyrian, 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, Soghdian and Manichaean manuscripts and a provenance or influence from Western and Indian tradition [1] [2].

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

Marie Orange[1], François-Xavier Le Bourdonnec[2], André D'Anna[3], Ludovic Bellot-Gurlet[4], Anja Scheffers[1], Gérard Poupeau[2,5], Carlo Lugliè[6], Renaud Joannes-Boyau[1]

1. *Southern Cross GeoScience, Southern Cross University, Military Rd, Lismore, NSW, 2480, Australia. m.orange.10@student.scu.edu.au; Anja.Scheffers@scu.edu.au; renaud.joannes-boyau@scu.edu.au.*
2. *IRAMAT-CRP2A, UMR 5060 CNRS - Université Bordeaux 3, Maison de l'Archéologie, Esplanade des Antilles, 33607 Pessac, France. Francois-Xavier.Le-Bourdonnec@u-bordeaux3.fr*
3. *Aix-Marseille Université (AMU), Laboratoire Méditerranéen de Préhistoire Europe-Afrique LAMPEA (UMR 7269) MMSH, BP 647, 5 rue du Château de l'Horloge, 13094 Aix-en-Provence, Cedex 2, France. danna@mmsh.univ-aix.fr*
4. *Laboratoire de Dynamique, Interactions et Réactivité (LADIR), UMR 7075 CNRS - UPMC (Université Pierre et Marie Curie Paris 6), 4 place Jussieu 75252 Paris Cedex 05, France. ludovic.bellot-gurlet@upmc.fr*
5. *UMR 5198, Département de Préhistoire, Muséum National d'Histoire Naturelle, Musée de l'Homme, Place du Trocadéro, Paris, France. gpoupeau@mnhn.fr*
6. *Dipartimento di Soria, Beni Culturali e Territorio, Università di Cagliari, Piazza Arsenale 1, 09124 Cagliari, Italy. luglie@unica.it*

The project "Statues-menhirs, Menhirs et Mégalithisme en Corse"* aims to shed light on the 'megalithic phenomenon' on Corsica 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 LAMPEA (University of Aix-Marseille/CNRS, France)

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119. Importations 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

Josefina Pérez-Arantegui[1], Andrea Gil[1], Lourdes Ventolá[2], Marius Vendrell[2] and José Antonio Mínguez[3]

1. *Instituto Universitario de investigación en Ciencias Ambientales de Aragón (IUCA), Universidad de Zaragoza, Zaragoza, Spain.*
2. *Departamento de Mineralogía y Cristalografía. Universidad de Barcelona, Barcelona, Spain.*
3. *Departamento de Historia Antigua y Medieval, Universidad de Valladolid, Valladolid, Spain.*

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 Cabañeta (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 Cabañeta 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 horrea, dealing with the office of an Italic immigrant corporation, probably dedicated to trade. The materials studied in the current work were found in this

area of the city.
The materials were characterized by several analytical techniques, like X-Ray Diffraction, Scanning Electron Microscopy, Energy Dipersive X-Ray Spectrometry, and Electron Backscattered Diffraction. Gas Chromatography-Mass Spectrometry was also used to investigate the presence of organic substances. The analytical results highlighted the presence of different chemical compounds related to the manufacture of these materials and/or their origin of production. The presence of more than 250 balls of Egyptian blue allowed us also to do a statistical study of their sizes (average weight: 2.67 grams per ball), related to the way of their production, and their chemical composition was also compared with Egyptian blue produced in Egypt and Mesopotamia. The archaeometric results enabled us also to draw some conclusions on the role of the Roman city for the trade in the inland eastern Iberia.

120. Catching Neolithic Humans Red-Handed: the Procurement of Colouring Materials in N. W. Mediterranean Neolithic

Pradeau Jean-Victor[1], Binder Didier[1], Vérati Chrystèle[2], Lardeaux Jean-Marc[2], Bellot-Gurlet Ludovic[3], Piccardo Paolo[4], Dubernet Stéphan[5], Lefrais Yannick[5] and Regert Martine[1]

1. *CEPAM/UMR 7264 CNRS - Université Nice-Sophia Antipolis, Nice, France.*
2. *Géoazur/UMR 6526 CNRS - Université Nice-Sophia Antipolis, Nice, France.*
3. *LADIR/UMR 7075 CNRS - Université Pierre et Marie Curie/ UPMC - Paris 6, Paris, France.*
4. *Metallurgia DCCI/Università di Genova, Genova, Italy.*
5. *IRAMAT - CRP2A/UMR 5060 CNRS - Bordeaux 3, Pessac, France.*

Materials procurement studies provide key data for determining territories, mobility systems and socio-cultural relationships. The transition to sedentary agricultural societies during Neolithic is often associated with a considerable increase in the complexity of exchange networks: varied goods diffuse 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 origin.
With this purpose, the study of colouring materials from both archaeological sites and putative sources was undertaken in the Liguro-Provençal arch.
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 analyticak approach: those of Pendimoun (Castellar, France), a rock-shelter site occupied by Impressa and Cardial groups (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"

Michela Ricca[1], Mauro Francesco La Russa[1], Silvestro Antonio Ruffolo[1], Donatella Barca[1], Barbara Davidde[2], Gino Mirocle Crisci[1]

1. *Università della Calabria, Dipartimento di Biologia, Ecologia e Scienze della Terra (DiBEST), Via Pietro Bucci, 87036 Arcavacata di Rende (Cs), Italy.*
2. *Istituto Superiore per la Conservazione ed il Restauro, via di San Michele 23, 00153 Roma (Italy).*

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 thermae 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 analysis 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

A. Sasani[1], F. C. Petrucci[2], C. Vaccaro[3], A. Murray[4]

1. *PhD student in Science and Technology for Cultural Heritage and Archaeology, TekneHub, University of Ferrara, Italy.*
2. *Department of Physics and Earth Sciences, INFN and TekneHub, University of Ferrara, Italy.*
3. *Department of Physics and Earth Sciences and TekneHub, University of Ferrara, Italy.*
4. *Art Conservation Faculty, Queen's University, Kingston, Canada.*

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 Iranian 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

M. Steven Shackley[1]

1. *Geoarchaeological XRF Laboratory, University of California, Berkeley, and Albuquerque, New Mexico, USA.*

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 the 20-30 ma time frame. These major events incorporated significant areas of crust over tens of thousands of km3 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 so similar between 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 elementally similar sources. In order to better understand the compositional and geological chronology, an isotope study was initiated that provided some clarity. The isotopic data do indicate that these sources are distinct, and using these results, a strategy for discriminating sources was devised using laboratory XRF. As well as the utility for North American Southwestern archaeology, the resolution of the MDVP problems signal that non-destructive XRF analyses of archaeological obsidian require care in provenance studies, at times calling for instrumental study beyond XRF in concert with a thorough understanding of the regional geology. While this is not a new idea, it reinforces the need for a broad geological and archaeological knowledge of a given region.

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

Ina M. St. George, M.A., M.Sc. D.Phil. Candidate[1]

1. *Oxford University, Archaeology/RLAHA, Oxford University, Oxford, England.*

This poster 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 Çatalhöyuk in Turkey. The range of mineral colourants includes common pigments 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 utilises PLM, FT-IR, 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 distinguishing distinct or similar geological sources for the four samples found in different spatial and chronological contexts. Variations in the accessory minerals between samples indicate similar sources for three of the four samples. Additionally, the detection of iron within the azurite points toward a specific type of geological source. Together with the context of the find spots of each sample, the pigments become a marker for social connections between households and people with access to an imported material from a specific type of geological context. This investigation of pigments informs the social connections and marks procurement events during the site's occupation.

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

Robert H. Tykot[1], Keri Brown[2]

1. *Department of Anthropology, University of South Florida, Tampa, FL 33620 USA.*
2. *Manchester Institute of Biotechnology, University of Manchester, Manchester, M1 7DN, UK.*

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 other stone tools and many ceramic sherds. This adds to the 61 obsidian artifacts previously collected as part of the Tavoliere-Gargano Prehistory Project and reported on at the 2010 ISA. Obsidian was found at 30 sites and indicates its wide presence far from any sources, and in some cases in notable quantity. Obsidian was found along with other stone tools, and ceramic sherds which allow us to confidently assign the finds to the Neolithic period (6200-5000 BC). The obsidian artifacts were analyzed to identify their geological sources and reconstruct trade and exchange networks.
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 earlier 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 filter 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 Gabellotto Gorge subsource, although one artifact may have been from Canneto Dentro. Ten obsidian artifacts were identified as coming from Palmarola, a tiny island in 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.

126. Studying Obsidian Sources and Trade in the Gamo Caste System in Southwestern Ethiopia

Robert H. Tykot[1], Kathryn J.W. Arthur[2], Matthew Curtis[3], Mauro Coltorti[4], Pierluigi Pieruccini[4], Sean Stretton[5]

1. *Department of Anthropology, University of South Florida, Tampa, FL, USA 33620.*
2. *Department of Anthropology, University of South Florida, St. Petersburg, FL, USA 33701.*
3. *Department of Anthropology, College of the Canyons, Santa Clarita, CA, USA 91351.*
4. *Dipartimento di Scienze della Terra, Università degli Studi di Siena, Italy 53100.*
5. *Department of Sociology and Anthropology, Illinois State University, Normal, IL, USA 61790.*

More than 300 obsidian artifacts from 16 archaeological sites in southwestern Ethiopia were analyzed to study trade and the socioeconomic characteristics of the Gamo caste system which still exists today, and their predecessors. Artisans generally produce crafts for people living in their own community and thus the chemical composition of obsidian artifacts should be homogenous with resident artisans, allowing us to identify the presence of caste groups. Prior to the development of the caste system, a greater range of obsidian source usage was likely. The obsidian artifacts tested in this study come from both historic Gamo sites, dating back at least several hundred years, and prehistoric cave sites of various time periods with the earliest dating to at least 5000 BP. Most of the historic tools are scrapers as well as flakes and cores, while the prehistoric obsidian assemblages also included blades, awls and arrowheads/points.
Since Ethiopian Antiquity regulations forbid the export of artifacts, it was necessary to use a portable X-ray fluorescence spectrometer to conduct all analyses in Ethiopia. A Bruker III-V pXRF was used, with the same filter,

voltage and amperage settings for other obsidian research projects, providing quantitative data for elements including Fe, Rb, Sr, Y, Zr, and Nb. 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 the rift lakes in Sidama about 150 km northeast of the Borada highlands. Obsidian has also been found in 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?

Robert H. Tykot[1], Jessica A. Morgan[1], John J. Herrmann, Jr.[2], Annewies van den Hoek[3]

1. *Department of Anthropology, University of South Florida, Tampa, USA 33620.*
2. *Museum of Fine Arts, Boston, MA, USA 02115.*
3. *Harvard Divinity School, Cambridge, MA, USA 02138.*

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, finding that despite having Algerian white marble sources such as Cap de Garde, Djebel Filfila, and Mahouna, that marble from Carrara (Italy) and Proconnesus (Turkey) were also used (Herrmann et al. 2012a). In addition, it has been found that Algerian marble was used for architectural purposes in Tunisia, Libya, and mainland Italy (Herrmann et al. 2012b). The realization that marble was moving in both directions made it difficult to assign sources to many sculptures in Algerian and Tunisian museums that were made from coarse-grained marble.

In this study, samples from many sculptures in the Annaba, Cherchell, Constantine, Djemila, Guelma, Lambese, Setif, Tebessa, and Timgad museums were tested for MGS, carbon and oxygen isotopes, 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.

Herrmann, Jr., J.J., D. Attanasio, R.H. Tykot & A. van den Hoek. 2012a. Aspects of the Trade in White and Gray Architectural Marbles in Algeria. L'Africa Romana 19: 1315-1330.

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

Robert H. Tykot[1], Andrea Vianello[2], Kyle P. Freund[3]

1. *Department of Anthropology, University of South Florida, Tampa, FL 33620 USA.*
2. *Department of Anthropology, McMaster University, Hamilton, Ontario, Canada L8S 4L9.*
3. *Oxford University, England, OX1 2JD, United Kingdom.*

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), the red painted figures to the Late Mesolithic (ca. 7000 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

Rong Wang[1] Weishan-Zhang[2]

1. *Department of Cultural Heritage and Museology, Fudan University, Shanghai 200433, P.R.China.*
2. *Department of Materials Science, Fudan University, Shanghai 200433, P.R.China.*

Abstract: Most ancient jades are excavated ones, and have suffered weathering 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, browning, redden, 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 Municipality, Liangzhu site in Zhejiang Province, Beiyinyangying site in Jiangsu Province, Lingjiatan site and Xuejiagang 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 Liangzhu culture in Zhejiang Province and Huangjiayan site in Anhui 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 nephrite jades were buried, they dissolved and hydrolyzed. Then more intergranular pores formed. Relatively speaking, the outside was weathered more severe than the inside, so the fibrous crystals of the outside would change to be granular, whereas the crystals of the inside is still fibous. 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 jades 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

Dobrochna Zielińska[1], Barbara Wagner[2] and Agnieszka Kijowska[3]

1. *Institute of Archaeology on the University of Warsaw, Poland.*
2. *Faculty of Chemistry on the University of Warsaw, Poland.*

3. *Laboratory for Conservation of Ancient Art of the National Museum in Warsaw, Poland.*

The three medieval kingdoms of Nubia joined the world of the byzantine culture in the 6th century as an area of interest of the emperor Justinian the Great. To the scientist, both archaeologist and art historians became known during 60-ties because of the International Campaign to Save the Monuments of Nubia when numerous remains of churches with painted decorations dated back to the 7th - 14th century were excavated in the region (the southern Egypt and the northern Sudan). Studies in the iconography of the discovered wall paintings are in progress, but many questions concerning the technology of their creation are still pending. The lack of historical textual evidence of the history of Nubian kingdoms makes many aspects of this art tentative and worth being investigated.

Portable X-ray fluorescence (pXRF), Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) and Raman spectroscopy (RS) were used during investigations of ancient Nubian wall paintings excavated in Faras, Old Dongola, Banganarti, Kulubnarti, Sonqi Tino, Abd el-Gadir, Abdallah-n Irqi and others. 26 large mural paintings in the form of transfers were examined directly in the National Museum in Warsaw by pXRF, while many fragments, which had been collected during the time of the excavations, were analyzed consecutively by pXRF, LA-ICPMS and RS in the laboratory. The main objective of the research was to develop of a multi-instrumental analytical strategy for chemical characterization of the Nubian wall paintings to allow comparison of materials used in different periods and archaeological sides reflecting various importance of historic Nubian centers. Distinguishing the materials, either local or imported, provided the possible varieties of techniques used in the art of wall painting in Nubia, what will be discussed during the presentation.

Acknowledgements

The authors kindly acknowledge the financial support from the National Science Centre (NCN) of Poland: projects No 2011/01/B/ST4/00478 and No. 2011/01/D/HS3/0611.

The study was partially carried out at the Biological and Chemical Research Centre, University of Warsaw, established within the project co-financed by European Union from the European Regional Development Fund under the Operational Program Innovative Economy, 2007 - 2013.

Ceramics, Glazes, Glass and Vitreous Materials

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

Yukiko Tonoike[1]

1. *Department of Anthropology, Yale University, New Haven, Connecticut, USA.*

This abstract presents the preliminary results of a project focused on the fifth millennia B.C. Halaf 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 Halaf sherds were found out of context in the basal layers of the site, suggesting that there once was a small Halaf 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 this 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 chaff temper in the Halaf period and the unexpected lack of chaff 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

C. R. Appoloni[1], R. A. Ikeoka[1], O. H. Marcori[1], F. Lopes[1], M. A. Rizzutto[2], J. F. Curado[2], R. B. Scorzelli[3], P. Munayco[3] and A. M. Bandeira[4]

1. *Departamento de Física/CCE, Universidade Estadual de Londrina; Caixa Postal 10.011, CEP 86057-970, Londrina, PR - Brasil.*
2. *Instituto de Física da Universidade de São Paulo, Laboratório de Análise de Materiais por Feixes Iônicos (LAMFI), Rua do Matão Travessa R Nr.187, CEP 05508-090 Cidade Universitária, São Paulo, SP - Brasil.*
3. *Centro Brasileiro de Pesquisas Físicas, Rua Dr. Xavier Sigaud, 150 - Urca, CEP: 22290-180, Rio de Janeiro, RJ - Brasil.*
4. *Museu de Arqueologia e Etnologia, Universidade de São Paulo; Av. Prof. Almeida Prado, 1466 CEP 05508-900, Cidade Universitária, São Paulo, SP - Brasil.*

This work deals with ceramic fragments from the Sambaquis of “Panaquatira” and “Rabo de Porco” located in the São Luiz city area, at Brazilian northeast. Ancient civilizations that inhabited that territory were characterized as fishing, catchers, hunters and ceramists populations. Dates obtained by termoluminescence ranged 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 six atomic and nuclear analytical methods employed were EDXRF, PIXE, Mössbauer and Raman Spectroscopy, XRD and Computed Radiography. Sixteen elements were measured with good statistics in the different ceramic samples through EDXRF and PIXE analysis: Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, Cu, Zn, Rb, Sr, Y and Zr. Bivariate plots and multivariate statistical analysis (HCA and PCA) of the fragments elemental composition were performed to separate and correlate the groups of the samples. It was analyzed the kind of surface treatment on the concave 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 atmospheres prevailed during the firing of the studied samples. The QS for Fe3+ species, of the archaeological samples, in the refiring curve meets the firing curve of the clay at 800 - 900 oC. 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 Mossbauer results. The XRD diffractograms from Panaquatira samples exhibit quartz, feldspars and layer silicates. Rabo de Porco samples show additionally mica and amphiboles suggesting a manufacturing process different from that employed in Panaquatira 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-Khidr Site, Kuwait: Chemical and Petrographic Characterization

Hasan Ashkanani[1], Robert H. Tykot[2] and Mary Ownby[3]

1. *Department of Anthropology, University of South Florida, Tampa, FL, USA*
   hasa@mail.usf.edu
2. *Department of Anthropology, University of South Florida, Tampa, FL, USA*
   rtykot@usf.edu
3. *Desert Archaeology, Inc., Tucson, AZ, USA*
   mary@desert.com

Dilmun sites on Failaka 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 cohesion with other entities in the region like Mesopotamia, the Iranian plateau, and the Indus Valley. As a natural shelter in northwestern Failaka, Al-Khidr 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-Khidr 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-Khidr. Interestingly, using Mesopotamian pottery as a reference is helpful to fingerprint nonlocal greenish ceramic sherds at Al-Khidr. 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

Hasan Ashkanani[1] and Robert H. Tykot[1]

1. *Department of Anthropology, University of South Florida, Tampa, FL, USA*
   hasan@mail.usf.edu

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 Mesopotamian 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 southwest corner of Failaka Island, tell F3, also known as a Dilmun Town, was founded along other occupational settlements (e.g. F6 and Al-Khidr) on the island that seemly had a strategic importance for Dilmun authority as a trading colony or transit point. The northern part is the oldest part 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-ridged 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.

135. Early Iron Age Ceramics from Eastern Tanzania: A Compositional and Technological Approach

Bonato Enrica[1], Patrick Quinn[1], Lara Maritan[2]

1. *Institute of Archaeology, University College London, 31-34 Gordon Square, London, WC1H 0PY, United Kingdom.*
2. *Department of Geosciences, University of Padova, Via Gradenigo 6, 35131 Padova, Italy.*

Excavations at the Iron Age sites of Limbo and Mlindondo in the coastal region of Tanzania have unearthed evidence for the large scale production of iron, including slag, metal remains and tuyere fragments. Both sites also contain significant amounts of unglazed earthenware pottery of the 'Kwale Type' that date the sites to the 3rd to 5th centuries AD. In order to investigate possible relationships between the domestic and refractory ceramics at Limbo and Mlindondo, we have characterised their composition, raw materials and production technology using a multi-analytical approach that includes petrographic analysis, X-ray diffraction (XRD), wavelength dispersive X-ray fluorescence (WD-XRF) and electron microprobe analysis (EMPA).
Our analysis reveals the use of local non-calcareous clay and quartzose alluvial sand, as well as grog and plant temper. Several related petrographic fabrics were distinguished within the 38 samples analysed, which were confirmed by statistical analysis of the XRF data. The pottery samples appear to have been fabricated by coiling and were fired at a temperature of 700-850°C under oxidising atmosphere. Few compositional differences were detected between the domestic and refractory ceramics save for the alteration of the latter during the smelting process. Though the presence of abundant sand temper would have improved the refractoriness of the tuyeres, it does not appear that the raw materials or technology of these artefacts were optimised for their use in the metalworking process. This might suggest that both types of ceramics were produced by the same artisans and in a single place. Compositional similarities between the ceramics of Limbo and Mlindondo suggests a strong connection between the two sites, which are only several kilometres apart. Given the absence of pottery making evidence at both sites, it is possible that the vessels and tuyeres were transported from a nearby settlement.
The function of the plain domestic pottery is not known. African metalworking is imbued with spiritual practices such as the giving of offerings. Women are not normally allowed to be present at such ceremonies. The vessels might therefore have had a ritual function or could have contained food for consumption during the smelting process. It may be possible based on the evidence of our analysis to envisage a pairing between the smith and his wife with the woman preparing domestic pottery and ceramic implements such as tuyeres at the village and the man smelting iron at a location away from the main settlement area.

136. The Glass Tesserae of the Amathous Acropolis Basilica: an Archaeometric Study

Olivier Bonnerot[1], Andrea Ceglia[2]

1. *Archaeological Research Unit, Department of History and Archaeology, University of Cyprus, Nicosia, CYPRUS.*
2. *Dept. Of Applied Physics and Photonics, Brussels Photonics Team B-Phot, Vrije Universiteit Brussel, Brussels, BELGIUM.*

The site of Amathous, situated 10 km east of Limassol, on the Southern coast of Cyprus was the capital of one of the Cypriot city kingdoms. During Roman it was an important city, being the capital of one of the four administrative regions of the island, and hosting the most important cult centre dedicated to Aphrodite after that of Paphos. The temple of Aphrodite, situated on the acropolis of the city, was transformed in a Christian church, at the end of the 4th or during the 5th century AD. After the early church was destroyed in the 6th - 7th century, a new basilica was bult next to it, reusing some material from the primitive church. Many (more than 8500) detached tesserae, as well as fragments of vessels and coloured chunks of glass were found in different parts of the site. While some of these glass artefacts have been described, the detached tesserae have not. Samples from the different parts of the site are therefore studied here for the first time. After a description of the samples (nature, colour, conservation state) and their archaeological context, attention is paid both to the raw glass composition and to the nature of the colourants and opacifiers. A multi-analytical approach, combining SEM-EDS, Raman spectroscopy and portable UV-vis spectrometry is used for this analysis. The methodology is detailed and discussed, in particular the use of the portable UV-vis spectroscopy, the use of which is still relatively uncommon for such studies. The results are compared with those from other sites in and outside Cyprus. Some archaeological assumptions are made based

on the results, in particular regarding the possible presence of a secondary glass workshop on the site.

137. Characterisation of Byzantine Primary Glass Furnaces

Dieter Brems[1], Rebecca Scott[1], Veerle Devulder[1,2], Frank Vanhaecke[2], Patrick Degryse[1] and Ian Freestone[3]

1. *KU Leuven, Department of Earth and Environmental Sciences, Division Geology, Celestijnenlaan 200E, Leuven, Belgium.*
2. *Universiteit Gent, Department of Analytical Chemistry, Krijgslaan 281 – S12, Ghent, Belgium.*
3. *University College London, Institute of Archaeology, 31-34 Gordon Square, London WC1H 0PY, UK.*

After decades of research, it still remains difficult to determine the primary provenance of Roman natron 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 B isotopic 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 isotopic composition of Nd is relatively homogeneous with εNd values between -5.1 and -4.5 for glass from Bet Eli'ezer and between -5.4 and -4.1 for raw glass fragments from a single tank furnace in Apollonia. The isotopic composition of B in the analysed raw glass varies between 22.7 and 29.9 ‰ δ11B. This is in good agreement with the mixing of sand and natron from Egypt.
Trace element data were obtained via LA-ICP-MS. Trace element patterns and ratios 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 (de)colouring 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

Dieter Brems[1], Jente Pauwels[1] and Patrick Degryse[1]

1. *KU Leuven, Department of Earth and Environmental Sciences, Division Geology, Celestijnenlaan 200E, Leuven, Belgium.*

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 process 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 within a sand deposit can occur due to a heterogeneous 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.

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[1], Craig Alexander[2] and Robert H. Tykot[3]

1. *Manchester Institute of Biotechnology, University of Manchester, Manchester, M1 7DN, UK.*
2. *McDonald Institute for Archaeological Research, University of Cambridge, Cambridge, CB2 3ER, UK.*
3. *Department of Anthropology, University of South Florida, Tampa, FL, USA.*

The Tavoliere, a plain located in northern Puglia, S.E. Italy, contains over 560 Neolithic ditched enclosures (c.6200-5000BC), the densest concentration of Neolithic settlement in Europe. These sites were discovered on WWII RAF aerial photos, but since then only 25-30 sites have been excavated with few radiocarbon dates available for the region. There are no visible signs of these sites today, except for scatters of pottery on the ground surface. The pottery varies from non-diagnostic coarse wares, Impressed Wares, painted coarse and medium wares and highly accomplished fine wares known as Passo di Corvo wares. Prior research on these ceramics has used XRF and other destructive laboratory based methods to analyse the clays. A polycentric mode of production was suggested in which each site produced its own ceramics from local clay sources but only 11 sites located in the N.E of the Tavoliere were studied. Our project uses a portable XRF spectrometer to analyse trace elements (Rb, Sr, Ba, Th, Nb, Y and Zr) present in ceramics and clay samples collected from rivers near the Neolithic settlements. Many more ceramic samples can be analysed rapidly and non-destructively with this instrument. Almost 400 sherds have been collected from 12 sites and multiple clay samples from 6 rivers across the Tavoliere. All collection points were recorded with GPS. Statistical analysis of the pXRF results indicate that Passo di Corvo fine wares are made from several different clays, and at the type site of Passo di Corvo at least 3 different clays could be distinguished, possibly indicating the movement of this fine ware between sites. Our social research objectives include questions about the circulation of pottery, the mode of production of fine wares (centralised vs. dispersed) and the distance between clay sources and settlement sites. The GPS data will be incorporated into GIS in order to analyse the latter. Excavated ceramics from museums will also be analysed by pXRF and these additional data will give a full picture of ceramic production and circulation in the Tavoliere Neolithic.

140. Shooting Sherds: Multi-period Pottery Classificationwith the p-XRF, from the excavations at Stromboli-San Vincenzo, Italy

Valentina Cannavò[1], Effie Photos-Jones[2], Sara Tiziana Levi[1], Daniele Brunelli[1], Maria Clara Martinelli[3], Erica Camurri[4], Pamela Fragnoli[1], Giacomo Lomarco[1], Elena Lusuardi[1] and Daniele Pantano[5]

1. *University of Modena e Reggio Emilia, Dip. ScienzeChimiche e Geologiche, Modena, Italy.*
2. *Analytical Services for Art and Archaeology (Scotland) Ltd, Glasgow, UK; Archaeology, School of Humanities, University of Glasgow, Glasgow, UK.*
3. *MuseoArcheologico Luigi Bernabò Brea, Lipari (Messina), Italy.*
4. *University of Leipzig,Fakultätfür Geschichte, Kunst- und Orientwissenschaften.*
5. *GEA S.c.ar.l. indaginiarcheologiche e antropologiche, Roma.*

Keywords: p-XRF analysis, petrographic analysis, pottery, Aeolian Islands, provenance

In the course of excavation of any multi-phase archaeological site, it is important to be able to begin the study of all finds(and sediments) as the excavation unfolds, rather than at the post-excavation phase, as is currently, the norm. The purpose of the exercise is to inform, query and guide the archaeological enquiry during the excavation process rather than after all evidence has been removed. In that way, all data, scientific and excavation-based, are collected in parallel and the feedback from

each has an active impact on excavation strategy and site interpretation. To that end, a fast and efficient method of non-destructive chemical analysis of, potentially all,findsis implemented with the use of the portable XRF (p-XRF). This paper focuses on the methodology and the results deriving from the p-XRF analysis of 246 multi-period ceramic sherds, from the Bronze Age site of San Vincenzo, on the island of Stromboli in the Aeolian Islands, Italy, as the excavation unfolded.

Stromboli is the northernmost island in the Aeolian Archipelago in the southern Tyrrhenian Sea.The BA settlement at San Vincenzo, dates to the Early-Middle Bronze Age (Capo Graziano: 2300-1430 BC). The village consists of several stone built huts and terraces revealed in a systematic excavation since 2009. The typical BA pottery is the handmade burnished called impasto, non calcareous with abundant temper. In historical times, there is evidence of occupation with few structural remains (also funerary) and a large amount of pottery in the upper stratigraphic layers. Pottery dates from classical to modern and includes typologically distinct groups: black glaze pottery, terra sigillata, amphorae, comune, cooking pots, glazed pottery and maiolica.

Parallel studies are presented here involving prehistoric (impasto), Hellenistic (black glaze), Roman (terra sigillata, amphorae, comune, cooking pots) and medieval/modern (glazed pottery and maiolica) wares, representing both coarse and fine wares. Our methodology tackles questions of pottery provenance in a staged way. Chemical classification with the p-XRF is followed by scrutiny on the basis of typology. Subsequent to that stage, particular sherds are chosen for petrographic study. The results suggest that this staged and three-pronged examination on the basis of chemistry (all sherds-non destructive), petrology (some sherds-destructive) and typology (all sherds), works well in separating local products from imported ones by targeting issues particular to fine or coarse fabrics.

141. Shedding light on the glass industry in late antique Cyprus

Andrea Ceglia[1], Peter Cosyns[2], Wendy Meulebroeck[1], Karin Nys[2], Herman Terryn[3] and Hugo Thienpont[1]

1. *Department of Electrochemical and Surface Engineering, SURF research group, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium.*
2. *Department of Art Sciences and Archaeology, MARI research group, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium.*
3. *Department of Applied Physics and Photonics, Brussels Photonics Team B-PHOT, Vrije Universiteit Brussel, Pleinlaan 2, B-1050 Brussels, Belgium.*

In the present study we discuss the results from UV-vis-NIR optical spectroscopy on the glass material from the basilica of Agioi Pente in Yeroskipou, near Paphos. The focus on glass from early Christian Cypriot basilicas (4th - 7th century AD) forms part of a PhD research on the application of optical spectroscopy on ancient glass in order to better understand the glass consumption in the late antique eastern Mediterranean.

It is well acquainted that from the Roman imperial period onwards glass industry was strongly hierarchical organized: large primary factories located in the Syro-Levantine and Egyptian coastline supplied secondary workshops throughout the Mediterranean and the European Continent. In order to assess the position of Cyprus in the late antique glass production and distribution there is so far only archaeometrical data available from the early Christian Cypriot glass material of Maroni Petrera, involving solely 19 fragments. Two compositional groups were distinguished: a Levantine glass and an Egyptian HIMT glass, with a strong predominance of the first, hinting that the island had contact with different suppliers of raw glass.

The use of UV-vis-NIR optical spectroscopy not only can counter the severely limited amount of authorized and manageable sampling of material, but can equally recognize the numerous compositional groups circulating in late antiquity. Furthermore, UV-vis-NIR spectra carry information about technology and chemistry of the artifact whereas elemental composition does not explain technological features as color and redox conditions. Hence, this methodology offers a new perspective to facilitate a better understanding of the production and distribution of late antique glass in the eastern Mediterranean.

Analyzing large sets of material (virtually the totality of the excavated glass objects) has the potential to impose a revision of the prevailing model concerning the glass distribution and consumption in late antiquity. Not only the ratio of approximately 1:1 between Egyptian and Levantine glass of the more than 200 analyzed objects from the basilica of Agioi Pente in Yeroskipou demonstrates to be different, also different subtypes of Egyptian HIMT glass were distinguished.

142. Glass tesserae form the 'Villa of the Antonines' at the Ager Lanuvinus. Chemical composition, technology of glass production, and state of deterioration

Deborah Chatr Aryamontri[1], Gregory A. Pope[2], Laying Wu[3]

1. *Dept. of Classics and General Humanities; Center for Heritage and Archaeological Studies /Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, USA.*
2. *Dept. of Earth and Environmental Studies; Center for Heritage and Archaeological Studies/Montclair State University, 1 Normal Avenue, Montclair, NJ 07043, USA.*
3. *Microscopy and Microanalysis Research Laboratory, Montclair State University, Montclair, New Jersey, USA 07043.*

In 2010 the Center for Heritage and Archaeological Studies (CHAS) at Montclair State University began investigation of archaeological remains of the "Villa of the Antonines," located along the Via Appia, eighteen miles from Rome.

The site, so far the least explored of the ancient Roman imperial residences in the area of the Alban Hills, has been identified, since 1701, as the residence at Lanuvium of the Antonine dynasty (138-192 CE) on the basis of literary sources and the discovery of high-quality marble busts portraying members of this family. The layout of this imperial estate is still largely unknown apart from the baths and the adjacent amphitheater, likely the one where the emperor Commodus, whose love for participating in arena sports is notorious, earned his nickname "Roman Hercules" for killing wild beasts.

Many of the construction and decorative materials of the villa complex lie in fragmentary form in sub-aerial or underground setting. Nonetheless, the opulence of this residence is shown by large quantity of flooring and wall decoration elements of costly imported marble and thousands of colored glass tesserae (tiles), used for mosaics execution, in innumerable shades of the chromatic spectrum, including gilded ones.

This paper discusses the ongoing scientific investigation of glass tesserae from the villa by means of several techniques in order to identify their chemical composition, production technology and state of deterioration. Qualitative and semi-quantitative analyses performed by means of scanning electron microscopy (SEM-EDS) show variability of chemical elements and have revealed surface microdeterioration such as pitting, etching, and glazing. Their components include silica, calcium, soda (Na), and minor peaks of chlorine - that might indicate their natron-type nature – copper, and iron. Ongoing acquisition of bulk chemical data by inductively coupled plasma, either optical emission or mass spectroscopy (ICP-OES/ICP-MS), x-ray diffraction (XRD) for mineralogy, and quantitative backscattered scanning electron microscopy (BSEM) for microscale elemental composition, are detecting exact quantity of major and trace elements. These analyses will assist in establishing coloring and opacifying agents, as well provenance of glass, and will assess the degree of loss of key elements (by weathering) that would render provenance parallels as uncertain. The data will be compared to existing data from other sites in order to estimate a degree of potential error and identify possible production workshops.

The results of the research will provide a further, important step toward our understanding of technological aspects of glass production in the Roman Imperial period.

143. Investigation on the Effects of Drying Time and Age of Glaze on a Macrocrystalline Glaze & an Analysis of Spherulite Growth

Amanda Chau[1], Aaron Shugar[1], and Jonathan Thornton[1]

1. *Art Conservation Department, SUNY - Buffalo State, Buffalo, NY 14222.*

The production of spherulites in a macrocrystalline glaze involves a complicated process that requires testing and specific conditions. This study investigates the effects that drying time and the age of a glaze batch have on the macrocrystalline glaze behavior. In addition, a comparative study of the prepared samples, with and without spherulite formations, was conducted. Glaze from a single batch was applied on ceramic tiles on separate days and dried for different durations. All samples were fired with the same firing schedule. Reflected light microscopy, Raman spectroscopy, and scanning electron microscopy (SEM) indicated that there was little variance between the samples, and thus, drying time and age of the glaze seem to have little effect on the production of spherulites. However, there were differences in the size, definition, color, and clarity of the glaze within a single sample. For these samples, the thickness of the glaze appears to contribute to the growth or inhibition of spherulites.

144. Investigating the Firing Protocol of Athenian Pottery Production: A Raman and colorimetric study of replicates and original samples

Ilaria Cianchetta[1], Karen Trentelman[1], Jeff Maish[2] and Marc Sebastian Walton[3]

1. *Getty Conservation Institute, Los Angeles, California.*
2. *J. Paul Getty Museum, Los Angeles, California.*
3. *Northwestern University Art Institute of Chicago, Chicago, Illinois.*

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 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 maghemite) 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 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 steps - 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 ancient sherds. The predictive scheme was thus used to infer the firing conditions of original Athenian black and red glosses from the Getty collection.

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

Gerardine Conejo Barboza[1], Jean Sanabria Chinchilla[1], Francisco Corrales Ulloa[2], Mavis Montero Villalobos[3]

1. *Escuela de Química - Centro de Electroquímica y Energía Química, Universidad de Costa Rica, San José, Costa Rica.*
2. *Departamento de Antropología e Historia, Museo Nacional de Costa Rica, San José, Costa Rica.*
3. *Escuela de Química - Centro de Electroquímica y Energía Química - Centro de Investigación en Ciencias e Ingeniería de los Materiales, Universidad de Costa Rica, San José, Costa Rica.*

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 ceramic shreds 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 shred powder in Milli-Q water, isopropanol and nafion (binder). This suspension was sonicated (10 minutes) and applied over the conducting 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 SW voltamograms for a magnetite sample showing typical signals previously reported [3]. The signal at -0.814 V corresponds to the reduction of Fe2+ ions and the signal at 0.186 V is also related to reductive process of magnetite. 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 –0.790 V can be assigned to the Fe2+/Fe redox 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.

The use of SWV, with a good preparation of a modified electrode, provides a very sensitive and fast technique to analyze and characterize archaeological pottery samples. Quantification of the Fe2+-to-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

Laura A. Conger[1]

1. *University College London, Institute of Archaeology, London, United Kingdom.*

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 still retain a common identity across sites (Star and Greissemer 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, archaeometric 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 (3-5%) than those typical of neighboring Near Eastern and Indian traditions (Freestone 2006). This hypothesis is tested against quantitative results obtained through SEM-EDS and EPMA analyses performed by the author at the Wolfson Laboratory in the Institute of Archaeology at University College London.

The quantitative results indicate that the majority of Merv glass is a soda-lime-silica type with raised levels of MgO (3.3%) and K2O (4.2%), as well as some with raised Al2O3 (3.7%), fitting well within the typical Central Asian typology labeled by Brill. Samples associated with secondary glassworking, such as trailings and moils are present along

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 glass-making/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.

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147. Archaeometric Comparison between the Early and Late Sasanian Period Ceramics at the Archaeological Site of Qizlar Qal'eh (North-Eastern Iran)

Maria Daghmehchi[1], Jebrael Nokandeh[2], Bahman Firoozmandi Shirejini[3]

1. *Department of Archaeology, University of Tehran, Iran.*
2. *Research Fellow Iranian cultural Heritage, Handcraft and Tourism organization.*
3. *Professor Department of Archaeology, University of Tehran, Iran.*

Petrographic and microfossil analyses have been conducted on thin section of ceramics, excavated on archaeological site of Qizlar Qale in Gorgan plain, northeastern Iran. The thermo-luminescence date has provided the precise chronology from the early Sasanian period (84±1817) to the late Sasanian period. In this study, thin sections of ceramics dated to the early Sasanian period and the late Sasanian period, were studied under the polarizing microscope and then compared together in terms of microfossils and mineralogical composition in order to identify the development and transformation in provenance and technology of the ceramics. By comparative study, it is possible to study the transformation of ceramics from early Sasanian period to late Sasanian period. The presence of microfossils from two different geological ages, chert, quartz, limestones, metamorphic rocks and crushed shell fragments present in the early Sasanian ceramics and in the alluvial samples derived around the site in adjacent Gorgan river, suggest a geological origin in northwest of Gorgan plain with alluvial sediments, while petrography analysis of late Sasanian period ceramics show compatible with the local geology of the south Gorgan plain. Mineralogical comparison of the ceramic assemblage have shown significant changes in clay paste composition in late Sasanian period ceramics in the site. These changes show displacement and conformity to a new clay source.The change in clay paste compositions of late Sasanian period ceramics can be attributed to the geographical variety in clay paste composition and/or a change in choice of raw material sources. These changes are also noticeable in firing technology. Microscopic examination of microfossils structure, suggested a firing temperature between 300 and 700 °C in early Sasanian period ceramics while petrographic analysis conducted onthin section of late Sasanian period ceramics suggested a firing temperature above 1000°C.

148. Copper and Antimony isotopic analysis via multi-collector ICP-mass spectrometry for provenancing ancient glass

Patrick Degryse[1], Lara Lobo[2], Domingo Gimeno[3], Andrew Shortland[4], Katherine Eremin[5] and Frank Vanhaecke[2]

1. *Department of Earth and Environmental Sciences, Katholieke Universiteit Leuven, Belgium.*
2. *Department of Analytical Chemistry, Ghent University, Krijgslaan 281-S12, 9000 Ghent, Belgium.*
3. *Department of Geochemistry, Petrology and Geological Prospecting, University of Barcelona, Barcelona, Spain.*
4. *Department of Engineering and Applied Science, Cranfield University, Shrivenham, United Kingdom.*
5. *Harvard Art Museums, Cambridge, MA 02138, USA.*

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 stabilizer, 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 (Sb content >1 %) from the late Bronze Age onwards. Calcium antimonite (white) and lead antimonate (yellow) are also commonly found, while Sb was also added to 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 were proved to be directly related to mineral raw materials in the silica source, colorants 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 Mesopotamian, Egyptian, Georgian, Turkish and European glasses from different periods. Results obtained show that the isotopic composition of Cu, expressed as δ65Cu, 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 isotope 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 deposit can exhibit different δ65Cu 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 stibnites, from different Mediterranean and other European areas have been investigated with the aim of obtaining information on the origin of Sb in glass.

149. Two pre-Columbian Pottery Productions of the Peruvian North Coast: An Archaeometrical Approach to Understand Technical Traditions of the Mochica and Cajamarca Cultures

DEL SOLAR Nino[1], DOLLWETZEL Philipp[1], CHAPOULIE Rémy[1], CASTILLO Luis Jaime[2]

1. *IRAMAT-CRP2A / Uni¬versity Bordeaux Montaigne - Maison de l'Archéologie - Esplanade des Antilles 33607, Pessac, France.*
2. *Ministery of cultural heritage and cultural industries, Lima, Peru.*
2. *PUCP Pontificia Universidad Catolica del Peru, Lima, Peru.*

San José de Moro (SJM) is one of the most remarkable pre-Columbian archaeological sites in northern Peru. Tombs showing large finds of Mochica and Cajamarca ceramics characterize this ritual and burial site. Archaeological data suggests that local technical traditions – represented in particular by the famous Mochica fineline stirrup spout bottles with their complex Iconography – were subject to modifications during the Late Mochica (7th - 9th AD) and the Transitional (9th -11th AD) periods due to the influence of numerous foreign highland styles and artefacts like e.g. ceramics attributed to the Cajamarca and Huari cultures. This research tries to answer several questions related to the intersection between technical traditions and pottery productions, particularly regarding the role played by the site SJM itself, located in the lower Jequetepeque valley at the crossroads between coastal and highland regions. This site seems to have been involved in the exchange of goods, technologies and knowledge between contemporary societies like the Mochica who inhabited the north coast, and the Cajamarca that inhabited the nearby Andean region. This archaeometrical study deals with the investigation of these two pottery traditions. Therefore, we selected altogether 30 pottery shards from SJM respectively attributed to the Mochica fineline and Cajamarca Costeño style. They had been discovered in the same area and chronological context. We compared the samples with regard to questions of technological features and provenance, i.e. identifying technological characteristics and possible improvements as well as the determination of local or foreign productions. The bodies of the ceramics were investigated by cathodolumines¬cence, energy dispersive X-ray spectrometry attached to a scanning electron microscope, and a portable X-ray fluorescence spectrometer. Cathodoluminescence allowed us to distinguish at least two luminescence groups

(yellowish and blackish bodies). At the same time, the amount of different key elements, like iron, rubidium and iridium, differs according to the two technical traditions. In this sense, we were able to identify the use of at least two different recipes and clay resources. Archaeologically, Cajamarca Costeño was usually considered to be a style originating from the coastal region; 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.

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

Kaatje De Langhe[1,2], Bart Vekemans[3], Wim De Clercq[1], Peter Vandenabeele[2], Laszlo Vincze[3]

1. *Historical Archaeology Research Group (HARG), Department of Archaeology, Ghent University, Ghent, Belgium.*
2. *Laboratory for Archaeometry, Department of Archaeology, Ghent University, Ghent, Belgium.*
3. *X-ray Microscopy and Imaging Research Group (XMI), Department of Analytical Chemistry, Ghent University, Ghent, Belgium.*

In Post-Medieval Flanders (15-17th cent.), tile stoves took a central place in the living quarters of castles, abbeys and wealthy urban houses. Elaborately decorated, they were more than just an innovative heating system. Their heraldic and religious displays often expressed personal values and political views. Although ceramic tile stoves have been well documented in Northern- and Central Europe, they have remained an almost forgotten aspect of daily life in the Low Countries and the historic county of Flanders more specifically. However, with thriving economic centres as Ghent and Bruges, these stoves must have played an important role in the material and social context of elite housing. During the last decennium several sites yielding stove tiles were discovered in Flanders. These Flemish tiles seem to use a different iconographic repertoire than the better-known examples from Germany and the Netherlands. Furthermore, the majority of the tiles is produced in red-firing clay, similar to the fabric of local redware pottery.

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 stove tiles were investigated using an Olympus Delta handheld XRF (hXRF) 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, misfires 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 from Ghent that cannot be linked to any other samples. The interpretation of the whiteware tiles is even more complex, since there is evidence of import of clay from Germany and other regions. So the clay body may not indicate local production, but the mould and iconography used can refute this.

151. An Application of Geological Survey and Ceramic Compositional Studies for Tracing Provenance and Probing Manufacture Practices during Pre-History in Alentejo (Portugal)

M. I. Dias[1] and M. I. Prudêncio[1]

1. *Centro de Ciências e Tecnologias Nucleares - C2TN. Campus Tecnológico e Nuclear. Instituto Superior Técnico, Polo de Loures. Estrada Nacional 10 (km 139.7). 2695-066 Bobadela, Loures, Portugal.*

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 intensive 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 non-correlation between ceramics and local raw materials, especially in the case of recipients for funerary purposes. Ceramic production at Perdigões site was complex and involved 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, with the adoption of weathered schists far from Perdigões, and also foreign raw materials. Mineral phases indicate low firing practices, around ~600ºC.

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.

In this study 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.

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

Joanna Dunster[1], Andrew Shortland[1] and Kelly Domoney[1]

1. *Cranfield University, UK*
2. *Institute of Archaeology, University College London, UK*

Soft-paste porcelain was produced in Britain in great quantities between the early 18th and early 19th centuries. 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 spectroscopic 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 Barkla, 1997; Owen, 1998; Ramsay et al, 2003; Ramsay and Ramsay, 2007), and to distinguish them from their contemporaries by applying discriminating factors (Owen and Sandon, 1998; Owen et al, 1998; Bimson and Freestone, 2002; Owen and Sandon, 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 Pans, Cookworthy's Plymouth and Bristol manufactories, and Pomona cannot be reliably distinguished.

153. Archaeometrical characterization of red opaque glasses

Monica Ganio[1,5], Veerle Devulder[2], Frank Vanhaecke[2], Domingo Gimeno[3], Olivier Bonnerot[4], Patrick Degryse[1], Marc Walton[5]

1. *Department of Earth and Environmental Sciences, Section Geology, Katholieke Universiteit Leuven, Celestijnenlaan 200E – bus 2410, BE-3001 Leuven, Belgium.*
2. *Department of Analytical Chemistry, Ghent University, Krijgslaan 281 – S12, B-9000 Ghent, Belgium.*
3. *Deptartment of Geoquímica Petrologia i Prospecció Geològica, Facultat de Geologia, Universitat de Barcelona, C/ Martí i Franqués s/n, 08028 Barcelona, Spain.*
4. *Archaeological Research unit, Department of History and Archaeology, University of Cyprus, P.O. Box 20537 CY-1678 Nicosia CYPRUS.*
5. *NU-ACCESS, Northwestern University, 2145 Sheridan Rd, Evanston, IL 60208, USA.*

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 mineral ore 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 beneficial to the formation of the red colorant. Lead could have prevented the copper from oxidizing by helping to achieve reducing conditions (Ahmed & Ashour, 1981), since this element displaces the redox equilibrium of copper to the cuprous state ($Cu^{2+} \rightarrow Cu^{+}$).
This work focuses on 15 red opaque glass samples excavated in different geographical areas. Six samples excavated in Barcelona and Zaragoza, Spain, and one samples from Potentia (modern Recanati), Italy, are dated to the 1st century AD; of the remaining eight glass fragments, four were excavated in Sagalassos, and four in Cyprus, and are late Roman in date (5th-6th century AD).
A combined approach of compositional analysis and Sr-Nd isotopic analysis is used to investigate the primary origin of the raw materials used in glass making. The preliminary results obtained will be presented.

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154. The archaeological site of Luni: first archaeometrical results on the glass findings

Monica Ganio[1,3], Kris Latruwe[2], Frank Vanhaecke[2], Patrick Degryse[1], Marc Walton[3]

1. *Department of Earth and Environmental Sciences, Section Geology, Katholieke Universiteit Leuven, Celestijnenlaan 200E – bus 2410, BE-3001 Leuven, Belgium.*
2. *Department of Analytical Chemistry, Ghent University, Krijgslaan 281 – S12, B-9000 Ghent, Belgium.*
3. *NU-ACCESS, Northwestern University, 2145 Sheridan Rd, Evanston, IL 60208, USA.*

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 war against the Apuan Ligurians. The town dominated the access to the port of Selene, greek divinity identified with the god Diana by the Romans, and founded its fortune on the intensive exploitation of the marble quarries located on the Apuan Alps.
With the emperors of the Julio-Claudian dynasty, Luni reached the height of its splendor, which continued in the following centuries. A violent earthquake at the end of the 4th century AD signs the end of the Civitas Imperialis. (Durante, 2001).
This study focuses on 38 glass fragments, all dated 1st to 4th century AD, mainly colourless or naturally colored (pale blue/pale green). Through a combined approach, involving compositional analysis and Sr-Nd isotopic analysis, the primary origin of the raw materials used in glass making is investigated. The isotopic ratios obtained for the glass samples are compared to a sand database (Brems et al., 2012; Brems & Degryse, 2013), which includes relevant sands from the regions described by Pliny the Elder, and

to the signature of primary glass from known production centers in the eastern Mediterranean.
In this way, the technology used for and occurrence of raw glass factories outside the Syro-Palestine and Egypt is investigated. Based on our results we have been able to address fundamental questions concerning the economics of glass making such as where mass producing 'primary' factories were situated, and how was the glass materials transported? Also, we address whether glass production in the early Roman days was primarily situated in the Near Easy or were there western factories also producing natron glass (Freestone et al., 1999; Gorin-Rosen, 2000; Nenna et al., 1997).

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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 Corsica. Insights of a Mycenaean influence?

Eleonora Canobbio[1], Ludovic Bellot-Gurlet[1], Céline Paris[1], Joseph Césari[2], Franck Léandri[3], Céline Léandri[3] and Kewin Peche-Quilichini[4]

1. *Laboratoire de Dynamique, Interactions et Réactivité (LADIR), UMR 7075 UPMC/CNRS, Université Pierre et Marie Curie, Paris, France. ludovic.bellot-gurlet@upmc.fr*
2. *Chercheur associé LAMPEA UMR 7269, Aix-en-Provence, France.*
3. *Service Régional de l'Archéologie, DRAC de Corse, LAMPEA UMR 7269, Aix-en-Provence, France.*
4. *Chercheur associé LAMPEA UMR 7269, post-doc UMR 5140, Aix-en-Provence, France.*

During the excavations of the Campu Stefanu 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 Corsica 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.
In order to respect the integrity of the very fragile resinous beads the first retained analytical approach 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-IR 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, underlining 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

for the Campu Stefanu beads is therefore the Northern European Baltic amber sources. The stylistic appearance of these resinous and glass beads is close to ones found in the Western Mediterranean area: Greece and near East. The network taken by this Baltic Amber to reach Corsica should thus pass through the Mycenaean trade which then extends until Corsica at this period.

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

Vanessa Muros[1,2], Nikolaos Zacharias[2] and John K. Papadopoulos[3]

1. *UCLA/Getty Conservation Program, Los Angeles, CA, USA.*
2. *Dept. of History, Archaeology and Cultural Resources Management, Univ. of Peloponnese, Kalamata, Greece.*
3. *Cotsen Institute of Archaeology, UCLA, Los Angeles, CA, USA.*

The application of archaeometric techniques to the study of archaeological glass has been critical to identifying how and where this material was manufactured. Despite the research that has been conducted to date, questions still remain about the raw materials used and the location of primary glass production centers, especially during the Late Bronze Age and Early Iron Age. Investigations of glass from sites such as Frattesina in Italy and Elateia in Greece have revealed new technological approaches that appear during this time period and possibly the identification of new regions where glass was produced. This challenges the idea that glass in the Mediterranean was imported from either Egypt or the Near East. Only with additional investigations of ancient glass from this region and time period can technology and production be better understood. This paper aims to add to the current body of knowledge of LBA/EIA glass production by presenting the study of vitreous materials from the tumulus of Lofkënd in southwestern Albania. In this ongoing project, several analytical techniques (XRF, SEM-EDS, ICPMS, SIMS) were employed to identify the technology of a group of 12th-9th c. BC glass and faience beads. The data obtained on trace elements and stable isotopes will allow for the method of manufacture of these materials from Lofkënd to be identified and to determine where the glass and faience was made. The results will provide crucial information to our understanding of ancient technology, trade, and glass manufacture during the transition from the Bronze to the Iron Age, and the relation of Lofkënd to production centers in the Mediterranean, Egypt and the Near East.

157. Not first but fast: on the Bronze-Iron Age transition in mainland Southeast Asia

T.O. Pryce

Centre Nationale de la Recherche Scientifique, UMR 7055 Préhistoire et Technologie, Nanterre 92023, France.

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/bronze/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, iconology 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 Nwa-htoe-gyi village where similar chemical compounds to those used by the ancient people on today's pumtek beads made of fossilized wood.

Metals and Metallurgical Ceramics.

159. Persian Crucible Steel Production: Chāhak Tradition

Rahil Alipour[1] and Thilo Rehren[1]

1. *UCL Qatar, Doha, Qatar.*

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 Merv and Akhsiket 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

Erez Ben-Yosef[1,2], Thomas E. Levy[2]

1. *Department of Archaeology and Ancient Near Eastern Cultures, Tel Aviv University, Tel Aviv, Israel.*
2. *Department of Anthropology, University of California San Diego, San Diego, CA, USA.*

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 have 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 throughout the 12th – 10th centuries BCE (indicated by decrease in Cu content from ~1 to ~2 wt.-%) was followed in the late 10th/9th centuries BCE by an abrupt 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 necessarily triggered 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

Agnese Benzonelli[1*], Ian Freestone[1], Marcos Martinón-Torres[1]

1. *Institute of Archaeology, University College London, 31-34 Gordon Square, London, WC1H 0PY, United Kingdom*
   ** agnese.benzonelli.12@ucl.ac.uk*

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 Sn, Ag and Au and treated them with solutions mimicking those used in traditional 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 some of 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

Alice Boccia Paterakis[1], Sachihiro Omura[2], Ellen van Bork[3]

1. *Director of Conservation, Japanese Institute of Anatolian Archaeology, Kaman, Turkey.*
2. *Director of the Excavations, Japanese Institute of Anatolian Archaeology, Turkey.*
3. *Lecturer in the Metals Conservation Program, Department of Humanities, University of Amsterdam, Amsterdam, the Netherlands.*

An unusual gold object was unearthed from the Kaman-Kalehöyük excavation in 2010 dating to 1800 BCE, the Assyrian Colony Period in Central Anatolia. Preliminary reconstruction 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 (Carter no. 585s) from King Tutankhaman'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 Ashur, 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, Uruk, 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 AuAgCu homogenous solid solution (< 10% silver). One point analysis reveals a Type II alloy of higher silver conent, 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 colloidal 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

Jorge A. Bravo[1], Mirian E. Mejia[1], Mercedes Delgado[2] and Alejandro L. Trujillo[1]

1. *Laboratorio de Arqueometria, Facultad de Ciencias Fisicas, Universidad Nacional Mayor de San Marcos, Lima, Peru.*
2. *Centro de Investigación QUALLTA, Lima Peru.*

On the basis of a detailed elemental quantitative analysis by energy dispersive X-ray fluorescence (EDXRF) of metal objects belonging to the Sipan (AD 0 – 700) and Sipan (AD

900 – 1375) cultures belonging to the Royal Tombs and Sican Museums respectively, an attempt is made to compare the metallurgic 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.

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

Florence Cattin[1], Matthieu Labaune[1], Aurelien Alcantara[2], Estelle Camizuli[1], Robin Furestier[3], Henri Gandois[4], Olivier Lemercier[1], Danièle Perrey[5], Maitena Sohn[6,7], Igor M. Villa[8,9] and Alain Villes[10].

1. *Laboratoire ArTeHiS UMR 6298, Université de Bourgogne, Dijon, France.*
2. *Archeodunum, Colomiers, France.*
3. *Cité de La Préhistoire d'Orgnac-l'Aven, France.*
4. *Laboratoire Trajectoires UMR 8215, CNRS - Université Paris 1 - Panthéon-Sorbonne, Nanterre, France.*
5. *Laboratoire Interdisciplinaire Carnot de Bourgogne UMR 6303, CNRS - Université de Bourgogne, Dijon, France.*
6. *Service archéologique, Toulouse Métropole, France.*
7. *Laboratoire TRACES UMR 5608, Toulouse, France.*
8. *Institut für Geologie, Universität Bern, Bern, Switzerland.*
9. *Centro Universitario Datazioni e Archeometria, Universita di Milano Bicocca, Milano, Italy.*
10. *Musée d'archéologie Nationale, Saint-Germain-en-Laye, France.*

This communication concerns the 3rd 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 (Gard), Castelnaudary (Aude), and the Grotte du Rhinocéros 4 (Hérault).
- The Saône 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-Saône 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

Michelle Chan[1], Alexandra Capek[2] and Simon J. Garrett[3]

1. *California State University, Northridge, Department of Chemistry & Biochemistry, Northridge, USA.*
2. *California State University, Northridge, Department of Chemistry & Biochemistry, Northridge, USA.*
3. *California State University, Northridge, Department of Chemistry & Biochemistry, Northridge, USA.*

Polished contemporary quaternary bronze coupons, nominally Cu93.8Sn6.2Pb0.5Zn0.5 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 hydrosulfide ion, HS-(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 α-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-lustrous dark gray in color and were very heterogeneous. The surfaces were composed primarily of copper (I) sulfide, Cu2S (both high and low chalcocite forms and djurleite), with minor amounts of copper (II) sulfate, CuSO4·nH2O. 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)

Andreas Charalambous[1], Vasiliki Kassianidou[1] and George Papasavvas[1]

1. *Archaeological Research Unit, Department of History and Archaeology, University of Cyprus, P.O. Box 20537, Nicosia, CY1678, Cyprus.*

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 subsided 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 in 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 belong to those "Crisis Years" will shade 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 objects contain a significant amount of silver (Ag) that varies from 3.9 up to 26.2%, while in two cases, a finger-ring 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 Laoniupo Site, Central Shaanxi

Kunlong CHEN[1], Yanxiang LI[1] and Lianjian YUE[2]

1. *Institute of Historical Metallurgy and Materials, University of Science and Technology Beijing, China.*
2. *Shaanxi Provincial Institute of Archaeology, China.*

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 metallurgy, compositional characteristics and casting technology of Shang-Zhou ritual bronze vessels kept attracting attention of scholars and resulted in a large amount of crucial literatures in both Chinese and English (e.g. Mei 2006, 2011; Fan Xiaopan et. al. 2012; Chen Kunlong 2009; Zhao Chunyan, 2006; Nickel 2006; Bargely 2009). However, most of these studies are artefacts-based, which only reflect information of the final steps of ancient metallurgical châine opératoire (Hauptmann 2007) and, unavoidably leave many meaningful aspects hardly touched.

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, University of Science and Technology Beijing (IHMM, USTB). Metal production remains dating to late second millennium BC have been found from a site named Laoniupo near Xi'an in central Shaanxi. Analytical result of slag revealed that arsenic content copper smelting have 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 central areas of early Bronze Age China. It also throws new lights upon early development of copper metallurgy in the Wei River Valley and the connection between the Central Plains and Northwest China.

168. New Insights to the Early 19th-Century Naval Technology: Metallurgical Examination of the Cargo of a British Transport Lost Off Catalonia Coast, Spain

Ciarlo, Nicolás C.[1]

1. *National Research Council of Argentina (CONICET) - Underwater Archaeology Programme, National Institute of Anthropology (INAPL). 3 de febrero 1370/78 (C1426BJN), Buenos Aires, Argentina. E-mail: nciarlo@yahoo.com.ar*

In June 1813, after an unsuccessful expedition to liberate the city of Tarragona of the domain of Napoleonic forces, eighteen ships of the combined fleet of British, Sicilian and Spanish forces supervised by the Lt. Gral. 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 Underwater Archaeology of Catalonia (Centre 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 contribute to the knowledge of British metallurgy at the beginnings of 19th century, especially regarding maritime craft. This was specifically accomplished by: first, typological and physico-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 application 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

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

Bryan Cockrell[1], José Luis Ruvalcaba Sil[2] and Edith Ortiz Díaz[3]

1. *University of California, Berkeley, Anthropology, Berkeley, USA.*
2. *UNAM, Instituto de Física, México, México.*
3. *UNAM, Instituto de Investigaciones Antropológicas, México, México.*

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 Mesoamerica and lower Central America.

Through non-invasive and non-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 Cantón in Mérida, Mexico, and the Museo Nacional de Antropología in Mexico City). Optical microscopy (vis-UV-IR) 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 sandals. Synchrotron-based XRD 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 Veraguas-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 Mexica tributary system, through such objects as the anomalous sandals, and the presence of brass extend the development of the Cenote deposit 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

Bogdan Constantinescu

Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, Magurele-Ilfov, Romania

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 Agighiol 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. Farkas, and the technical examination of USA museum artifacts in "Three Silver Objects from Thrace: A Technical Examination" by Pieter Meyers, papers published in Metropolitan Museum Journal 16, 1982. The princely tomb at Agighiol, 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

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 fingerprint for 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-“master”) of these four valorous Thracian silver artifacts from USA and from Romania. Based on 1931 investigation - excavation information from the recent recovered “excavation book” of Andriesescu the possibility all the four artifacts belong to Agighiol princely tomb is discussed.

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

J. Corsi[1,2], C. Ricci[1], A. Scherillo[3,4], A. Re[1,2], A. Lo Giudice[1,2], F. Grazzi[5] and F. Barello[6]

1. *Università di Torino, Dipartimento di Fisica, Torino (TO), Italy.*
2. *Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Torino (TO), Italy.*
3. *STFC, Rutherford Appleton Laboratory, ISIS facility, Chilton-Didcot, United Kingdom.*
4. *IPCF-CNR, Messina (ME), Italy.*
5. *ISC-CNR, Sesto Fiorentino (FI), Italy.*
6. *Soprintendenza per i Beni Archeologici del Piemonte e M.A.E., Torino (TO), Italy.*

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 in northern Italy between the 4th and the 1st century B.C. The drachmas are all characterized by the imitation of the iconography of Massalia’s heavy drachm, bearing a lion with the ethnic ΜΑΣΣΑ on reverse. The different styles in the depiction of the lion have been used by numismatists to group the drachmas in different typologies. The smaller fractions bear, instead, a new depiction showing a spotted panther.

This coinage is characterized by many issues such as chronology, attributions and relationships within the several emissions and nominals [1-2], which only recently have started to be solved. While stratigraphic excavations provided data for an absolute dating of some emissions and for the attribution to specific tribes, the archaeometric approach presented here is bringing new light on other aspects, such as the composition and the technological aspects of the mint production in pre-Roman times. To this aim, we performed time-of-flight neutron diffraction measurements with the INES diffractometer [3] at the ISIS facility (Rutherford Appleton Laboratory, UK). This technique for non-destructive bulk analyses was essential to overcome the problem of the silver surface enrichment, often occurring in ancient coins. A selection of specimens coming from different hoards and collections from museums, representative of different emissions, has been analyzed. The analysis of diffraction patterns has been carried out with the GSAS software to determine phase weight fractions through Rietveld refinement. Then, thanks to the relationship between d-spacing and Ag, Cu content in the α and ß phase (respectively, copper-rich and silver-rich phase) the Ag/Cu ratio, important for numismatic studies, has been determined.

The results show a clear silver debasement occurring 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 with 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.

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

Kim Eekelers[1], Rebecca Scott[1], Patrick Degryse[1] and Phillipe Muchez[1]

1. *KULeuven, Department of Earth and Environmental Science, Leuven, Belgium.*

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 LiBO2-fusion. The other part 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-qualitative results were obtained by using the peak area. To compare the results, the quantitative and the qualitative data were normalized over iron. Statistical tests were employed to check the consistency of both datasets (spearman correlation and the wilcoxon test). Individual element to element comparisons show a strong correlation between quantitative and qualitative results. Density plots show a constant shift for Ca, Cr, K, 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 Ca/Fe. 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 smithing 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

Kim Eekelers[1], Elvira Vassilieva[1], Phillipe Muchez[1] and Patrick Degryse[1]

1. *KULeuven, Department of Earth and Environmental Science, Leuven, Belgium.*

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 analyzed 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 ironsilicates, metallic iron and refractory 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. Langmyhr and Paus [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 three acid (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 a complex matrix and 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.

Afterwards it was dissolved in 2.5 M HCl. Platinum crucibles are often recommended when decomposing slag, but the Pt forms an alloy with the metallic iron. Another possibility is to use graphite crucibles. The problem here is that the metallic iron reacts with the carbon of the crucible to form steel, implying that almost half of the sample remains in the crucible and is not dissolved. To overcome this problem a new protocol was developed to decompose ancient iron slag, which generally have a high iron content. The proposed method outlined in this poster, is an easy, fast and safe way to decompose a large number of iron slag (ca. 35 per day).

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174. Mill scale on historic wrought iron: characterisation and impact on corrosion behaviour

Nicola Emmerson[1], Eric Nordgren[1] and David Watkinson[1]

1. *Department of Archaeology and Conservation, School of History, Archaeology and Religion, Cardiff University, John Percival Building, Colum Drive, Cardiff, CF10 3EU*

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 historic 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

Monica Ganio[1], Francesca Casadio[1,2], Katherine Faber[1,3], Anne Leonard[4], Johanna Salvant[1], Marc Walton[1]

1. *NU-ACCESS, Northwestern University/ Art Institute of Chicago, Evanston, IL 60208, USA.*
2. *The Art Institute of Chicago, Chicago, IL 60603, USA.*
3. *Department of Materials Science and Engineering, Northwestern University, Evanston, IL 60208, USA.*
4. *Smart Museum of Art, The University of Chicago, Chicago, IL 60637, USA.*

Most of the bronze sculptures produced by European masters in the early 1900s 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 sculpture bearing the Parisian Valsuani 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 sculpture 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 bronzes include important works by Rodin, Lipchitz, 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 20th century. This is of particular importance for art historians and connoisseurs 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.

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

Mainardo Gaudenzi Asinelli[1], Marcos Martinón-Torres[1]

1. *University College London, Institute of Archaeology, London, UK.*

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 concentrates on the archaeometric characterisation of a set of gilded and silvered artefacts recovered from two archaeological sites of the medieval Italian region of Tuscia: Leopoli-Cencelle and Miranduolo (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.
Three finger-rings, three small hemispherical buttons and three binding strips were analyzed by portable XRF, optical microscopy, SEM-EDS, and EPMA. These analyses allowed the characterisation of both the coated surfaces and metal substrates of the artefacts. Portable XRF was employed as a fast, non-invasive technique that allowed the screening of numerous artefacts to identify those with traces of mercury and/or noble metals, and help the selection of

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 show the presence of a gold-mercury or silver-mercury amalgam layer applied to a base metal substrate. Mercury silvering 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 Diversis Artibus of Theophilus, and Arab and Andalusian 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 silvering seem to have been the most common decoration techniques for small, portable and personal metal objects in medieval minor centres of the Tuscia region such as Leopoli-Cencelle and Miranduolo. 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 cinnabar deposits of Mount Amiata.

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

Myrto Georgakopoulou[1], Stamatis Bonatsos[2] and Yannis Bassiakos[3]

1. *UCL Qatar, Doha, Qatar.*
2. *Department of Antiquities, Hellenic Ministry of Culture and Sports, Athens, Greece.*
3. *Section of Materials Science, NCSR "Demokritos", Athens, Greece.*

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 networks of this period connecting the north-east Aegean urban centers (e.g. Troy, Poliochni) with the Cycladic islands and the east coast of the Greek 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 analyses of a large 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 utensils 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

R.G.V. Hancock[1], J.-F. Moreau[2], K. Michelaki[3], and W. Fox[4]

1. *Department of Medical Physics and Applied Radiation Sciences and Department of Anthropology, McMaster University, Hamilton, ON, Canada L8S 4K1.*
2. *Laboratoire d'archéologie, Université du Québec à Chicoutimi, Chicoutimi, Québec, Canada G7H 2B1.*
3. *School of Human Evolution and Social Change, Arizona State University, 900 S. Cady Mall, Tempe, AZ 85287, USA.*
4. *Royal Ontario Museum, Toronto, ON, Canada M5S 2C6.*

European copper artifacts appearing in Northeastern 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 Ontario. However, based on the existing analyses it is impossible to know whether copper 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 (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.

We established 11 coarse chemistries, 3 of them splittable each into two sub-coarse chemistries, 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 copper samples in four of the eleven primary course chemical groups; Wendat communities and their western neighbours, the Petun, had the majority of two other chemistries, and Quebec sites had the majority of the remaining three coarse chemistries. If our sampling is representative, this implies that while some kettles of specific chemistries were preferentially kept in Quebec, the majority of kettles were traded to the west through the Wendat to peoples of other nations in eastern Ontario.

Our initial efforts to establish a clear copper chronology have produced tantalizing indications that there might be one.

179. The Importance of Kestel in Anatolian Metal Supply

Philly Howarth[1], Mark Pollard[2] and Peter Bray[3]

1. *RLAHA, University of Oxford, Oxford, UK.*
2. *RLAHA, University of Oxford, Oxford, UK.*
3. *RLAHA, University of Oxford, Oxford, UK.*

The search for the source of tin in Bronze Age Anatolia has been a focus of archaeological research for over 150 years1. Since the discovery of evidence for the exploitation of the Kestel mine during the Late Chalcolithic and Early Bronze Age2, debates have ranged from whether it was the main source of tin across Turkey and surrounding regions to whether it was mined for tin at all. The evidence of pottery sherds in the cassiterite veins suggests that this mine was exploited to supply tin. However, Avilova states that the ores present are polymetallic, in which case it is also possible that extracting gold and silver was the main purpose of mining activity in the area.3 Even so, the Kestel Mine is only one potential source of tin. What of external sources of tin or imports of bronze from other neighbouring regions?

The results from the database I have collected so far suggest a difference in bronze use between the northwest half of Anatolia and the south east, cut roughly along the Taurus and Anti-Taurus mountain ranges. From the 3rd Millennium to the 2nd Millennium bronze ubiquity decreases 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 focussing on the source of tin, will 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

my database developed by Bray and Pollard4 which assigns each object into one of 16 Copper Groups by the presence or absence of As, Ni, Sb and Ag. The results I have obtained have the potential to indicate the degradation of certain copper types over time, suggesting multiple re-melts of prevalent copper groups. Adding these results to those from the data collected by Aurelie Cuenod, a former PhD student at RLAHA, of objects from Iran, Mesopotamia, and the Arabian Peninsula, I hope to discover the presence or pattern of bronze and copper trade into Anatolia.

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180. Exploitation of Manganese-Rich 'Ore' to Smelt Iron in Mwenge, Western Uganda

Louise Iles[1]

1. *Marie Curie Research Fellow, University of York, Department of Archaeology, York, UK.*

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

Lajiang Jia[1], Pujun Jin[2], Congcang Zhao[1], Xue Lin[1], Xiaogang Yang[3], Puheng Nan[4],

1. *Northwest University, Xi'an, China.*
2. *School of Materials Science and Engineering, Shaanxi Normal University, Xi'an, China.*
3. *Chongqing Cultural Heritage Research Institute, Chongqing, China.*
4. *Shanxi Provincial Institute of Archaeology, Taiyuan, China.*

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 (LIRR) 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 Qin Dynasty 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 RadiographyAnalysis of Metal and Corrosion Products for Luristan Bronzes, Iran

Zahra Karamad[1,2], Zahra Nikoei[3]

1. *Earm High Educational Institute, Shiraz, Iran.*
2. *Faculty of Art and Architecture, Islamic Azad University, Shiraz, Iran.*
3. *Faculty of Art and Architecture, Islamic Azad University, Beyza, Iran.*

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), Metallographic 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, Metallurgraphy, XRD, Radiography

Session II
Archaeo-Chrometry

183. The Aegean Early Bronze Age, Tracing the Absolute Timeframe - Looking for Boundaries

Theodora Arvaniti[1], Yannis Maniatis[2]

1,2. Laboratory of Archaeometry, NCSR "Demokritos", 15310 Ag. Paraskevi, Attiki, Greece.

The value of radiocarbon dating is indisputable. Moreover Aegean Early Bronze Age is an Era with great changes and pioneer applications. This research is based on the idea of processing all the available results in order to create the main timeframe of the Aegean EBA. This could easily serve as a tool for an overall study of this Era and the investigation of immigration routes for people and ideas.
The method that is being used is the radiocarbon dating. The raw data includes all the available datings produced by the Laboratory of Archaeometry, NCSR "Demokritos" and also by other radiocarbon laboratories around the world and are available in the relevant published literature. All data have undergone a process of re-evaluation and only the reliable data have been used.
The data for each prehistoric settlement was treated separately using Bayesian analysis and the various occupational phases were defined in the absolute time taking into consideration all the available archaeological data. Then, the results for the whole Aegean and to a certain extend for Asia Minor were integrated and an overall absolute time frame was attempted.
Bayesian analysis was also used for the calculation of the boundaries between the three cultural phases (EBA I, EBA II, EBA III) of the EBA. The first preliminary results show a start for EBA I around 3234 ± 97 BC (Cataraktes Cave) in North Greece. Concerning the EBA II we could see a start in Cyclades (Daskalio) around 2780 ± 185 BC and for the EBA III a start around 2544 ± 39 BC in Sporades (Palamari).
As a conclusion we tried to interpret the results and look for a specific time wave in the appearance of the EBA settlements. These correlations contribute to answering the question if this new culture, that brought a different way of living and the metal technology, is something that appeared simultaneously in many geographical places by the spreading of ideas or it was transmitted through a wave of immigration.

184. Embracing In-Homogeneity in Archaeomagnetism: Implications for Sampling and Analysis

Eric Blinman[1], and J. Royce Cox1.

1. Archaeomagnetic Dating Laboratory, Office of Archaeological Studies, Museum of New Mexico, New Mexico Department of Cultural Affairs, Santa Fe, New Mexico.

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 are often variable in composition, heating is directional, heating may not achieve Curie temperatures, the depth of heating can vary dramatically, and p-TRM 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 experimentation have resulted in our shift to the recovery of burned surfaces rather than simply the recovery of volumes of 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 monuments. 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 values.
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. Compositional in-homogeneity can be evaluated in the field and lab (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

Christodoulakis John[1,2], Bassiakos Yannis[1], Tsakalos Evangellos[1] and Kazantzaki Maria[1]

1. *Section of Materials Science, IAMFPNM, National Center for Scientific Research "Demokritos", Aghia Paraskevi, 15310, Greece.*
2. *Climate Research Group, Division of Environmental Physics and Meteorology, Faculty of Physics, University of Athens, Panepistimiopoli-Zografou, 15784, Greece.*

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 palaeoanthropological point of view due to the important findings that have been revealed through excavations at the area. Recent publications suggest that Neanderthal 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 them. Another mechanism which could interpret those findings is the mixing of the layers due to the high energy of the flow in the river which is capable for even reversing big parts of layers. The research on this issue is still ongoing.
This study is funded by the NARNIA/FP7 Marie Curie Initial Training Network project.

186. Back to Basics: Understanding the Major Factors Affecting Absorbed Organic Residue Preservation in Archaeological Ceramics

Marisol Correa Ascencio[1], Richard P. Evershed[1].

1. Organic Geochemistry Unit, School of Chemistry, University of Bristol, Cantock's Close, Bristol, BS8 1TS, UK.

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

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 materical analysis of masonries

Caterina Giannattasio[1], Silvana Maria Grillo[1].

1. *DICAAR - Department of Civil Environmental Engineering and Architecture / University of Cagliari / Cagliari, Italy.*

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 highlighting 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 building.
Following steps of investigation were undertaken:
- architectural survey;
- masonries survey, referred to basements, pilasters, arches, angles, portals, window frames;
- mapping, sampling 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-artistical significance, and traditional urban fabric.

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

Becket Lailson[1], Jose R. Alvarez[2], Jorge Balmaseda[2], Ana M. Pelz[3], Nicolás Caretta1, Niklas Schulze[1], Marisol Martínez[1] and Eli Puch[4]

1. *Escuela de Ciencias Sociales y Humanidades, Universidad Autónoma de San Luis Potosí, San Luis Potosí, C.P. 78494, México.*
2. *Departamento de polímeros, Instituto de Investigaciones en Materiales, Universidad Nacional Autónoma de México, México, D.F. C.P. 04510, México.*
3. *Instituto Nacional de Antropología e Historia, Aguascalientes, México.*
4. *Posgrado en Estudios Mesoamericanos, Universidad Nacional Autónoma de México, México, D.F. C.P. 04510, México.*

Chronometric dating methods are invaluable in constructing sequences of events in archeology. Since 2009, rehydroxylation 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 Ocote”, “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 hydroxyl groups could not be detected by combining the attenuated total reflectance sampling technique with Fourier Transform Infrared (FTIR) spectroscopy. This result could be explained by the low concentration of hydroxyl groups and the low penetration depth of infrared radiation in the samples. However, the presence of hydroxyl 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 decomposition 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/or 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, rehydroxylation dating can be used in most of the samples without any additional treatment. Based on this, four different archaeological artifacts were successfully dated. To the best of the authors’ knowledge, this is the first time the rehydroxylation dating has been applied to Mexican fired-clay artifacts.

189. COMPARATIVE STUDY OF TWO ETRUSCAN BUCCHERO AMPHORAS

E. Minina[1], A. Mazina[2] and S. Sokolov[2].

1. *Pushkin State Museum of Fine Arts, Moscow, Russia; e-mail: amazina@mail.ru.*
2. *Grabar Art Conservation Centre, Moscow, Russia.*

This study analyses two Etruscan “heavy bucchero” amphoras also known as “Nikosthenic 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 amphoras in different museums. This type of amphoras is characterized by significant width of sides, lightly burned ceramics and cracked crock.
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≥Fe) 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>Ca>K>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 absence of calcite. In comparison in ceramics of amphora N 3449 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 characteristic 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)

Ester Oras[1], Thomas Higham[2], Ian D. Bull[3] and Lucy Cramp[3]

1. *Chair of Laboratory Archaeology, Department of Archaeology, University of Tartu, Tartu, Estonia; Division of Archaeology, University of Cambridge, Cambridge, United Kingdom.*
2. *Oxford Radiocarbon Accelerator Unit, Research Laboratory for Archaeology and the History of Art, University of Oxford, Oxford, United Kingdom.*
3. *Organic Geochemistry Unit, School of Chemistry, University of Bristol, Bristol, United Kingdom.*

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 20th century. This is an unusual find including the northernmost Roman bronze lamp, which has no parallels in the local archaeological material, and a rare collection of bronze bars.
The aim of the project was to analyse the provenience, 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 analysis 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 provenience and date: an exquisite foreign bronze lamp which must have travelled thousands of kilometres over several centuries, but which has not been used 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.

191. Radiocarbon Dating of Pacific Island Wooden Figures: Multiple Analyses Produce Better Age Determinations

Christine A. Prior[1]

1 *Rafter Radiocarbon Laboratory, National Isotope Centre, GNS Science, Lower Hutt, New Zealand*

Radiocarbon dating often serves two purposes when used by collectors, conservators or museums in the study of art and antiquities. As one part of the scientific testing of an object, 14C is often used first to confirm authenticity and provenance and secondarily to determine the time of manufacture. Modern reproductions (post-1950) are easily distinguished by the presence of bomb carbon, but precise calendar ages for objects made within the last 300 years are difficult to determine due to the alteration of natural 14C levels in the atmosphere by the combustion of fossil fuels. For example, a radiocarbon age of 160 ± 40 years corresponds to a 280 calendar year interval and is not particularly informative in determining the real age of an historical object. Recent improvements in AMS radiocarbon measurement technology have resulted in greatly improved precision and reported error is often as low as 2‰. Coupled with refinements in the radiocarbon calibration datasets, greater precision makes it possible to produce calendar age ranges for recent historical objects with smaller intervals.
This presentation describes the radiocarbon analysis of carved wooden objects from Pacific Islands. While the original intent of the owner was to establish that they were not late twentieth century replicas of authentic pieces, we used the opportunity to make a more comprehensive study. One of the difficulties of accurately dating wooden objects is the so-called ‘inbuilt age’ of wood. Since the carving may be from inner rings or done decades after the death of the tree, the radiocarbon date does not necessarily reflect when the sculpture was made. In order to evaluate any old-wood effect, samples were taken from surface coatings and purported historic repairs as well as interior wood. Pretreatment methods were chosen to identify and remove possible contaminants and included cleaning with organic solvents and analysis of components with gas chromatography/mass spectrometry.
A single radiocarbon date is often used at the point of sale in order to affirm authenticity of an artifact. This study shows that radiocarbon can go further and be a powerful tool in the examination of antiquities. Comparing multiple radiocarbon analyses on the same object can refine the calibrated age range, excluding some calendar age intervals and reinforcing confidence in age assignment. Multiple radiocarbon analyses can also be used to reconstruct the history of an object.

192. Reexamining the Archaeology of the Colorado Plateau (USA)
Using Radiocarbon Dating of Collected Wood

Dana Drake Rosenstein,[1] Ronald H. Towner,[2] Gregory W.H. Hodgins[3] and Jeffrey S. Dean[2]

1. *School of Anthropology, University of Arizona, Tucson, Arizona, USA*
2. *Laboratory of Tree-Ring Research, University of Arizona, Tucson, Arizona, USA*
3. *Department of Physics, University of Arizona, Tucson, Arizona, USA*

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’ - dry 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 hearth charcoal range to 1300 CE, while the firewood samples all 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 abandonments due to reliance on ‘old’ wood charcoal dating. The results of this study have important implications for the Fremont and Ute chronologies, interpretations of ethnogenesis 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 Transurals

PhD, I.A.Shuteleva, Bashkir State Pedagogical University (Ufa, Russia), shutelevai@gmail.com
PhD, N.B.Sherbakov, Bashkir State Pedagogical University (Ufa, Russia), sherbakov@rambler.ru, +7(917)7502795
PhD, T.A.Leonova, Bashkir State Pedagogical University (Ufa, Russia), leonotan@mail.ru

Investigation of archaeological monuments of the Late Bronze Age in Southern Transurals and identification of chronological succession of Abashevskaya, Srubnaya and Andronovskaya cultures led to development of chronological scales in 1970-1980's. However, in the beginning of 2000's using more extensively data of radiocarbon dating, archeologists supposed that for investigated area such scientific conclusions are not correct. It has been found out that radiocarbon analyses performed aged the communities of the Bronze Age as well as didn't confirm succession of these cultures being proved before.

In 2012 while continuing to investigate Kazburun I burials belonging to the Late Bronze Age and located in Dema-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 Usmanovo III settlement the following scientific analyses have been carried out. In the Laboratory Beta Analytic (Oxford, Great Britain and Miami, USA) they tested ceramics samples of Kazburun I burial and Usmanovo III settlement by means of AMS-radiocarbon dating, and also AMS-dating of teeth buried in Kazburun I burial mound (1890 – 1750 BC) was performed.

To define technics to prepare ceramics of Kazburun I burial and Usmanovo III settlement technical and process analysis of ceramic material was carried out, that let identify existence of two similar traditions which could be observed in materials of both monuments – Srubnaya and Alakul.

Data obtained in the process of radiocarbon dating performed in Beta Analytic also confirmed synchronism of two traditions – Srubnaya and Alakul, moreover, results of this dating were the same as data of radiocarbon dating performed for Muradymovo settlement, and technical and process analysis of ceramics also implies similarity of traditions to prepare ceramics.

194. Dating of Submerged Landscapes by Electron Spin Resonance

Anne R. Skinner[1], Justin K. Dix[2], Edward Cho[3], Fraser Sturt[4], Justin P. Mangope[1], Bonnie A. B. Blackwell[1],[3]

1 *Chemistry Department, Williams College, Williamstown, MA, USA*
2 *National Oceanography Centre, University of Southampton, Southampton, UK*
3 *RFK Science Institute, Glenwood Landing, NY*
4 *Archaeology Department, University of Southampton, Southampton, UK*

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. This region and period have produced the earliest archaeological evidence for the occupation of the British Isles (Parfitt et al. 2010). Mapping of the English Channel revealed c. 15,000 km2 of paleolandscapes, including well-defined traces of the original river course. Recently electron spin resonance (ESR) dating has been extended to quartz grains, where the age obtained represents the last exposure of the sample to light (Rink et al. 2007). The existence of multiple ESR signals within quartz allows in principle for dating by internal consistency. The age range extends into the millions of years. Rink's initial testing of the technique focused on beach sands. As another type of deposit, cores were extracted from the paleochannel of the Thames River. While originally fluvial and coastal, it is currently submerged beneath 30-50 m of water and buried at a depth of several meters beneath the surface. For the cores presented, foraminiferal analysis, amino acid racemization and ESR all suggest an early Pleistocene age. The ages resulting from this study predate the proposed occupation, but the experimental protocols developed could be applied to other sites.

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

S. Solongo[1],[3], A.Ochir[2] , S.Tengis[1] and K.Fitzsimmons[3]

1. *Institute of Physics and Technology, Mongolian Academy of Sciences, Enkhtaivan ave.54b, Ulaanbaatar 13330, Mongolia*
2. *International Institute for the Study of Nomadic Civilizations, Mongolian Academy of Sciences, Sukhbaatar Square 3, Ulaanbaatar 11, Mongolia*
3. *Department for Human evolution, Max Planck Institute for Evolutionary Anthropology, Deutscher Platz 6, Leipzig, Germany School of Social Sciences, Mongolian University of Science and Technology, Ulaanbaatar, Mongolia.*

A breathtaking discovery took place in 2011, at the Royal tomb "Ulaankhermiin Shoroonbumbagar" in Bayannuur somon Bulgan province, Mongolia (N:47057'305"; E:104032'340"). It features 117 clay figurines, 150 gold and stone wares, ancient coins and altogether over 550 items (Ochir A., et al. 2013) at a depth of 7 meter below the ground. A slope of over 40 meters long leads down to the chamber; the walls were covered by mortar and chalk with paintings which are unique and more or less influenced by the style in the early Tang Dynasty (618-907).

In this study, different materials (clay figurines, mortar and host sediment) were successfully dated using different luminescence dating methods, such as post-IR IRSL on 4-10μm fine grains and single grain technique on 212÷250μm grains of quartz in order to reconstruct the geo-archaeological chronologies. The recently developed feldspar approach - post-IR IRSL was applied to the fine grains of fired clay samples and DeIR180=6.50±0.33Gy was obtained using the pIRIR180. In contrast, fine-grained aliquots yielded results where the natural signal was over the growth curve. Single grain De distributions of the host sediment showed a normal distribution with a few outliers, justifying the use of the Central Age Model (CAM). In comparison, the mortar sample showed a broad De distribution, which is assigned to the incomplete bleaching at the time of manufacturing. The mortar sample did not came into direct sunlight during the manufacturing of the mortar into the walls of the tomb. The broad dose distribution showed 2 populations: the lower dose refers to the date of manufacturing and the higher dose corresponds to the history of the clay depositon.

The ages obtained on different materials using pIRIR180 and IR50 are from 580±77AD to 652±36AD; which are in good agreement with the historically expected age of the Royal tomb at Ulaanhermiin Shoroon Bumbagar (Mongolia).

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

N. Zacharias

Laboratory of Archaeometry, Department of History, Archaeology and Cultural Heritage Management, University of Peloponnese, East Center, 24 100 Kalamata, Greece

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 geoarchaeological material in a routine base. The key-advent of the Optically Stimulated Luminescence (OSL) techniques and the potential for exploring a spectrum from mono-minerallic single grains to polymineral 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

- the effect of alteration and contamination phenomena and of the seasonal/spatial variations on the obtained ages of archaeological materials, artefacts and geoarchaeological studies
- the importance of the context for field studies

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

- dating of mortars from historical and archaeological sites (Late Roman-Byzantine Greece and Medieval Spain)
- sediment dating from Mesolithic settlements, Palaeolithic 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

Maria Kazantzaki[1,2], Yannis Bassiakos[1], Theodora Rondoyanni[2], Evangelos Tsakalos[1] and John Christodoulakis[1]

1 *Laboratory of Archaeometry, I.M.S., N.C.S.R. ''Demokritos'', 153 10, Athens, Greece.*
2 *School of Mining and Metallurgical Engineering, National Technical University of Athens, 157 80, Zografou, Greece.*

North Evoikos Gulf, an extended active graben located in central Greece, comprises a tectonically reformatted 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, epirogenetic vertical movements and volcanic activity, leaving behind traces which have been encoded on the coastal deposits of the area. Despite the great number of geomorhological studies conducted in the area, little work has been done regarding the geochronology of the different sedimentary formations found on 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 /phases of environmental changes.
Preliminary dating results of Evoikos Gulf coastal deposits are presented here, using a number of Luminescence dating techniques, namely; Optically Stimulated Luminescence (OSL), Isothermal Thermoluminescence (ITL) from quartz and post-Infrared Infrared Stimulated Luminescence (p-IR-IRSL) from feldspars. 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 (dating limits of the technique) led to the utilization of the p-IR-IRSL signal from feldspars 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, fact which 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

Sachiko Sakai[1]

1. *Department of Anthropology, University of California Santa Barbara, Santa Barbara, California.*

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 A.D. 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-tempered ceramics 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 how 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 couples mass spectrometry (LA-ICP-MS). Eight compositional groups were found in the chemical compositional data of 1069 sherds from Mt. Trumbull and the lowland Virgin area in southern Nevada, which is one of the destinations of the olivine-tempered ceramic trading.
In this paper, I examine how the use of each clay group changed over time by combining the data sets of the optimal luminescence (OSL) dating on 113 sherds as well as the elemental compositional analyses. These analyses clearly show the change in the use of clay over time. The study reveals that (1) olivine-tempered pots were moved to the lowland Virgin area from Mt. Trumbull as a result of population movement early on and by exchange later on, (2) 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 involved at both Mt. Trumbull and the lowland Virgin area during the later time period when the population increased, and (4) only optical clay was used in Mt. Trumbull when the population increased even more during the Pueblo III period to reduce the production cost of the pots and leave more time for agricultural intensification.

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

Evangelos Tsakalos[1], Yannis Bassiakos[1], Maria Kazantzaki[1,2] and John Christodoulakis[1]

1. *Laboratory of Archaeometry, I.M.S., N.C.S.R. "Demokritos", 153 10, Athens, Greece.*
2. *School of Mining and Metallurgical Engineering, National Technical University of Athens, 157 80, Zografou, Greece.*

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. Numeric 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 principally based on radiometric and radiation-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 provides 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 consider on the basis of a wider geographical framework, including the Late Quaternary littoral formations of resembling creation and evolution that appear along the coasts of the eastern Mediterranean.
Our luminescence dating estimations assign 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 FP7, 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 Micro-Raman Study

Diego Badillo[1], Wolfram Baumann[2]

1. *Postgraduate Student of Chemistry Department, Universidad de Los Andes, Bogotá D.C. Colombia.*
2. *Professor and Director of Chemistry Department, Universidad de Los Andes, Bogotá D.C. Colombia.*

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 scientist. The application of modern instrumental analytical techniques and in this way introducing reproducibility and objectivity may change the history.

The present study is planned as an in Colombia novel study to elucidate the painting material and technique of the 19th century's Colombian painter Epifanio Garay (1849 -1903), applying the modern technique of micro-Confocal Raman Spectroscopy (μCRS). The results then allow put in question the authorship of one painting ascribed usually to Garay.
Garay is considered one of the fathers of the Colombian School of Arts, and is of great interest for his artistic trajectory, his painting style and his innovative use of painting materials. Up to now his painting or color palette as well as his painting technique has not been studied by modern instrumental methods of analysis.
The present study uses a confocal micro Raman spectrometer (XploRA from Horiba), with an areal resolution of 2–3 μm2 to determine the chemical composition of individual pigment grains through their Raman spectra. These grains are microscopically selected from so-called micro-cuttings of 1–5 mm2, which had been cut from selected paintings at sites of the paintings of no visual importance. For easy manipulation these micro-cuttings have been glued to one end of a thin tubular stick, the other end of which was stuck into a small piece of moldable plastic, by which any desired orientation of the sample with respect to the Raman beam was possible. Hence, the surface and the stratigraphy of the cutting of samples from seven oil paintings of Garay were analyzed by μCRS.
Resulted that Garay used a palette of inorganic color pigments: carbon black, vermillion, prussian blue, yellow and red ochre, lead white, and fayalite (Fe_2SiO_4). Base preparation was with mixtures of gypsum, cerussite ($PbCO_3$) and chalkite on fine canvas. To achieve color tones he painted in thin layers. The fine grain of homogeneous size distribution indicates the use of industrialized products.
This palette together with stylistic characteristics defines a profile for the oil paintings of Garay. On its basis, one out of the seven paintings studied and hitherto ascribed to Garay must now be put in question.

201. Rapid Identification of a Blood Encrustation on an African Ritual Mask by DART-MS

Daniel Fraser[1], Cathy Selvius DeRoo[2], Robert Cody[3], Sylvia Torres[4], and Ruth Ann Armitage[4]

1. *Department of Chemistry and Physical Science, Lourdes University, Sylvania, OH, USA.*
2. *Conservation Department, Detroit Institute of Arts, Detroit, MI, USA.*
3. *JEOL USA, 44 Dearborn Rd, Peabody, MA, USA*
4. *Department of Chemistry, Eastern Michigan University, Ypsilanti, MI, USA.*

Colorimetric presumptive tests have a long – and somewhat troubling – history in the identification of blood in and on archaeological materials. Such tests establish only the likelihood that a substance is blood, and presumptive tests suffer significantly from a high rate of false positives from other contaminants. In forensic science applications, positive presumptive tests must legally be followed up with confirmatory tests. Archaeometry and conservation science have a less rigorous burden of proof, and are often limited by the expense of DNA or proteomic analysis.
A multianalytical approach was undertaken to characterize the flaking encrusted coating on the surface of an African Komo mask from the Detroit Institute of Arts. Preliminary XRF and FTIR examination of the coating revealed the presence of significant quantities of iron and protein, possibly indicating the presence of blood. Raman spectroscopy showed evidence for the porphyrin structure of heme as well. Several presumptive tests were applied to the coating, all of which supported the likelihood that blood was present. To confirm these tests, we developed a novel method for identifying the heme moiety from blood by use of in-situ methylation and direct analysis in real time mass spectrometry (DART-MS).
Following a denaturing step with formic acid, the resulting solution was combined with an excess of phenyltrimethylammonium hydroxide to promote desorption, applied to a melting point tube, and placed into the ion source gas stream at 550 °C. The permethylated heme ion (m/z 644.208) from myoglobin, hemoglobin, fresh blood, and blood aged in the laboratory for 10 years was readily observed above the background. By the described DART-TOF-MS method, permethylated heme was positively identified in the mask coating, confirming the presence of blood. Further applications of this novel method to the identification of dried blood stains on fabric will also be reported.

202. The use of enzyme-linked immunosorbant assay and mass spectrometry for the characterization of binding media in Egyptian Romano portraits

Takashi Nakazawa[1], Yoko Taniguchi[2], Kazuki Kawahara[3], Shunsuke Fukakusa[1], Joy Mazurek[4], Marie Svoboda[5], Jeffrey Maish[5]

1 *Nara Women's University; Kita-Uoya-Nishi Machi, Nara, Nara 630-8506 Japan*
2 *University of Tsukuba 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8571 Japan*
3 *Osaka University; 1-6 Yamadaoka, Suita, Osaka 565-0871 Japan*
4 *Getty Conservation Institute; 1200 Getty Center Drive, Suite 700; Los Angeles, CA 90049 USA*
5The J. Paul Getty Museum; 17985 Pacific Coast Highway, Pacific Palisades, CA 90272, USA

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 Media, proteomics

203. Analysis of an Egyptian Sarcophagus Fragment

Colleen O'Shea[1], Aaron Shugar[1], and Lucy Skinner[1]

1. *Art Conservation Department, SUNY - Buffalo State, Buffalo, NY 14222.*

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?

Shawn Owens[1], Marshall Ligare[1], Mattanjah S. de Vries[1], Stuart Tyson Smith[2], Anabel Ford[3]

1. *Department of Chemistry and Biochemistry, University of California Santa Barbara, CA 93106, USA.*
2. *Department ofAnthropology, University of California Santa Barbara, CA 93106, USA*
3. *Institute of Social, Behavioral and Economic Research, University of California Santa Barbara, CA 93106, USA*

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

Capri Price[1], Natasja Swartz[1], Doug Wilson[2] and Tami L.Clare[1]

1. *Department of Chemistry/Portland State University, Portland, OR, USA.*
2. *Department of Anthropology/Portland State University, Portland, OR, USA.*

Elemental analysis of historic soil has been established as a useful technique for assisting scientists in establishing 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 (ICP). However, X-ray fluorescence spectroscopy (XRF) is rapidly becoming a more popular technique because of its non-destructive nature, rapid analysis capabilities and portability. In this study, XRF was employed to analyze historic soils from Fort Vancouver (FOVA), Washington, to determine whether this instrumentation could be used to produce quantitative results in an elemental analysis. Standard addition techniques and tailored background spectra were used to produce quantitative amounts of Ca, P, K and Sr in the soil samples provided. These same soils were also analyzed by AAS, 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 anthropogenically 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

Diana C. Rambaldi[1], Sergey V. Prikhodko[2], Vanessa Muros[3], Elizabeth Burr[3], and Ioanna Kakoulli[2,3]

1. *Conservation Center, Los Angeles County Museum of Art, 5905 Wilshire Blvd, Los Angeles, CA 90036, United States.*
2. *Department of Materials Science and Engineering, University of California, Los Angeles, 410 Westwood Plaza, 3111 Engineering V, Los Angeles, CA 90095-1595, United States.*
3. *UCLA/Getty Conservation Program, Cotsen Institute of Archaeology, University of California, Los Angeles, 308 Charles E. Young Drive North A210 Fowler Building/Box 951510, Los Angeles, CA 90095-1510, United States.*

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 materials1. 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)2. 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 AgNP 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 cochineal 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 SEM was used to select areas showing diverse deposition of AgNPs. SERS analyses were then directly carried out in these areas without 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 AgNP 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.

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

Yukiko Tonoike[1], Nicholas F. Bellantoni[2], Gary P. Aronsen[3], Gerald J. Conlogue[4], John Krigbaum[5], Lars Fehren-Schmitz[6], Natalie A. Pellatier[7], Robert Lombardo[8], Kylie Williamson[9], Judith A. Schiff[10], and Frank Hole[11]

1. *Department of Anthropology, Yale University, New Haven, Connecticut, USA.*
2. *Connecticut Archaeology Center, Connecticut State Museum of Natural History, University of Connecticut Storrs, Storrs, Connecticut, USA.*
3. *Department of Anthropology, Yale University, New Haven, Connecticut, USA.*
4. *Department of Diagnostic Imaging, Quinnipiac University, Hamden, Connecticut, USA.*
5. *Department of Anthropology, University of Florida Gainesville, Gainesville, Florida, USA.*
6. *Department of Anthropology, University of California Santa Cruz, Santa Cruz, California, USA.*
7. *Department of Diagnostic Imaging, Quinnipiac University, Hamden, Connecticut, USA.*
8. *Department of Diagnostic Imaging, Quinnipiac University, Hamden, Connecticut, USA.*
9. *Department of Anthropology, Yale University, New Haven, Connecticut, USA.*
10. *Yale University Library and New Haven City Historian, New Haven, Connecticut, USA.*
11. *Department of Anthropology, Yale University, New Haven, Connecticut, USA.*

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 1900s. This poster 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

Shuya Wei[1*], Qinglin Ma[2], Shuhong Lou[3]

1. *Institute of Historical Metallurgy and Materials, University of Science and Technology Beijing, 30 Xueyuan Road, China.*
2. *Chinese Academy of Cultural Heritage, 2 Gaoyuan Street, Beijing, China.*
3. *Zhejiang Province Museum, 25 Gushan Road, Hongzhou, China.*

This work presents the results of the analysis investigation of the incense and the lamp oil residue from a Tang Dynasty aristocrat tomb (Shuiqiu Shi tomb, 901 AD) in Lin An County, Zhejiang Province of 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 azlaic acid, palmitic acid and stearic acid as their methyl esters were detected, indicating plant oil, perhaps Tung oil are present, while the oil of the lamp was identified as mixture of plant oil and animal fat due to the detection of azlaic 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 national pharmacopaeia, the Tang Materia Medica (Táng 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.

* Correspond author, Email: sywei66@hotmail.com

Human Environment Interactions and Bio-Materials Bioarchaeology

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

Ruth Ann Armitage[1], Kathryn Jakes[2] and Calvin Day[1]

1. *Department of Chemistry, Eastern Michigan University, Ypsilanti, MI, USA.*
2. *Department of Human Sciences, The Ohio State University, Columbus, OH, USA.*

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 methods and materials used in dyeing these ancient fabrics are still not well understood, and the research presented herein seeks to add to that body of knowledge.
To investigate the sources of dye colorants in samples from Paracas textiles, we applied direct analysis in real time – time-of-flight mass spectrometry (DART-MS). 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 (Galium) roots. In the comparative materials prepared from cochineal insects, flavokermesic acid and kermesic acid (the aglycone of carminic acid) were readily identified, with intact carminic acid present in some samples, at low abundance. One of the Paracas samples (421-39 #3) provided for analysis had previously been studied by UV, IR, and visible microspectroscopies and determined to contain dye colorants characteristic of Relbunium (Saltzman 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 that purpurin, 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

Murilo Q. R. Bastos[1], Roberto V. Santos[1] and Robert H. Tykot[2]

1. *Universidade de Brasília, Departamento de Geociências, Brasília, Brazil.*
2. *University of South Florida, Department of Anthropology, Tampa, Florida, USA.*

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 2,520,000 captives from Africa arrived in these cities between the years 1678 and 1830.
In the present paper we did δ13C, δ15N 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, to bring information about 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 δ13C enamel analyses were performed in a MC-ICP-MS Neptune and a Kiel IV connected to a MAT 253, respectively, both from Thermo Scientific. The δ13C and δ15N dentin 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 0.7058 and 0.7498 and in Catedral da Se values from 0.7078 to 0.7320. Based on strontium 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 compatible with the historic records about 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 δ15N results below 10‰, indicating that plants played an important role in their diets. The δ13C of these individuals shows that 71.5% were eating more C4 plants like 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 δ15N values compatible with significant consumption of animal protein in the diet, including two individuals that were probably eating freshwater fish due to δ15N values above 14‰ and very negative results of δ13C.

211. Non destructive identification and diagnosis of natural organic substances in cultural heritage: insight from Raman and infrared signatures

Ludovic Bellot-Gurlet[1], Céline Daher[2], Céline Paris[1] and Martine Regert[3]

1. *MONARIS "de la Molécule aux Nano-objets : Réactivité, Interactions et Spectroscopies" UMR 8233 UPMC/CNRS, Université Pierre et Marie Curie, Paris, France. ludovic.bellot-gurlet@upmc.fr*
2. *Centre de Recherche sur la Conservation des Collections (CRCC), USR3224 MNHN/MCC/CNRS, Paris, France.*
3. *CEPAM "Cultures-Environnements. Préhistoire, Antiquité, Moyen Âge" UMR 7264 CNRS / Univ. Sophia Antipolis, 06300 Nice, France.*

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 conservation and challenging characterisation. With the re-evaluation of vibrational spectroscopies (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 is here proposed, based on spectral decomposition of CH stretching massif followed by Principal Component Analyses of the extracted decomposition parameters. Applying PCA on the raw data, as commonly done, was tried and appeared to be indiscriminative. 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.

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

Chelsea Budd[1], Rick Schulting[1], Necmi Karul[2], Songül Alpaslan-Roodenberg[3], Ron Pinhasi[4] and Malcolm Lillie[5]

1. *School of Archaeology, Oxford University, Beaumont Street, Oxford, UK.*
2. *Department of Prehistory, Istanbul University, 34134 Laleli, Istanbul, Turkey.*
3. *Independent Researcher, The Netherlands.*
4. *School of Archaeology, University College Dublin, Dublin, UK.*
5. *Department of Geography, Hull University, Cottingham Road, Hull, UK.*

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, form the origins 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 Neolithic 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 forerunners for change in this debate. 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 resource procurement strategies, populations that placed a reliance on fishing, mollusc collecting, hunting and gathering, alongside the exploitation of some domesticated animals and plant cultivation [8]. Equally, there are some sites in the North-West region, and on the Central Anatolian plateau, that show evidence for fully formed 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 effects 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 analyzing δ13C and δ15N ratios of collagen from human, and wild and domestic fauna skeletal remains. This research produces new stable isotope data for the sites of Aktopraklık, and utilizes δ13C and δ15N ratios present in the published literature [10-13]. 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 isotope data values demonstrate consistent enrichment in both carbon and nitrogen values as the site locations move along a West to East transect.

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213. The use of strontium isotope data from human dental enamel as prima facie evidence for evaluating human provenience and mobility.

James H. Burton[1]

1. *Department of Anthropology, University of Wisconsin-Madison, USA.*

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 of strontium, how and when they are incorporated into calcified tissues, and how human cultural practices might affect these factors. Without such consideration, the use of geological and 'bioavailable' proxies for human isotope ratios can lead to demonstrably wrong, even absurd, inferences of locality and mobility. Because we are beginning to accumulate large sets of human data, we can also begin to make inferences about mobility and geographic origins directly, empirically, from the human data as prima facie data, without such proxy information. Specific examples of false inferences from proxy data and the utility of empirical human data will be presented.

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

Maria Perla Colombini[1], Celia Duce[2], Andreas Kurzweil[3], Sibilla Orsini[2], Erika Ribechini[2], Alessio Spepi[2], Maria Rosaria Tinè[2]

1. *ICVBC-CNR and Department of Chemistry and Industrial Chemistry, University of Pisa, Pisa, Italy.*
2. *Department of Chemistry and Industrial Chemistry, University of Pisa, Pisa, Italy.*
3. *Arbeitsgruppe Teerschwele in Museumsdorf Düppel, Berlin, Germany.*

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 (pyrolysis)-type processes. Tar and pitch have been of great importance for their properties, such as insolubility in water, adhesion and glasslike 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 added. Traditionally, mixtures 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 pine pitch. With this aim, pine pitch replicas from Pinus sylvestris prepared following test of experimental archaeology, were added with different proportion of beeswax and studied by a multi- analytical approach comprising the use of gas chromatography/mass spectrometry (GC/MS) and thermoanalytical techniques (DSC, TG and TG-FTIR). GC/MS was use to assess the molecular composition of pitch replica and to identify a series of species acting as markers of technological manipulation and eventually of degradation. In addition, GC/MS analysis was applied to pine pitch heated up to 300°C under nitrogen and air flow. Studying the mixtures of pine pitch with different amount of additive by thermal analysis allowed us to extend the knowledge of the techniques used in the past. The comparisons between the thermal analysis of the pure pine pitch and of the pine pitch added with different amount of beeswax allow us to shed light on the effects induced on the pitch by the presence of beeswax. In addition, DSC highlights that the melting point of mixtures increase with the increase of the amount of beeswax.
The same multi-analytical approach was also used to study archaeological samples consisted of pine pitch and beeswax

to establish a correlation with the mixtures obtained by experimental archaeology.

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

M. E. Delgado Burbano[1], C. H. Langebaek[2], L. Aristizabal[2], R. H. Tykot[3], L. Johnson[3]

1. *División Antropología, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata. Paseo del Bosque s/n. (B1900FWA), La Plata, República Argentina. Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), República Argentina. (medelgado@fcnym.unlp.edu.ar)*
2. *Departamento de Antropología, Facultad de Ciencias Sociales, Universidad de los Andes, Bogotá D.C. Colombia. (clangeba@uniandes.edu.co, lucero.aristizaballosada@googlemail.com)*
3. *Department of Anthropology, University of South Florida, Tampa, Florida, 33620 USA. (rtykot@usf.edu, ljohnson@usf.edu)*

Carbon (collagen and apatite) and nitrogen stable isotopes as well as trace elements (Sr and Ba) from archaeological human bone samples from Tibanica, a Muisca settlement (1000-1600 AD) in the eastern highlands of Colombia, were used to study the human diet and subsistence in the region during the Late Muisca Period (1200-1600 AD). Isotope and elemental data for 60 human and 7 faunal samples were used to perform, in a detailed and quantitative form, dietary reconstructions for both humans and animals inhabiting the study region during the final late Holocene. The carbon isotope-based regression model reflects a mixed diet where maize and other C4 tropical crops played an important roll 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 Muisca 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)

Laura Fanti[1,2], Carlo Lugliè[2] and Martine Regert[1]

1. *Univ. Nice Sophia Antipolis, CNRS, CEPAM, UMR 7264, 06300 Nice, France.*
2. *LASP, Dipartimento di Storia, Beni Culturali e Territorio, Università degli Studi di Cagliari, Italy.*

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 traceological and biomolecular approach and discussed 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, Terralba (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 crossing dimensional, traceological 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

organic residues analysis revealed distributions of fatty acids (C14-24) with palmitic (C16:0) and stearic (C18:0) acids prevailing, and sometimes sterols. Even if δ13C isotopic analysis are necessary to identify exact residues origin, higher lipid concentrations (700-2500 µg/g) appear to be limited to higher size vessels (5-9 liters). In this category, clearly linked to cooking, we observe two different relations between lipid concentration and traces:
a) lipid concentrations between 700-2500 µg/g, sooting, and/or fine carbonized layer in the bottom;
b) low lipid concentration (< 5 µg/g), stronger sooting, slight carbonized impregnations in the bottom and sometimes internal walls abrasion.
According to our hypothesis, these different patterns of traces could reflect two different ways of functioning, respectively boiling of high fat foods vs. cooking of low fat contents such as cereals or pulses.

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

Yogambar Singh Farswan and Jaibir Singh Pharswan

H.N. Bahuguna Garhwal University (A Central University)
Srinagar, Garhwal-246174, Uttarakhand (INDIA)
E-mail: farswanys@yahoo.co.in

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 Ghunghati 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 reining deity – Goddess Nanda to her divine destination of Ghunghati, 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.

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 Nitrogen and 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 palaeodiet behaviour of bone remains collected from high altitudes.

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

Rafael R. Galindo[1], Brian Castro[2], Cesar Sierra[2] and Helen H. Henderson[1]

1. *Departamento de Antropología/Universidad Nacional de Colombia, Bogotá, Colombia.*
2. *Departamento de Química/Universidad Nacional de Colombia, Bogotá, Colombia.*

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 paleodiet 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 Suta archaeological site located in Sutamarchán 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 established the relation 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 identify the following fatty acids associated with animal fats: margaric and vaccenic acids.
TGA-DSC and FT-IR analyses showed the properties of the ceramic in the conservation of the organic material. One of these properties corresponds 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 silicates and metasilicates 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 isotope analysis of human and animal from the Qinglongquan site, China

Yi Guo[1], Yilu Fan[1], Yaowu Hu[2], Junying Zhu[3], Changsui Wang[2], Benjiamin Fuller[2] and Michael P. Richards[5]

1. *Department of Cultural Heritage and Museology, School of Humanities, Zhejiang University, 310028, P.R. China.*
2. *Lab of Human Evolution, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, Beijing 100044, P.R. China.*
3. *Hubei Provincial Institute of Cultural Relics and Archaeology, Wuhan, 430077, P.R. China.*
4. *Department of Human Evolution, Max-Planck Institute for Evolutionary Anthropology, Leipzig, 04103, Germany.*

The Qinglongquan site, China, including materials during Yangshao (3500-3000 BC), Qujialing (3000-2600 BC) and Shijiahe (2600-2200 BC) periods, lies within Sui-Zao Corridor which connects Nanyang Basin in the north and Hanjiang 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 Qujialing and Shijiehe 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 strongly suggests a geological variation as 'migration' in the Qinglongquan site which matches a Chinese legend 'Zheng Sanmiao' very well.

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

Alan J Hall[1], Alex Alexander[1] , Alan Stroud[1] and Effie Photos-Jones,[2,1]

1. *Archaeology, School of Humanities, University of Glasgow, Glasgow, UK.*
2. *Analytical Services for Art and Archaeology (Scotland) Ltd, Glasgow, UK.*

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 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

partaking in the ritual of drinking from a holy well was sufficient for a 'cure' to be effected.
In this paper we illustrate our methodology for a pilot study of a number of holy wells from various localities around Scotland based on the following criteria: a) the evaluation of long standing historical documentation as well as local oral tradition regarding the identification of a particular well as 'holy', b) the presence of other known archaeological features in the greater landscape surrounding the holy well and suggest possible implications of that proximity, c) the evidence for 'clay' deposits deriving from the spring, usually, but not necessarily, of red colour, d) the in-situ measurement of physical and chemical water parameters (alkalinity, TDS, pH, heavy metals contents) mostly with test strips and as a basis for intra- well water quality comparison, e) the recording of the local geology and hydrology, f) the sampling and analysis of the 'clay' residues (chemical and mineralogical) and g) the compilation of an 'archaeometric' profile for each holy well, based on the above criteria. Examples are given for each.
The results so far suggest variations which have the potential to characterise each holy well along one or more quantifiable parameters and beyond the relevant folkloric narratives, which now form the core for intra-well comparisons. Our project is at its beginning stages but we argue that unless a systematic geo-hydro-archaeological approach is undertaken for the study of these archaeological features, they run the risk of either being perpetually delegated to the realm of New Age spirituality or of being gradually 'eliminated' by private landowners concerned for safety or by urban development.

221. How to fit vegetation in a box? Building a palaeobotanical and chemical database for the project "Exsudarch"

Auréade Henry[1], Claire Delhon[2], Arnauld Jouvenez[2], Antoine Pasqualini[2], Maxime Rageot[2] and Martine Regert[2]

1. *CNRS- UMR 7209 AASPE, MNHN, 55 rue Buffon, 75005 Paris, France.*
2. *CNRS- UMR 7264 CEPAM, Campus SJA3, 24 Av. Des Diables Bleus, 06375 Nice cedex 04, FRance.*

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 archaeobotanical and palaeobotanical data covering the Northwest Mediterranean area. The challenge was to make this base compatible with the archaeological information and chemical data on archaeological samples containing birch bark tar and with the present-day vegetation distribution maps.
This poster 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 attribution?
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 made efficient 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 unleash the shackles of fitting palaeovegetation 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

Kathryn Jakes[1], Ruth Ann Armitage[2] and Calvin Day[2]

1. *Department of Human Sciences, The Ohio State University, Columbus, OH, USA*
2. *Department of Chemistry, Eastern Michigan University, Ypsilanti, MI, USA.*

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 textile 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 than 5 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 sumac (Rhus sp.) berries as a source of tannins. Fibers from a yarn fragment shed from a red and yellow colored textile recovered by Shetrone and Greenman (1931) and curated by the Ohio Historical Society that were examined in this work were shown to be colored (dyed rather than pigmented) rabbit hair.
Anthraquinones make up the primary colorants obtained from bedstraw roots. In the comparative materials prepared from 3-year-old Galium verum roots, rubiadin was the primary colorant observed in both positive and negative ion spectra obtained with DART-MS. Purpurin, alizarin, and lucidin were also identified in the bedstraw. The dye colorants in bloodroot are benzoisoquinoline alkaloids including sanguinarine, norsanguinarine, and protopine. These compounds were only detectable in positive ion mode DART-MS, as they are quaternary ammonium salts that are readily protonated. The bloodroot-dyed materials contained none of the anthraquinone compounds. None of the bedstraw or bloodroot compounds were observed in the ochre-stained yarn samples.
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 rubiadin 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 MEDIEVAL RURAL COMMUNITIES FROM BASQUE COUNTRY (SPAIN)

Carmine Lubritto[1], Maite Iris García-Collado[2], Carmina Sirignano[1], Paola Ricci[1], Simona Altieri[1], Juan Antonio Quirós Castillo[2]

1. *Second University of Naples, Department of Environmental Science and Technology, IRMS CIRCE Lab, Via Vivaldi 43. I-81100, Caserta (Italy).*
2. *University of Basque Country (UPV-EHU), Department of Geography, Prehistory and Archeology. Calle F. Tomás y Valiente s/n. E-01006, Vitoria-Gasteiz (Spain).*

The paper presents the results of a paleodietary 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 paleodietary patterns and their implications into the analysis of social differences between and within the different sites. δ13C and δ15N were measured 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 Aistra and Zornoztegi, 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 Dulantzi showed values intermediate between these two groups. Statistical analysis showed significant correlation between sex and δ15N at the sites

of Dulantzi and Zaballa. At Dulantzi and Treviño statistically significant correlation was found between the presence of certain archaeological status markers, such as grave goods, and high protein intake, confirming the presence of local elites at these sites. Finally, the comparison between the Basque sites and other contemporary contexts from the Iberian Peninsula revealed remarkable heterogeneity during Middle Ages in this region, mainly due to local differences in ecosystems and social organization.

224. Climate driven dietary and agricultural change in the late Eneolithic/early Bronze Age Ukrainian Steppe recorded in organic residues in ceramic vessels

Simona Mileto[1, 2], Richard P. Evershed[2], Elke Kaiser[1], Yuri Rassamakin[3] and Wolfram Schier[1]

1. *Institut für Prähistorische Archäologie, Freie Universität Berlin, Altensteinstr. 15, Berlin 14195, Germany.*
2. *Organic Geochemestry Unit, Biogeochemestry Research Centre, School of Chemistry, University of Bristol, Bristol BS8 1TS, United Kingdom.*
3. *Institute of Archaeology of the National Academy of Sciences, Kiev, Ukraine.*

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 economy and diet (Pashkevych, 2012). The warm/humid early phase appears to have been dominated by terrestrial wild animals and crops, whereas in the later arid/colder period terrestrial domesticates were more common (Pashkevych, 2012; Rassamakin, 2006). Moreover, stable isotope (C and N) signatures of humans, and faunal and fish remains, from the Middle and Lower Dnieper Basin indicate that significant exploitation of aquatic resources occurred (Lillie et al., 2011). The aim of this project is to deepen our knowledge of the economy and lifestyle of the ancient Ukrainian populations during this transitional period, through the study of material culture and faunal evidence, together with organic residue analyses of food vessels. In particular, this work will investigate the role of Ukrainian settlements in horse domestication, since they occur contemporaneously (3500 BC) with the horse-dominated economy of Botai in Kazhakstan (Outram et al., 2009).
The molecular and isotopic evidence recoverable from absorbed organic residues preserved in archaeological pottery are proving to be a powerful tool in reconstructing ancient diet and economy (Evershed 1993, 2008). Compound-specific stable carbon isotope analysis of preserved fatty acids (δ13C and Δ13C values) allows the identification of animal fats (e.g. non ruminant adipose, ruminant adipose, ruminant dairy), whereas compound-specific stable deuterium isotope analysis (δD values) allows resolution of more challenging fats, such as equine milk and adipose fat, in addition to providing information about temperature and precipitation driven climatic change (Outram et al., 2009).
In this work >200 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 absent 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. δD 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

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

Mirva Pääkkönen[1], Richard Evershed[2] and Henrik Asplund[1]

1. *Archaeology, University of Turku, Turku, Finland.*
2. *Organic Geochemistry Unit, University of Bristol, Bristol, United Kingdom.*

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 Kiukainen 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 scarce 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 investigate 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.
Nearly 200 sherds from different vessels from Middle and Late Neolithic period have been studied. Reference materials comprised a range of different salt and freshwater fish species and large mammals, including elk, wild reindeer, grey seal and bear. >60 % of studied vessels were found to contain fatty acids. The finding of 4,8,12-trimethyltridecanoic acid, 3,7,11,15-tetramethylhexadecanoic acid and ω-(o-alkylphenyl)alkanoic acids, known to be formed during heating of aquatic fats, indicate strongly the use of vessels for processing aquatic resources. Since 80 % of the vessels with fatty acids contain these biomarkers, it is clear that the vessels were used extensively for processing aquatic resources. Although palaeobotanical and zooarchaeological evidence indicates the arrival of farming, no evidence of a dominance of intensive farming was discernable from the organic residues. These results suggest that the harsh climatic conditions made it extremely difficult for early farming to be sustained in the region and survival demanded foraging, such that the aquatic environment continued as an important dietary resource.

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

Pozo S.[1], García L.[2], Carrera F.[3] and Rivas T.[2]

1. *Getty Conservation Institute. Los Angeles, CA 90049, USA.*
2. *Department of Natural Resources and Environmental Engineering. 36310, University of Vigo, Spain.*
3. *Escuela Superior de Conservación y Restauración de Bienes Culturales de Galicia.36002, Spain.*

Petroglyphs are prehistoric 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 Places. 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 geothecnical 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 oucrop 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 geothenic 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 warm and humid climate of Galicia and is directly linked to the distribution of the intense joint network which characterize this granite outcrop The presence of hematite and the neoformation of mullite indicated that the rock is also affected by high

temperatures, above 950oC, 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

Rageot M.[1], Fernandez X.[2], Filippi J.-J.[2], Bellot-Gurlet L.[3], Le Hô A.-S.[4], Pêche-Quilichini K.[5] and Regert M.[1]

1. *Univ. Nice Sophia Antipolis, CNRS, CEPAM, UMR 7264, 06300 Nice, France.*
2. *Univ. Nice Sophia Antipolis, CNRS, ICN, UMR 7272, 06300 Nice, France.*
3. *LADIR UMR7075 UPMC-CNRS, Paris, France.*
4. *C2RMF, Paris, France.*
5. *LAMPEA UMR 7269, MMSH, Aix-en-Provence Cedex 2, France.*

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 adhesives 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 analysis. The DART atmospheric pressure ion source allows direct analysis on the objects, without any sampling nor preparation. Initially developped in 2005, this versatile technique has proved to be useful in a variety of fields including forensic science, but it has been applied in the domain of cultural heritage only recently1.
We first tested this method on contemporary reference substances such as beeswax, plant tars and resins. The mass spectra obtained provided a clear discrimination of these different materials based on the study of molecular ions and on the fragments related to specific carbon skeleton. It was then possible to characterize birch bark tar used for repairing ceramic vessels from Neolithic sites of Mediterranean area. In combination with DART, direct non-destructive analysis by vibrational method, particularly ATR-IRTF 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 Protohistory. 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

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

S.Y. Waksman[1], A. Pecci[2], R.S. Gabrieli[3], E.J. Stern[4], J. Vroom[5] and the POMEDOR collaboration

1. *Laboratoire de Céramologie, CNRS, UMR5138 Archéométrie et archéologie, Lyon, France.*
2. *DiBEST, Universita' della Calabria, Cosenza, Italy.*
3. *Department of Archaeology, University of Sydney, Australia.*
4. *Israel Antiquities Authority, Nahalal, Israel.*
5. *Faculty of Archaeology, Leiden University, The Netherlands.*

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 analysis 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.

http://www.pomedor.mom.fr

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

Wenjuan Wang[1,2], Guoding Song[1,2*], Zhanyang Li[3], Yan Wu[1]

1. *Key Laboratory of Vertebrate Evolution and Human Origins of Chinese Academy of Sciences, Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences , Beijing100044, China.*
2. *Department of Scientific History and Archaeometry, University of Chinese Academy of Sciences, Beijing 100049, China.*
3. *Institute of Cultural Relics in Henan Province, Zhengzhou 450000, China.*

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 smearing 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.

* Correspond author: Guoding Song, Email: guodings@ucas.ac.cn

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 (Alvaiázere, Portugal): Preliminary Results

Anna J. Waterman[1], Robert H. Tykot[2] and Alexandra Figueiredo[3]

1. *Mount Mercy University, Department of Natural and Applied Sciences, Cedar Rapids, IA, USA.*
2. *University of South Florida, Department of Anthropology, Tampa, Florida, USA.*
3. *Instituto Politécnico de Tomar, Centro de Pré-História, Tomar, Portugal.*

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 Alvaiázere) 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 δ13C and δ18O from bone apatite were obtained to quantify the intake of marine versus terrestrial protein, C4 versus C3 plants, animal milk consumption, and water source diversity. The results of this study point to diets based primarily on C3 plants and terrestrial animals for the sampled individuals. However, some variation in protein type and intake, and plant and water consumption are noted, suggesting some amount of dietary heterogeneity. The results of this study are compared with recently obtained stable isotope data from other regions of Portugal to assess interregional dietary trends. Directions for future research are discussed.

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

J. Watson[1], R.A. Bentley[1], K.A. Robson Brown[1], G.M. Nowell[2], A. Pearson[3], A.W.G. Pike[4]

1. *Department of Archaeology and Anthropology, University of Bristol, Bristol, UK.*
2. *Department of Earth Sciences, Durham University, Durham, UK.*
3. *Pearson Archaeology, Cardiff, UK.*
4. *Faculty of Humanities, University of Southampton, Southampton, UK.*

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 slaving ships were intercepted 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 Greece using Stable Isotopes from Lipid Residues in Pottery

Helen Whelton[1], Mélanie Roffet-Salque[1], Kostas Kotsakis[2], Dushka Urem-Kotsou[2] and Richard P. Evershed[1]

1. *Organic Geochemistry Unit, School of Chemistry, University of Bristol, Cantock's Close, Bristol BS8 1TS, UK.*
2. *Department of Archaeology, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece.*

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 sheep, goat and pigs predominate, with kill-off patterns suggesting that herd structures maximised 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 nature and origins 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, Makriyalos, Paliambela, Ritini, Stavroupoli, Thermi, Toumba Kremastis Koliadas and Paliambela.

The lipid recovery rates were 20-30% of potsherds analysed, consistent with those previously observed for Neolithic pottery from central and south-eastern Europe. Lipid biomarkers (vicinal dihydroxy fatty acids (DHYAs) and ω-(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 triterprenoids.

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

Hsiao-chin Yang[1] and Wen-shan Chen[2]

1. *Research and Collection Division, National Museum of Prehistory, Taitung, Taiwan.*
2. *Department of Geosciences, National Taiwan University, Taipei, Taiwan.*

The lack of archaeological records from late Paleolithic to Early Neolithic age is a big riddle for archaeologists in Taiwan. The first appearance of human activity can be traced to 27,000 years ago at Pahsiandong (Pahsian sea 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 Hsiaomalongdong 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 Taipenken 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 (18,000-6,000yr 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 extant coastal plains forming. The newly formed coastal plains could provide a good inhabitant for the Neolithic migrating population.

234. MRI and NMR-MOUSE study of reindeer skin tanning processes

Lizheng Zhu[1], Andy Ilott[1], Torunn Klokkernes[2], Cindie Kehlet[3], Eleonora Delfederico[3], and Alexej Jerschow[1]

1. *Department of Chemistry, New York University, New York, NY, 10003.*
2. *Museum of Cultural History, University of Oslo, Oslo, Norway.*
3. *Department of Mathematics and Science, Pratt Institute, Brooklyn, NY 11205.*

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 shorter T2 than untreated samples, which implies that the skin becomes less mobile after salix treatment and aging. Cross-linking may dominate the tanning process. While the sample treated with cod liver oil has longer T2 than untreated sample, which indicates that reindeer skin becomes more mobile after oil tanning treatment. This information can be helpful in understanding the cultural heritage and their different tanning methods.

Remote Sensing, Geophysical Prospection and Field Archaeology

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

Andrei Asandulesei[1], Ionuț Cristi Nicu[1], Radu Balaur[1], Stefan Caliniuc[2], Vasile Cotiuga[3], Cristian-Constantin Stoleriu[4], Oana Mihaela Stoleriu[4]

1. *"Alexandru Ioan Cuza" University, Interdisciplinary Research Department-Field Science, Iasi, Romania.*
2. *"Alexandru Ioan Cuza" University, Interdisciplinary Research Platform-Arheoinvest, Iasi, Romania.*
3. *"Alexandru Ioan Cuza" University, Faculty of History, Iasi, Romania.*
4. *"Alexandru Ioan Cuza" University, Faculty of Geography and Geology, Iasi, Romania.*

The present work is part of a complex research project targeting the prehistoric settlements in eastern Romania. The primary objective of our investigation is to identify a habitation model for Cucuteni settlements present in our area of study, following the constant interaction between man and environment.
Use of aerial photography, geophysical prospection and GIS based analysis in archaeological research was shown to be, undoubtedly, one of the effective tools when it comes to dealing with such requests.
Thus, in order to identify key features describing settlements belonging to the Cucuteni culture, we employed spatial analysis tools (viewshed, density, etc.) as well as non-destructive investigation methods (cesium magnetometry, soil resistivity survey, GPR). In an initial stage, all Cucuteni settlements in the Bahluieț catchment were mapped, and several of them were later subjected to geophysical prospecting and aerial photography.
In addition, a careful analysis of the landscape of the region revealed the presence of various types of natural resources, essential for the development of agricultural communities, which undoubtedly had a major influence on settlement placement. Besides major water sources (springs) and fertile soil, salty areas present in this region may have been of paramount importance. Their source resides in ancient salt deposits formed upon withdrawal of the Sarmatian Sea and as a consequence of climate changes. We observed a very high density of prehistoric settlements around these areas, which can prove that they were used by the population.
Integration of above mentioned methods and strategies allowed us to capture the dynamics of Chalcolithic communities in the area, and to assign the most densely inhabited areas in this basin. Nevertheless, relying mainly on geophysical data, we were able to obtain valuable insight on the various types of fortifications of these settlements and their planimetry.

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

Luis Barba[1], Ivan Muñoz[2], Agustín Ortiz[1] y Jorge Blancas[1]

1. *Laboratorio de Prospección Arqueológica. Instituto de Investigaciones Antropológicas. Universidad Nacional Autónoma de México. Ciudad Universitaria. México, D.F. 04510.*
2 . *Departamento de Antropología. Universidad de Tarapacá. Arica. Norte de Chile.*

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.
Some previous archaeological excavations in the Az80 archaeological site have revealed that most of the mounds are built using alternated layers of dry vegetation and sediments. It is remarkable the conservation of the organic materials in this environment near the Atacama Desert, one of the driest of the word. All that has preserved the shape and size of the mounds and allows the use of geophysical techniques. Among them we decided to use the gradiometer Geoscan FM36 and the georadar SIR 3000 from GSSI with 400 MHz antenna.
Results of this first approach revealed that magnetic gradient maps detected the use of slightly magnetic stones in some specific places during the building of the mounds but most important, the radar reflections revealed the interior of the mound structures with previous building steps and in some cases perhaps some burials and small funerary chambers.

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

Luis Barba[1], Agustín Ortiz[1], Jorge Blancas[1] y Joaquín Arroyo[2]

1. *Laboratorio de Prospección Arqueológica. Instituto de Investigaciones Antropológicas. Universidad Nacional Autónoma de México. Ciudad Universitaria. México, D.F. 04510.*
2. *Laboratorio de Arqueozoología. Subdirección de Laboratorios y Apoyo Académico. Instituto Nacional de Antropología e Historia. Moneda # 16.Centro Histórico. México D.F. 06060.*

A great opportunity for the application of geophysical prospection techniques to a paleontological problem was presented during 2013, when the inhabitants of Santa Ana Tlacotenco, Milpa Alta, D.F. found molars 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 geophysical techniques detected clear anomalies in the same place and at the same depth all of 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 buried. 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)

F. D'Andria[1], S. Bracci[2], P. Caggia[3], E. Cantisani[2], T. Ismaelli[3], C. Riminesi[2], B. Sacchi[2], G. Scardozzi[3], S. Vettori[2]

1. *Department of Cultural Heritage/University of Salento, Lecce, Italy. Director of the Italian Archaeological Mission in Hierapolis of Phrygia.*
2. *Institute for the Conservation and Valorization of Cultural Heritage/CNR, Sesto Fiorentino (FI), Italy.*
3. *Institute for Archaeological and Monumental Heritage/CNR, Lecce, Italy.*

The ancient Phrygian city of Hierapolis in the Denizli district in Turkey, today named Pamukkale ("Cotton Castle"

in Turkish), is one of the UNESCO World Heritage sites, and it is located in the east of the Büyük Menderes Graben. The thermal springs and snow-white travertine formed by the great precipitation of CaCO3, have contributed to make Pamukkale a famous tourist location. The Hierapolis town is cut longitudinally by several parallel fractures of the Pamukkale fault (Altunel and Hancock, 1996, D'Andria and Silvestrelli, 2000). Directly located on one of these faults is the Plutonium, the sanctuary of the Gods of Underworld, Hades and Kore, with the theater above a grotto (Theatron), discovered during the 2012 excavation campaign of the Italian Archaeological Mission (D'Andria, 2013). The impact of the tourist flow and the action of natural agents are the unavoidable sources of deterioration of Plutonium's unearthed marble ruins.

From 1994 some studies have been performed to analyse the water and gases dissolved therein of the Pamukkale thermal springs. According to these previous studies a monitoring network in the Plutonium was installed in August 2013. The network consists of several sensors allowing to the measure of environment parameters (T and RH%), both in external and in confined environment, and gases (CO2, CO, O2, H2S). The positions of these sensors have been chosen according to the results of preliminary measurements made by means of portable instrumentations (IR-thermography, thermometers, hygrometers, and CO2 and CO loggers). These preliminary measurements have shown a high peak of CO2 content with a day/night variation, and a constant temperature of the thermal water (about 35°C) and of the air temperature in confined environment (35°C too).

These extreme environmental conditions are a challenge for the conservation of the marble stone materials constituting the famous Apollo Temple, the Plutonium and the others buildings unearthed in Hierapolis. An exhaustive diagnostic campaign has been conducted by non-invasive instrumentation (colorimeter, sponge test), and by laboratory analyses (XRD, FT-IR, OM, SEM-EDS) on samples properly collected in order to characterize the mainly decay processes observed (granular disintegration, biological patina, encrustations) and to suggest the suitable strategies of intervention. The preliminary results of the aforementioned analyses and their correlation with the registered environmental parameters will be presented.

The research activity presented in this paper is co-founded by the Ministry of Education, Universities and Research in the framework of the FIRB project "Marmora Phrygiae".

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239. Wireless Environmental Monitoring Devices for Historical Collections and Cultural Heritage Sites

JEBERIEN, Alexandra[1], LITTY, Susanne[2]

1. *HTW/University of Applied Sciences/Berlin, Germany / Alexandra.Jeberien@htw-berlin.de*
2. *HTW/University of Applied Sciences/Berlin, Germany.*

The dependencies between temperature and relative humidity changes and their influence on the degradation of archaeological collections is a substantial and highly discussed topic in conservation sciences. To record and observe even minimal alterations of the environmental parameters within a collection's context as well as on archaeological sites, highly sensitive measuring instruments are required. Data loggers, which are at present available to record environmental parameters, derive almost without any exception from industrial purposes and therefore lack conservation based needs in terms of precision, frequency pulsing and practicality.

The interdisciplinary research project Wireless Environmental Monitoring Devices for Historical Collections and Cultural Heritage Sites investigates and evaluates the potential of radiotelemetric measurement devices by the supplier Virtenio GmbH in terms of their applicability for collection's or site monitoring and material research requirements. A fundamental characteristic of the devices is a higher frequency pulse which contributes to a better precision of the transmitted data. A further novelty is displayed by the live data transmission technique in combination with an automatic analysis function. This function facilitates an early detection of object damaging conditions - even from within great distances, like archaeological site monitoring. Not only the small size of the devices, also their flexibility in terms of sensor positioning and extensibility of measurement variables in combination with a self-sustaining, low-energy operation modus top off the application of these devices in various cultural heritage environments.

Due to Virtenio instruments likewise industrial background the modifications and adaptions, 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 Virtenio 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

Miomir Korać[1], Snežana Golubović[2], Željko Jovanović[3]

1. *Archaeological Institute, Project Viminacium, Belgrade, Serbia.*
2. *Archaeological Institute, Project Viminacium, Belgrade, Serbia.*
3. *Center for New Technologies - Viminacium, Belgrade, Serbia.*

Viminacium, capital city of 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 rebuild in several phases total visual documenting was crucial for the reconstruction. Villa along the limes road to Lederata 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.

241. Roman Legionary fort Viminacium – Multidisciplinary Research

Miomir Korać[1], Nemanja Mrđić[2]

1. *Archaeological Institute, Project Viminacium, Belgrade, Serbia.*
2. *Archaeological Institute, Project Viminacium, Belgrade, Serbia.*

Legionary fort Viminacium was located at the mouth of rivers Mlava and Danube on the frontier of the Roman Empire. It was one of two legionary forts protecting hinterland of the province Moesia Superior.

Legio VII Claudia pia fidelis was the unit whose permanent

garrison was located here throughout Roman age. Next to the fort a new city emerged that will become capital of the province – municipium Aelium Viminacium from the reign of Hadrian and later colonia Viminacium from 239 AD.
Although it was never lost or forgotten today nothing remains on the surface. Systematic exploitation of building material for nearby mediaeval fort and surrounding villages left no visible architecture. Parts of the suburban zones were endangered by thermoelectric power plant "Kostolac B" and open pit coal mine "Drmno". Because of this situation salvage excavations are concentrated on city suburban zone and surrounding cemeteries that are being destroyed while very few excavations were done within walls of the city and legionary fort. Results of the project provided enough evidence to protect primary site and save it from destruction.
Fort and Roman city lay in fertile fields of valley Stig with no modern settlement over the ancient remains. This enabled us to use all available methods in research. Primary a series of aerial photographs ranging from 1967 to 2007 were analyzed and overlaid with plans of the once visible roman ruins from 16th, 19th century and 1902. Entire fort was surveyed using geophysical methods - Proton Magnetometer and Ground Penetrating Radar. Digital Terrain Model was also created and incorporated in the GIS Data Base that merged all the imagery and spatial data needed for comprehensive interpretation.
Finally we have insight in floor plan of the Legionary fort, as well as its vicinity - canabae legionis, capital city, amphitheater, surrounding cemeteries, water supply and road network. Complete defensive concept of Viminacium now is defined and can be implemented into the global strategy of the Moesian frontier.

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

Křivánek Roman

Institute of Archaeology of the Academy of Sciences of the Czech Republic, Prague, v.v.i., Dept. of Landscape archaeology and archaeobiology, Letenská 4, 118 01 Prague 1, Czech Republic

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 Soudský 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 of archaeological 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 (Faltysová-Marek). Newly identified one double circular ditch enclosure was subsequently verified by archaeological trench (Zápotocká) with dating of roundel to 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 roundels 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.

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

Kulbhushan Mishra[1] and Sudesh Nangia[2]

1. *Research Associate, Indian Archaeological Society, New Delhi-110016, India.*
2. *Former Professor, Jawaharlal Nehru University, New Delhi-110067, India.*

The Indus-Saraswati civilization deemed to have existed during 3rd to 2nd millennium BCE and extended to more than one million sq. km. It covers a large area of North-West India and Pakistan. In India, the regions covered under this civilization form parts of the States of Gujarat, Haryana, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh and Uttaranchal.
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 2007-2013. 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, mature 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 by using ArcGIS 9.2 software. The maps have been prepared at district level which reflect geo-spatial pattern of the spread of Indus-Saraswati civilization. The visual patterns from the maps reveal that the civilization moved from north-west to south, southeast with time. The regions in close proximity of river Saraswati showed a higher concentration of sites than the ones away from it. During the late period, sites appeared along the tributary of Saraswati, river Yamuna, now flowing as an independent stream.
Through the innovative techniques of GIS for archaeological mapping, the spatial and temporal trends in the spread of Indus-Saraswati civilization have been identified. This technique has also helped in exact location of sites on the maps drawn. The study reflects upon the regions' rich cultural heritage that needs to be conserved, preserved and protected.

244. Elucidation of the degradation mechanisms in archaeological birch bark

Sibilla Orsini[1], Erika Ribechini[1], Francesca Modugno[1], Johanna Klügh[2], Maria Perla Colombini[3]

1. *Department of Chemistry and Industrial Chemistry, University of Pisa, Pisa, Italy*
2. *Erziehungsdirektion des Kantons Bern Amt für Kultur Ressort Archäologische Konservierung, Bern, Switzerland*
3. *ICVBC-CNR and Department of Chemistry and Industrial Chemistry, University of Pisa, Pisa, Italy.*

The availability and unique physical properties of wood and barks 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 bow 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 birch bark 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 birch bark revealed that the hydrolysis in a water bath is better than in a microwave oven: water bath allows us to preserve the

labile components of the suberin, such as those contain an epoxy groups. Samples collected from the archaeological objects show chromatographic profiles different from that obtained for the reference material: the chemical variations can be related to the aging processes taken place in the environmental conservation conditions. In particular, the amount of free acids increases in suberin, while the epoxy compounds decrease. In addition, an increasing of oxidation degree can be observed only in the archaeological samples conserved in waterlogged sites.

245. Application of REMPI Laser Mass Spectrometry to Cultural Heritage

Shawn Owens[1], Jacob Berenbeim[1], Mattanjah S de Vries[1], Stuart Tyson-Smith[2] and Anabel Ford[3]

1. *University of California Santa Barbara, Department of Biochemistry and Chemistry, Santa Barbara, CA USA.*
2. *University of California Santa Barbara, Department of Anthropology, Santa Barbara, CA USA.*
3. *University of California Santa Barbara, MesoAmerican Research Center, Santa Barbara, CA USA.*

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, a bean 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 with traditional methods.
A system combining laser desorption, jet-cooling, REMPI spectroscopy, and time-of-flight mass spectrometry (TOF-MS) generates exceptionally well resolved vibronic spectroscopy and fragment free mass spectrometry for molecules within a complex matrix. Following laser desorption directly from the sherd surface, gas-phase molecules are entrained in a supersonic molecular beam of argon. This causes extremely efficient jet-cooling of the internal degrees of freedom within the molecules, and makes it possible to perform high resolution spectroscopy while at the same time stabilizing the molecule, permitting its eventual detection at the parent molecular mass. REMPI couples optical spectroscopy with mass spectrometry, enhancing the specificity for selected compounds and allowing for distinction between isomers. The cold molecule is resonantly excited to the first electronic excited state by a tunable dye laser, and subsequently ionized by another photon before being detected in the TOF-MS. The result is the ability to selectively ionize a single target compound within an extremely complex matrix.
The analysis of ceremonial Maya vessels confirms the presence of cacao beverages, based on ratios of the 'molecular markers'. Surprisingly, the investigation of the common Maya pottery reveals a much larger abundance of the minor component theophylline than of the normally dominant theobromine. This result suggests that the pottery was used, at least in part, for beverages made from sources outside of the cacao plant.

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

Jeannette Jacqueline Lucejko[1], Magdalena Zborowska[2], Diego Tamburini[3], Leszek Babiński[4], Bogusława Waliszewska[2], Francesca Modugno[3], Maria Perla Colombini[1,3]

1. *Institute for the Conservation and Valorization of Cultural Heritage, CNR, Sesto Fiorentino (Florence), Italy.*
2. *Poznan University of Life Science, Faculty of Wood Technology, Institute of Chemical Wood Technology, Poznań, Poland.*
3. *Department of Chemistry and Industrial Chemistry, University of Pisa, Pisa, Italy.*
4. *Archaeological Museum in Biskupin, Conservation Department, Biskupin, Poland.*

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 gas chromatography and mass spectrometry (Py-GC/MS) with in situ silylation, which has the main advantage to provide information at a molecular level.
The results highlighted that the external parts of archaeological wood had undergone loss of the polysaccharide 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 analysis 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.

Other

247. The Red and The Gray: Ochre Pigments and Iron Ores from Twin Rivers Kopje, Zambia

Andrew M. Zipkin1,2, Alison S. Brooks2,3, John M. Hanchar4, Kathy Shick5,6, Nicholas P. Toth5,6

1. *Hominid Paleobiology Doctoral Program, Department of Anthropology, The George Washington University, Washington D.C., U.S.A.*
2. *Center for the Advanced Study of Hominid Paleobiology, Department of Anthropology, The George Washington University, Washington D.C., U.S.A.*
3. *Human Origins Program, National Museum of Natural History, Smithsonian Institution, Washington D.C., U.S.A.*
4. *Department of Earth Sciences, Memorial University of Newfoundland, St. John's, Canada.*
5. *Department of Anthropology and Cognitive Science Program, Indiana University, Bloomington, U.S.A.*
6. *Stone Age Institute, Bloomington, U.S.A.*

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 300 – 140 ka 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 present 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

Dr S. Mohammad Amin Emami[1], Parvin Soleimani[2]

1. *Assis. Prof. Dr. rer.¬ nat. Mineralogist & Crystallography¬. Universität Siegen, Faculty of Conservation, Art University of Isfahan, Iran.*
2. *M.A Conservation of Historic Properties, Faculty of Conservation and Art University of Esfahan, Iran.*

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 unearthed from 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 internal structures and to compare them in terms of origin. The present study aims to identify the structures of marble works discovered in Kenar sandal, Jiroft. In addition to petrography studies, XRD and XRF instruments were used to analyze the crystalline structures of the discovered marble works. The obtained results revealed that the major constituents of the discovered marble works in Jiroft were Ca and CaO. Also, the structure of marble stones discovered had orderly compact patterns resulted mainly from metamorphism conditions.

Keywords: jiroft, Kenar-Sandal, Marble Stone, Structure.

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249. Study on the Smelting and Casting Technology of Copper and Copper Alloy Wares from Central Plains in the Early Bronze Age of China

Yu Liu[1] Jianli Chen[2] Hong Xu[1] Nu He[1] Chunqing Zhao[1]

1. *Institute of Archaeology, Chinese Academy of Social Sciences, Beijing, China.*
2. *School of Archaeology and Museology, Peking University, Beijing, China.*

Casting technology played a more significant role in the formation of Chinese ancient civilization than any other early civilizations. However, so little is known about the beginning and early period of piece-mould casting technology in early bronze age of China. So far fewer copper objects, smelting and casting remains were found in the central plains than in the surrounding area during the late phase of Longshan Culture (2600B.C.-2000B.C.), the metallic technology and production in the area are of great interest yet not fully explored in academic. Through analyze some metallic, slag, clay-mould and crucible samples newly unearthed from different sites in this area, the early use of copper and its alloy, and the beginning of the piece-mold casting technique were discussed.

All the metallic samples are mainly from the 3 sites, including Taosi site (2300B.C.-1900B.C.), Xiangfen County, Shanxi province; Xinzhai site (1850B.C.-1700B.C.), Xinmi County, Henan province; and Erlitou site (1800B.C.-1500B.C.), Yanshi City, Henan province. Those slag, mould and crucible samples are from Erlitou site. Through SEM-EDS, EPMA, XRD, ICP analysis and microscopic examinations, the composition and microstructure of samples were analyzed. The technical investigation was also done through observation and X-ray photos.

The smelting and casting techniques of metallic wares in central plains during 2300BC-1500BC are discussed based on the experimental data. During this period, the usage of copper alloy seems gradually increased, while the usage of pure copper reduced. In the Erlitou period, the 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 technique to make artefacts can be traced to Taosi 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 Yinxu and Xinzheng. 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, Glazes, Glass and Vitreous Materials

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

Rita Giannini[1], Andrew Shortland[2]

1. *Cranfield University, Cranfield Forensic Institute, Shrivenham, UK.*
2. *Cranfield University, Cranfield Forensic Institute, Shrivenham, UK.*

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 ceramic sherds of ambiguous 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 REE 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.

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251. Clays, Kilns and Ceramic Productions in Northern Apulia

Gliozzo, E.[1], Turchiano, M.[2] and Memmi, I.[1]

1. *Department of Physics, Earth and Environmental Sciences, University of Siena, Italy.*
2. *Department of Human Sciences, University of Foggia, Italy.*

Facts and figures

Seven contexts in six archaeological sites with an area of 80 Km. From north to south: 1) the pottery kiln at San Giusto; 2) the villa of Posta Crusta; 3) the infill of the cistern of domus B, on the hill overlooking the Forum of Herdonia; 4) a 'waste tip', close to the San Pietro Episcopal complex at Canusium; 5) the ceramic kilns connected to the San Pietro Episcopal complex at Canusium; 6-7) the ceramic kilns of Faragola and the decantation basins for clays preparation. A wide chronological frame. From the 4th century AD to the 7th century AD.

A large sampleset (584 samples) including 136 samples of cooking wares, 81 samples among table wares and storage vessels, 43 samples of building materials, 11 samples of by-fired clays from the kilns structures, and 21 samples of clays outcropping in the territory under examination.

A large number of chemical, mineralogical and petrographical data obtained by inductively coupled plasma optical emission spectrometry, inductively coupled plasma mass spectrometry, instrumental neutron activation, X-ray fluorescence, optical microscopy, scanning electron microscopy and electron microprobe.

Results and future aims

In 2004, the major aim of the research was to characterise the ceramic production of the San Giusto kiln. In 2008, the completion of numerous typological studies and the increase of archaeological discoveries in the territory under examination, suggested to broaden the starting objectives and to set a long-term research on the ceramics productions of northern Apulia.

In 2013, a major step forward has been made in terms of historical and archaeological reconstruction of both the local ceramic productions and their exchange. Short- to large-range trades were reconstructed for some of the examined sites, while others were apparently self-sufficient, at least for some ceramic forms. Moreover, it was possible to link geosources and ceramics, through the analysis of raw materials outcropping in the vicinity of the archaeological sites. The future research will develop this latter aspect, in order to reconstruct the mode of exploitation of the area and assess how the presence of a particular clay source may have influenced the production of specific ceramic types.

252. Digital Radiography of Macro-Scale Variation in Archaeological Ceramics: The Assemblage-Based Analysis of Ancient Eurasian Potting Techniques

Alan F. Greene[1], Charles W. Hartley[2], Paula N. Doumani[3], and Michael R. Chinander[2]

1. *Stanford University, Department of Anthropology, Palo Alto, USA.*
2. *University of Chicago, Department of Anthropology, Chicago, USA.*
3. *Washington University in St. Louis, Department of Anthropology, St. Louis, USA.*

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 marshaled 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 potsherd datasets (n > 500), the basic fragmentary data of traditional archaeology. Eight years of research and experimentation with the digital radiographic analysis of archaeological potsherd 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 potsherd 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.

253. Waste Not, Want Not: A Technical Approach to Identifying Grog in the Pre-Columbian Caribbean

Amanda J. Guzman[1], Corinne L. Hofman[2] and Dennis Braekmans[3]

1. *Department of Anthropology, University of California, Berkeley, USA.*
2. *Faculty of Archaeology, Leiden University, Leiden, the Netherlands.*
3. *Faculty of Archaeology and Material Culture Studies, Leiden University, Leiden, the Netherlands; Centre for Archaeological Sciences, Department of Earth and Environmental Sciences, K.U. Leuven, Leuven, Belgium.*

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 criteria of shape – angular as opposed to rounded (Petersen and Watters 1991). Furthermore, a distinct ring, indicating a pre-fired condition, is present around grog particles in petrography (Braekmans 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 Millspaugh 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, microprobe study (EMPA) and experimental reconstruction, 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 2008; 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

Anno Hein[1], Noémi S. Müller[2] and Vassilis Kilikoglou[1]

1. *Institute of Materials Science, N.C.S.R. "Demokritos", Athens, Greece.*
2. *Fitch Laboratory, British School at Athens, Athens, Greece.*

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.

Earlier studies have examined heat transfer in cooking pots by assessing 'heating effectiveness', 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

Ellen Hsieh[1] and Christian Fischer[1]

1. Cotsen Institute of Archaeology, UCLA, Los Angeles, USA.

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 diplomacy purposes. During the 16th-17th century, Jingdezhen and Zhangzhou 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 Miao, 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; Ma, et al., 2012) providing solid support for provenance studies (Dias, et al., 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, glaze 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 Zhangzhou 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.

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256. Glass beads from the Middle Danube basin: chemical composition and production

Rezida Khramchenkova[1], Olga Roumiantseva[2]

1. *Institute of History of Tatarstan Academy of Science, Kazan, Russia.*
2. *Institute of Archaeology of Russia Academy of Science, Moscow, Russia.*

Investigation of a chemical composition of 127 beads from late antique necropoleis of the Middle Danube basin (actually the North Serbia, Vojvodina region) is carried out. Analogies to all of them are found in a workshop of the Roman time that produced glass jewelry. The workshop was excavated on the territory of the Roman castrum Tibiskum (the Province of Dacia, modern Romania). The studied group included beads with various morphology and manufacturing techniques.
All beads belongs to the Na-Ca-Si type of chemical composition . The correlation between chemical composition of glass and its color was established. Glass of colorless and dark blue translucent, blue semi translucent and white opaque beads is made using natron. Opaque glass of orange, red and green color is made using ashes of saline plants. The part of the samples has high content of calcium – 12-15%.
One of the most interesting samples was the three-layer bead of a polyhedral form. Its external layer is made from violet glass, average – from red glass, and internal – of yellow opaque glass. Beads of this type remind similar in form jewelry made of cornelian and probably imitate them. It seems that by imposing of layers of different color of glass craftsmen tried to achieve the similarity to stone jewelry.
The analysis showed that the bead is made of glass layers with a different chemical composition. In more detail the bead was studied by electronic microscopy. They were studied by emission spectroscopy and for more detail by electronic-microscopy with the laser analyzer. In violet glass manganese was used for coloring. In red and yellow glass, copper and lead were used correspondingly. That is typical for glass of these colors.
The studied glass of beards from the Middle 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

Francesca Licenziati[1], Thomas Calligaro[2]

1. *Université Paris Ouest Nanterre La Défense, UMR 7041 - ArScAn - Archéologies et Sciences de Antiquité, F-92023, Nanterre Cedex, France.*
2. *Centre de Recherche et de Restauration des Musées de France (C2RMF), Palais du Louvre, 14 Quai François Mitterrand, 75001 Paris, France.*

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 various 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 faience, which is remarkable for that period.
The aim of the present work is to understand the glassmaking technology and the raw materials employed by measuring the glass tesserae composition, colour and surface microfeatures. About three hundred glass tesserae from twenty mosaics and few isolated fragments were analysed in situ using a set of complementary non-destructive techniques: digital microscopy (DM), fiber optic reflectance spectroscopy (FORS) and portable X-ray Fluorescence (pXRF). The colour of the investigated glass tesserae are yellow, red, turquoise and different shades of blue and green.
Examination with DM highlighted a peculiar fibrous glass microstructure probably related to the fact that the tesserae were cut from canes. The absorbance spectra recorded by FORS allowed to rapidly distinguish among the blue glass tesserae those coloured only by copper from those in which cobalt is the main chromophore.
The chemical composition of glass measured by pXRF showed that the matrix is generally a natron-based glass bearing a variable level of lead (~0.1 wt% to ~40 wt%).
The red tesserae appeared to contain high levels of lead and copper indicating the use of the well known “sealing wax red glass”. Cobalt was found to be the main chromophore for the blue tesserae, while copper is responsible for the colour of the turquoise ones. Green tesserae owe their colour to copper, iron and probably a yellow lead-based opacifier. The coloration and opacification of yellow tesserae is probably linked to the lead antimonate crystals. As for the opacifiers, calcium antimonate was probably used for blue and turquoise tesserae, whereas a lead-based opacifier was employed for the yellow (lead antimonate) and green tesserae (lead antimonate and/or lead stannate). Cuprite crystals might be responsible for the opacification of the red tesserae. These hypothesis need to be confirmed by additional techniques, such as Raman µ-spectroscopy.
A striking feature of blue and turquoise tesserae that call for further investigations is the presence of a variable content of lead which was probably unintentionally added with others ingredients (chromophores and/or opacifiers).
Overall the glassmaking techniques of the studied tesserae, i.e. glass type, colouring and opacifiers, bear certain similarities with the ones used in glass tesserae of the Roman period.

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

Kuei-chen Lin[1] and Christian Fischer[1]

1. *Cotsen Institute of Archaeology, UCLA, Los Angeles, USA.*

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’erqiao (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 oxidization/reduction degrees of the ceramic body. Our results suggest that these three nearby sites produced similar types of vessels using different technologies while also 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 seemingly close or feature only 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

Pedro A. López-García[1], Noemí Román-Carrera[2], Manuel Ornelas-Rodríguez[2], R. Santiago-Montero[2], J.H. Puga-Soberanes[2], J.M. Carpio-Valadez[2], Denisse Argote-Espino[3]

1. *Posgrado de Arqueologia, Escuela Nacional de Antropologia e Historia, Mexico City, Mexico.*
2. *Instituto Tecnologico de Leon, Leon, Guanajuato, Mexico.*
3. *Subdireccion de Laboratorios y Apoyo Academico, Instituto Nacional de Antropologia e Historia, Mexico City, Mexico.*

In this work we implement a computational model for the extraction of characteristic vectors in digital images of ceramic pastes through the application of Gabor Filters Banks. These vectors allow the recognition of textures with a wide tolerance in colour and illumination changes in the images. The model demonstrates that the characteristic vectors are unique for each image. Those images with similar characteristic vectors belong to the same texture type.
On the other hand, we propose a filter parameter calibration through the use of a Particle Swarm Optimization (PSO) algorithm. Once the characteristic vectors are obtained by means of the Gabor Filter Bank and the PSO, these are employed as input patterns of a KNN (K-nearest neighbors) classifier. KNN is a supervised classification method that estimates the probability density function in which element belongs to class from the information given by the prototype set, evaluating the hit rate and the confusion matrix to determinate the variability of the supervised method.
The proposed methodology was applied for the characterization and classification of ceramic samples proceeding from the archaeological site of Los Teteles de Ocotitla, Tlaxcala, Central Mexico, obtaining good results in the discrimination of ceramic types and avoiding subjective classification methodologies.

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

Fatma S. Madkour

Conservation Department, Faculty of Fine Arts, Minia University, Minia, Egypt, fatma_madkour@yahoo.com

Commercial amphoras are large ceramic vessels which were used, in the Greaco-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 crystallization of salts. Furthermore, many shards are broken from the body and some are missing. The aim of the present paper is to the study the chemical and the mineralogical composition of the clay body, the soil residues and the crystallized 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 5% Paraloid- B72 dissolved in acetone, and fixing broken parts 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 safety 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

Fatma S. Madkour[1], Rezida Khramchenkova[2]

1. *Conservation Dept. Faculty of Fine Arts, Minia University. Egypt.*
2. *Institute of History of Tatarstan Academy of Sciense, Kazan, Russia.*

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.

262. A mosaic of colours. Comparing production technologies of Roman and Late-Roman glass tesserae from various sites of Northern-Eastern Italy

S. Maltoni[1*], A. Silvestri[2**], G. Molin[1], M.T. Guaitoli[3], A.N. Rigoni[4], M. Salvadori[1]

1. *Dipartimento di Beni Culturali, Università degli Studi di Padova, Padova-Italy *sarah.maltoni@studenti.unipd.it*
2. *Dipartimento di Geoscienze Università degli Studi di Padova, Padova-Italy.*
   ***alberta.silvestri@unipd.it*
3. *Dipartimento di Storia Culture Civiltà, Alma Mater Studiorum Università degli Studi di Bologna, Bologna-Italy.*
4. *Museo Archeologico del Friuli Occidentale, Pordenone-Italy.*

Due to the extraordinary range of colours, the use of opacifying agents, the complex firing regimes utilized and the high degree of technological skill required for their manufacture, glass mosaic tesserae represent a challenging and complex field of research in archaeometry, as the complex pyrotechnologies used as well as their technological evolution from the Roman to the Late Roman period are still not completely clear.
It is well known that the production and trade of glass was highly influenced by the great political changes which occurred after the fall of the western Roman Empire: from the 4th century onward new glass compositions were produced and traded in the eastern Mediterranean and, in parallel, tin-based compounds start to replace the antimony-based opacifiers in mosaics and enameling. The existence of trade routes between the Middle-East and the north-Adriatic opens the way to questions about the adoption and diffusion of both the new compositions and the new technologies in the West.
In order to investigate and compare different production technologies employed in the manufacture of mosaic tesserae in Roman and late Roman North Eastern Italy, three assemblages, and a total of 99 glass tesserae were studied. Samples come from the in situ-mosaic of the Domus delle Bestie Ferite (Aquileia, dated to the mid-4th century), the disrupted mosaic decorations of the Domus of Torre di Pordenone (Pordenone, probably dated between the 1st and 5th centuries) and Santa Maria Maggiore cathedral (Trento, probably dated between the 2nd and 4th centuries).
The same multi-methodological approach, previously applied to the Palaeo-Christian glass mosaic tesserae from Padova and Vicenza (NE Italy), was carried out

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 glassy 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)

S. Maltoni[1*], A. Marcante[1], A. Silvestri[2**], G. Molin[1], F. Gallo[1], M. Ganio[3], P. Degryse[3]

1. *Dipartimento di Beni Culturali Università degli Studi di Padova, Padova-Italy; *sarah.maltoni@studenti.unipd.it*
2. *Dipartimento di Geoscienze Università degli Studi di Padova, Padova-Italy; **alberta.silvestri@unipd.it*
3. *Department of Earth and Environmental Sciences-Division of Geology, Katholieke Universitaet Leuven, Leuven- Belgium.*

The archaeometric 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. The assemblage from the Domus “Fondi ex Cossar” includes mainly tablewares dated to the 3rd-7th centuries and some glass working evidence, including raw glass chunks. From a total of 724 samples, 78 samples, including the most frequent vessel types and all the working debris and chunks, were selected for archaeometric analysis. Chemical data were collected by X-ray-Fluorescence (XRF) for major and minor elements and Electron Micro Probe Analysis (EMPA) for trace elements. Multivariate 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 of ‘Roman’ composition were also identified.
The relationships between the chemical compositions, archaeological types 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)

Verònica Martínez-Ferreras[1], Anno Hein[2], Josep M.Gurt-Esparraguera[1], Edvard V. Rtveladze[3], Shakir Pidaev[3], Vassilis Kilikoglou[2]

1. *ERAAUB, Department of Prehistory, Ancient History and Archaeology, Universitat de Barcelona, Barcelona, Spain.*
2. *Institute of Materials Science, N.C.S.R. ‘Demokritos’, Athens, Greece.*
3. *Institute of Fine Arts, Academy of Sciences of Uzbekistan, Tashkent, Uzbekistan.*

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-Seleucid 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 (thin section) analysis was undertaken on 50 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-fine petrographic fabric. Secondary calcium carbonates, calcium sulphates and sodium chlorides were identified in most of them by OM, SEM-EDS and XRD, as a result of weathering processes occurring during their deposition in a semiarid 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

Doris Möncke[1], Ferdinand Drünert[1], Eleni Palamara[2], Maria Kaparou[2], Nikos Zacharias[2] Dimitri Palles[3] and Efstratios I. Kamitsos[3]

1. *Otto-Schott-Institute, Friedrich-Schiller Univerisity, Jena, Germany.*
2. *Department of History, Archaeology and Cultural Resources Management, Laboratory of Archaeometry, University of Peloponnese, Kalamata, Greece.*
3. *Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, Athens, Greece.*

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 absorbance of Co2+ ions which are dissolved in glass of typical soda-lime-silica composition.
Of special interest are original 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

Q3 groups (silicate tetrahedra with 3 bridging and 1 non-bridging oxygen atoms). In case (i) corroded surface areas show silicate tetrahedra with 2 or even 3 non-bridging oxygen atoms, while the vibrational spectra in case (ii) may be very similar to those of the borosilicate layers discussed above. Therefore, different weathering mechanisms were studied as well on model glasses and on non-gilded blue Classical Hellenic glass vessel fragments.
The presence of the newly generated borosilicate layers on the model glasses is also studied by LA-ICP-MS, XPS and XRF. A non- or micro-destructive method for the analysis of boron in thin layers on archaeological artefacts is to be developed.

266. Prehistoric Pottery from SE Albania: A Compositional and Mineralogical Study

A. Oikonomou[1], C. Papachristodoulou[2], K. Stamoulis[3], P. Lera[4], S. Oikonomidis[5], A. Papayiannis[6], A. Tsonos[7] and K. Ioannides[2,3]

1. *Dept. of Environmental Technologists, Specialization in Conservation of Cultural Heritage, TEI of Ionian Islands, Zante, Greece.*
2. *Dept. of Physics, The University of Ioannina, Ioannina, Greece.*
3. *Archaeometry Center, The University of Ioannina, Ioannina, Greece.*
4. *Institute of Archaeology, Center of Albanological Studies, Tirana, Albania.*
5. *University College for Global Studies Abroad, Philadelphia, U.S.A. Arcadia.*
6. *Fifth Ephorate of Prehistoric and Classical Antiquities, Sparta, Greece.*
7. *Dept. of History-Archaeology, University of Ioannina, Greece.*

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 and long 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 Transbalkanic 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 radioisotope-induced, Energy-Dispersive X-Ray Fluorescence (EDXRF) spectroscopy 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 pottery 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 Diffractometry (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 analysis, 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 illite mineral phases, respectively.

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

C. Pacheco[1,2], Q. Lemasson[1,2], B. Moignard[1,2], L. Pichon[1,2], Ph. Walter[2,3]

1. *C2RMF, Palais du Louvre, 75001 Paris, France.*
2. *New AGLAE FR 3506 - CNRS/Ministère de la Culture et de la Communication.*
3. *LAMS - UMR 8220 CNRS UPMC Paris VI, 75005 Paris, France.*

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, involving less irradiation during the analysis, it can also provide large and/or fast maps. A Digital X-ray 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.

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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

E. Palamara[1], N. Zacharias[1], L. Papakosta[2], D. Palles[3] and E.I. Kamitsos[3]

1. *Laboratory of Archaeometry, Department of History, Archaeology and Cultural Resources Management, University of Peloponnese, 24100 Kalamata, Greece.*
2. *6th Ephorate of Prehistoric and Classical Antiquity, Ministry of Culture, 26110 Patras, Greece.*
3. *Theoretical and Physical Chemistry Institute, National Hellenic Research Foundation, 11635 Athens, Greece.*

Introduction: During a systematic excavation of a Roman funerary complex at the city of Patras, Achaia, 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 rich in sulfur and potassium that points to an aluminosilicate substance of the alum-type mineral group, known in antiquity for its astringency and styptic/haeomostatic 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 luxurious 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. Posadas[1]

1. *University College London, Institute of Archaeology, London, United Kingdom.*

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 Empire of Mali (AD 1210 –1500) (MacDonald et al. 2011). EPMA-WDS and SEM-EDS were used to investigate the potential origins and production technologies by analyzing the general glass matrix, as well as colorants and opacfiers present as inclusions. Three compositionally distinct groups can be distinguished from the analysis.
Group A consists of copper-blue beads that may have been recycled from Islamic plant ash glass and a lead-rich mineral-soda glass containing alumina, titania, and iron oxide as impurities (Freestone 2006; Henderson 2002). These beads were likely imported from the Islamic world and recycled along the route to Sorotomo.
Group B contains chemical similarities to comparative samples of 15th century Venetian glass. They are plant ash soda-lime-silica glass, most likely made with halophytic plant ash from the Near East and crushed quartz pebbles (Freestone 1991; Tite et al. 2006). These beads are likely to have arrived from Western Europe.
Group C beads contain high alumina levels (Al_2O_3: 8.16 – 13.45 wt%) and lower magnesia to potash ratios than the other samples. Each of the Group C glass objects is distinct, with some objects containing high Fe_2O_3 and TiO_2 levels. One blue bead in this group was colored by 0.02 wt% cobalt oxide, and is made from a very unusual high-lime and high-alumina glass. It contains very little soda at 1.50 wt%, and high potash at 8.68 wt%, which would normally indicate the use of a plant ash, however the magnesia content is unexpectedly low at 0.02 wt%, and does not correspond with wood or plant ash compositions (Jackson et al. 2005; Brill 1999, II, XXIV C; Wedepohl and Simon 2010). It has low Fe_2O_3: 0.38 wt% and low TiO_2: 0.04 wt%, which sets it apart from the high-iron and high-titania glass samples. These beads may represent links to a local West African primary glass production industry (Lankton et al. 2006).

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

M. I. Prudêncio[1], M. I. Dias[1], Zsolt Kasztovszky[2], Imre Kovács[3] and Zoltán Szőkefalvi-Na[3]

1. *Centro de Ciências e Tecnologias Nucleares - C2TN. Campus Tecnológico e Nuclear. Instituto Superior Técnico, Polo de Loures. Estrada Nacional 10 (km 139.7). 2695-066 Bobadela, Loures, Portugal.*
2. *Centre for Energy Research, Hungarian Academy of Sciences, Budapest, Hungary.*
3. *Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, Budapest, Hungary.*

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 the framework of an FCT funded project (PTDC/HIS/HEC/101756/2008) and a CHARISMA project at BNC (BRR-345). They comprise tiles from the Department of Cultural Heritage tile collection, Lisbon City Hall, as well as, from the National Tile Museum. Among these, the panel "The Great View of Lisbon" will be studied to identify degradation pathologies. The ceramic tile panel "The Great View of Lisbon", in exhibition at the National Tile Museum (MNA), is a unique masterpiece of Portuguese tiles which depicts the city before the tragic earthquake of 1755. Compositional characterization of ceramic body and production technologies, namely firing temperatures, of glazed tiles of various epochs, places and contexts were studied in an interdisciplinary approach, comprising historical information and chemical and mineralogical characterization of tile's glazes and bodies by INAA, PGAA, PIXE and XRD.
Main mineralogical associations of ceramic bodies consist of quartz, gehlenite and calcite in variable proportions, along with high temperatures phases, like wollastonite or diopside. Accordingly they contain a Ca- or Mg-rich raw material. Mullite was detected only in a few cases, indicating the use of non-carbonated raw materials. Traces of K-feldspar, hematite, analcime, plagioclase, vaterite and cristobalite were also found in some samples. Hence, diverse firing temperatures were found, mostly within a range of 800-900ºC, but the 20th century tiles reaching the highest (1000ºC).
Chemical results of tile bodies enhance a more diverse chemical composition for the more recent tiles, in opposition to a homogeneous composition for the older tile samples. Similar geochemical patterns were found for the 17th and 18th century tiles, especially the rare earth elements (REE), pointing to the use of similar raw materials. Glaze compositions also reinforce these chronological differences.

271. Is Non-destructive Provenancing of Pottery Possible With Just a Few Discriminative Trace Elements?

D. Rauch, P. Rauch and D. Wilke*

Dr. Wilke Management & Consulting GmbH, PO Box 301031, D 30967 Wennigsen, Germany
** Corresponding author: wilke@xrfarchaeometrics.com*

At present portable or handheld XRF instruments are the only devices for non-destructive elemental analysis of archaeological and museum specimens. Whereas provenancing of obsidian with non-destructive XRF analysis is already well established, non-destructive elemental analysis of ceramic vessels and sherds is still experimental. The main difference with obsidian is pottery`s heterogenous 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 and Nb 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

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 consisting of 37 standards was used to develop a quantitative calibration [4]. As an empirical result, the core groups of the ten production sites could be distinguished by a simple bi-plot of Rb vs. Sr. Zr and Nb concentrations enforced the separation of adjacent/overlapping clusters. Fe values were discriminative for wares but not for provenances. Mean values and standard deviations for the various clusters are provided as an index of local paste variability, and p-values for cluster distinction. The variability per sherd is discussed as an issue of methodological constraints like surface geometry, and surface modifications which hide the underlying paste. Finally the caveats of assigning pottery of unknown provenance to chemically characterized production centres are considered.

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272. Pottery Provenance in the Eastern Mediterranean-Combining Isotope Ratios with Neutron Activation Analysis

Renson V.[1], Slane K.[2], Kidd B.[2], Rautman M.[2], Guthrie J.[1] and Glascock M.[1]

1. *Research Reactor Center, University of Missouri, 1513 Research Park Drive, Columbia, Missouri, 65211, USA.*
2. *Department of Art History and Archaeology, 109 Pickard Hall, Columbia, Missouri, 65211-1420, USA.*

The Archaeometry Laboratory at the University of Missouri Research Reactor Center (MURR), USA, has a longstanding experience in chemical analysis of artifacts and raw materials, using mainly neutron activation analysis and X-ray fluorescence. The laboratory recently acquired a Nu Plasma II multi collector - inductively coupled plasma - mass spectrometer, which is the ideal instrument for measuring isotopic ratios with high precision and reproducibility.
It has been demonstrated that lead isotope analyses, widely used as tracers on lead-rich artifacts, constitute an efficient tool to document on pottery origin in the Eastern Mediterranean and more specifically in Cyprus (Renson et al. 2011, 2013). This study also evidenced that combining lead isotope analysis with elemental chemistry and petrography has a strong potential to trace pottery provenance.
Various Late Hellenistic to Late Roman pottery wares (including Eastern Sigillata A, Cypriot Sigillata and Cypriot Red Slip) excavated in northern Israel and/or in Cyprus were previously analyzed by neutron activation at MURR which resulted in hypotheses, sometimes contradictive, regarding their origin in Cyprus or in the Levant (Rautman et al. 1993, Slane et al. 1994). Here isotopic analyses are applied to selected Eastern Sigillata A, Cypriot Sigillata, Cypriot Red Slip and related wares. Data are compared to the isotopic composition of Cypriot clay sources and ceramics and integrated to existing chemical data obtained by NAA to better document on these ceramic origins. More largely, this study aims to develop approaches combining isotopic and elemental chemistry to trace pottery provenance and better understand exchanges between ancient civilizations.

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273. New Technological and Provenance Studies of Pueblo I Glaze Paints from the American Southwest

Brunella Santarelli[1], David Killick[2] and Sheila Goff[3]

1. *Department of Materials Science and Engineering, University of Arizona, Tucson, AZ, USA.*
2. *School of Anthropology, University of Arizona, Tucson, AZ, USA.*
3. *History Colorado, Denver, CO, USA.*

Although widely employed in prehistoric Eurasia, lead glazes were produced in only two small regions of the Americas prior to European contact, both in the Southwest. Southwestern glaze paints are unique in that they developed as decorative elements instead of as protective surface coatings. The first independent invention of glaze paints was in the Upper San Juan region of southwestern Colorado during the early Pueblo I period (ca. 700-850 CE). Despite recent interest in the later Pueblo IV glaze paints of New Mexico (ca. 1275-1400 CE), there have been no technological analyses of the Pueblo I glaze paints. It is in the production of the glaze paints that the potters are innovating and experimenting with materials; the selection, processing and use of the lead-glazed materials developed as a culturally patterned technological behavior. These early glaze paints have the potential to provide important information regarding both technology of production as well as the relationships and interactions of potters during this period in the Upper San Juan region.
This research project presents the first analysis and technological reconstruction of the Pueblo I glaze paints 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 provenience 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.

274. Diversity at the Eve of Encounters: Reconstructing the Technology and Craft Organisation of the Meillacoid Ceramics in northern Dominican Republic during the Late Ceramic Age (AD 600-1500)

Carmen Ting[1], Patrick Degryse[2], Jorge Ulloa Hung[1,3] and Corinne L. Hofman[1]

1. *Faculty of Archaeology, Universiteit Leiden, Leiden, The Netherlands.*
2. *Centre for Archaeological Sciences, Division of Geology, KU Leuven, Leuven, Belgium.*
3. *Instituto Tecnologico de Santo Domingo, Santo Domingo, Dominican Republic.*

This paper investigates the production, with particular focus on the procurement of raw materials, technology, and craft organisation, of the Meillacoid ceramics in northern Dominican Republic. The Meillacoid ceramics are considered to be a major ceramic tradition in the Greater Antilles during the Late Ceramic Age (ca. AD 600-1500), a time period that remains little known in many ways. The conventional yet widely accepted interpretation of the Meillacoid ceramics holds that they represented the occurrence of migration of people and culture into the Dominican Republic, replacing the preceding Ostionoid

tradition (Rouse 1992). However, a re-examination of the stylistic traits of the Meillacoid ceramics reveals that the variation in the styles of Meillacoid and Ostionoid ceramics is not as distinct, and that a mixture of these two styles and even with later ceramic styles is evident (Ulloa Hung 2013; Ortega et al. 2003). This finding, therefore, contrasts with the migration hypothesis by highlighting the interaction and transculturation among indigenous communities. Nonetheless, the emphasis on the stylistic aspects of ceramics of the previous research leaves a void in our understanding of whether or not changes in the ceramic styles were also reflected in their production and exchange. Thus, this research focuses on the technological study of the Meillacoid ceramics that were recovered from various sites in northern Dominican Republic, namely El Flaco, La Luperona, Juan Alonso, and Boca de Unijica. The objectives of this pilot study include the characterisation of compositional and technological variability that exists within and between assemblages, the determination of the potential provenance of the raw materials, the distinction of local from non-local products, and the reconstruction of craft organisation at least at the site-level. In order to achieve these ends, archaeometric techniques such as thin-section petrography, ICP-OES, and SEM-EDS are employed. The resultant data will be studied in conjunction with the result of the previous stylistic analysis to construct a better understanding of the dynamic social and cultural landscape of the Greater Antilles at the eve of European contact.

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275. Local Production vs. Importation of Ceramics in Late Bronze Age Sicily: Non-Destructive Elemental Analysis Using pXRF

Robert H. Tykot[1], Andrea Vianello[2], Erin Mckendry[1]

1. *Department of Anthropology, University of South Florida, Tampa, FL 33620 USA.*
2. *Oxford University, England, OX1 2JD, United Kingdom.*

By the Late Bronze Age in Sicily and the Mediterranean overall, long distance exchange was well established as proven by materials such as copper oxhide ingots, amber, glass, ivory, and both decorated pottery and ceramic transport vessels. At some sites in southeastern Sicily, 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 Milena. 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 Milena museum, in an attempt to distinguish elemental signatures in these geologically distinct areas and probe 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 western 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

Robert H. Tykot[1], John W. Arthur[2], Kathryn J.W. Arthur[2], Matthew Curtis[3], Sean Stretton[4]

1. *Department of Anthropology, University of South Florida, Tampa, USA 33620.*
2. *Department of Anthropology, University of South Florida, St. Petersburg, USA 33701.*
3. *Department of Anthropology, College of the Canyons, Santa Clarita, CA, USA 91351.*
4. *Department of Sociology and Anthropology, Illinois State University, Normal, IL, USA 61790.*

More than 240 ceramic artifacts from 11 archaeological sites in southwestern Ethiopia were analyzed to study trade and the socioeconomic characteristics of the Gamo caste system which still exists today, and their predecessors. Potters generally produce pots for people living in their own community and thus the chemical composition of ceramic artifacts should be homogenous in communities with resident potters, allowing us to identify the presence of caste 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 Guyla, Ochollo Lante, Chileshe Fagana, 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-V 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.*

Svetlana Valiulina

Kazan Federal University, Kazan, Russia. svaliulina@inbox.ru

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, Iranian luster, ladzhvardin, etc.

Peculiar chronological rapper is a “closed” complex - the pre-Mongol capital Bilyar - 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 Bilyar as well as in other destroyed and not restored towns, there was no vessel painted with enamel and gold. These wares include lamps, 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 (analysts: B. Gareev, G. Batalin) and scanning electron microscopy (analyst: A. Trifonov). Studies were carried out on 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 minai; 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

determining the chemical composition of glass weights - K-Ca-Al-Mg-Si, sometimes with the addition of Pb. Weights of pre-Mongolian monuments made of transparent thick manganese or green glass, have a clean surface and by weight multiples of dirham (2.82 g).
According to analyzes datum (146), graphs of the ratio of main glass-forming elements and trace admixtures of decisive importance were produced. The derived data filled up a consolidated database on the chemical composition of glass from Bulgar monuments in a wide chronological range: 10-15 cc. Processing test results made it possible to create the type-chronological scale of medieval glass wares of Volga region monuments to identify their origin. Currently, four periods in the history of glass production in Volga Bulgaria are defined. It became possible to rank the Bulgaria towns according to their social status within the state. Dynamics of intercultural interaction is more expressive, including the mediating role of Bulgaria towns in receipt of eastern goods to the North-Eastern Russian lands. New evidence has been obtained for earlier findings about the priority contacts of Volga Bulgaria with Caucasus and Middle Eastern centers of glassmaking as compared to Central Asian.

*The reported study was partially supported by RFBR, research project № 13-06-00686 “Medieval Glass of the Middle Volga Region as a Historical Source“.

278. Mössbauer Studies of Molded Prikamsky-Priuralsk Ceramics*

Svetlana Valiulina, Elena Voronina, Rafil Manapov and Andrew Pyataev.

Kazan Federal University, Kazan, Russia.

Ceramic complex of Volga Bulgaria primarily is characterized by the pottery ceramics of handicraft manufacture. However, as a reflection of the multi-ethnic character of Volga Bulgaria and constant infiltration into her new groups of the population such as nomadic Turkic and Finno-Ugric, in the structure of ceramic material Bulgar monuments there are different ethnic and cultural groups of the traditional molded ceramics. The identification of resource base of molded Prikamsky-Priuralsk dishes, study of its technological features and their dynamics in the historical perspective in the 9-15 centuries was the purpose of the present study. The composition of the analytical sample includes materials of the key monuments of the Bilyarsk micro region within 25 km: ceramic samples from Proto-Hungarian burials of Bolshie Tigany of the 9- early 10cc., pottery and raw clay from the pottery workshop in the center of the capital Bilyar of the 10-early 13cc., ceramics and clay of Bulumer town (Toretzkoye) of the 15 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 clay. The mineral 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 are 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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*The research is carried out with the financial support of the Russian Humanities Research Foundation, Project No.12-01-00096 “Material Culture of Toretzk Trade-Handicraft settlement of the XVth century.”

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

Svetlana Valiulina, Elena Voronina, Rafil Manapov and Andrey Pyataev.

Kazan Federal University, Kazan, Russia. svaliulina@inbox.ru

Bolshie Tigany burial of the 9-10 cc., the largest in Eastern Europe Early Hungarian monument, was discovered and investigated by archaeological expedition of the Kazan State University in 1974 - 1986 (heads - E.A.Halikova, A.H.Halikov). For several decades, one of the main problems of attribution of materials from the burial, as well as from other monuments of its circle, has been the problem of determining the production base which provided richness of material culture 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 search, given an integrated approach, both in the selection of item categories and methods used, which combine complementary analyzes of representative series. This report focuses on one of the most interesting categories of funerary equipment, which represents products of the two handicraft manufactures - jewelry craft and glassmaking. Analytical sample consisted of 15 rings, in which composition of the metal of the base had been determined as well as composition of the glass insets (three rings had carnelian insets).
The chemical composition was carried out by X-ray fluorescence (XRF) analysis with use of tube-above wavelength dispersive X-ray fluorescence spectrometer ZSX Primus II (Rh anode, 4k W). X-ray fluorescence technology is one of the simplest methods, provides quantitative determination of major and minor atomic elements, including light elements with minimal standards. The technique is generally non-destructive, requiring little (if any) sample preparation.
Nature of metal alloys, the alloying elements in their chemical composition and chemical types of glass insets were determined by analyzes. Nine rings were made of fairly high-grade silver – up to 75%, three rings – of Billon, and further three – of alloy of copper (brass).
Technological and raw material characteristics of both, metal and glass, is complemented by elements - trace impurities. By the composition of glass, rings insets are divided into three chemical types. The largest number (13 specimens) is represented by type 1 - Na (K)-Ca-Al-Mg-Si - alkaline soda glass made of plant ash - halophytes of arid climate - corresponds to the basic recipe of Near East glassmaking. Type 2 (1specimen) - K-Ca-Al-Mg-Si: glass is clear, transparent, colored by Co, is distinguished by high chemical resistance due to a balanced presence of alkaline-earth elements and Al. Glass Egyptian weights (Vagelli et al., 2012) and weights from Bolgar and monuments of its surroundings (Valiulina, in press) have the same composition. Type 3 (1 specimen) - Pb-Si - glass of which cameos, double-layer and other products were made in the Islamic glassmaking (Brill, 1987).
Assuming that metal rings and glass insets in them had been done in one craft center, we assume their further import from Near East or a closer production region, for example, Khazar Khanate, where the workshops of incomplete production cycle could work on the Near East semi-finished goods.

*The reported study was partially supported by RFBR, research project № 13-06-00686 “Medieval Glass of the Middle Volga Region as a Historical Source“.

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

Neill J. Wallis[1], Zackary Gilmore[2], Ann S. Cordell[1], Keith H. Ashley[3], Thomas J. Pluckhahn[4], and Michael D. Glascock[5]

1. *Florida Museum of Natural History, University of Florida, Gainesville, USA.*
2. *Department of Anthropology, University of Florida, Gainesville, USA.*
3. *Department of Sociology and Anthropology, University of North Florida, Jacksonville, USA.*

4. *Department of Anthropology, University of South Florida, Tampa, USA.*
5. *Research Reactor Center, University of Missouri, Columbia, USA.*

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 protolith, the southern Appalachian mountains. 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 are 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 Bay, 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 silicious 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 Northeast Florida, Swift Creek (ca. cal A.D. 200 to 800) and Ocmulgee pottery (ca. cal A.D. 950-1250) made in Georgia and brought to Northeast Florida, and Swift Creek pottery made in Southwest Georgia and brought to sites throughout the Florida peninsula.

281. The rectification of name of Proto-celadon — Discussion on the origin of celadon also

Changsui Wang[1], Wenjing Li[1], Yue Chen[1]

1. *Department of Archaeometry, University of Chinese Academy of Sciences, Beijing, P. R. China, 100049.*

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 be 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 Elisseeff, 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 archaeologists 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. Jiazhi 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 H5 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 H5 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 H5 is much higher than them of others from Yue kilns, and is almost the highest in all of Chinese celadon. It is entirely wrong, despite almost experts in ancient ceramics and science circles supported Prof. Jiazhi 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 clay or porcelain 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 mullite. 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

Kuan-Wen Wang[1], Caroline Jackson[1], Yoshiyuki Iizuka[2] and Kun-hsiu Lee[3]

1. *Department of Archaeology, University of Sheffield, Sheffield, United Kingdom.*
2. *Institute of Earth Sciences, Academia Sinica, Taipei, Taiwan.*
3. *National Museum of Prehistory, Taitung, Taiwan.*

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 Analysis of the Glass Beads from Balikun Site Xinjiang China

Rui WEN[1], Zhiqiang ZHAO[1] and Jianxin WANG[1]

1. *School of Cultural Heritage, Northwest University, 229 Taibai Beilu, Xi’an, China.*

The Balikun is an Iron Age site located in the northern foot of the Tianshan Mountains, east part of Xinjiang area. The site is 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 mainly are PbO-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 carving 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 trading route connects the Central Asia and Eastern Xinjiang had been built up no later than 200 BCE. The multi-techniques applied on these beads include drilling, coloring and polishing. The matured bead quickly spread from the West to the East indicates that the fine glass beads were popular goods across the continent 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

Patrick Woodruff[1] and Robert H. Tykot[2]

1. *MA Student, Anthropology Department, University of South Florida, Tampa, US.*
2. *Professor, Anthropology Department, University of South Florida, Tampa, US.*

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 goods, 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 importance 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 sample base for local and non-local crafted ceramics. The artifacts were analyzed non-destructively using a Bruker III-SD portable X-ray fluorescence spectrometer (pXRF), which has been shown to be highly successful in other archaeological studies. The pXRF emits primary X-rays onto the object that produces secondary X-rays which are measured and provide atomic signatures for the material elements on the surface. Similar signatures from different ceramic artifacts indicate these items were constructed using the same materials. Since bricks and tiles are most likely locally crafted building materials, these materials were used as a control source. Other ceramic types with the same signature are interpreted to originate from the same general source. For example, a preliminary assessment of the analytical data suggests that most of the La Piana tableware seems to have been produced non-locally, whereas most of the non-gloss tableware from Cetamura was crafted locally. These analyses suggest that small remote settlements throughout Etruria were using non-locally produced ceramics even though facilities to create ceramics locally were present. Additionally, the geography and accessibility of the remote settlements can also determine which ceramics are likely to have been produced locally.

285. Analytical study of Achaemenid Glazed Bricks of Persepolis by multiple instrumental analysis methods

Soodabeh Yousefnejad[1], Reza Vahidzadeh[2], Mohammad Hasan Talebian[3]

1. *M.A. in Restoration & Conservation of Cultural Heritage, Islamic Azad university ,Central Branch, Tehran, Iran.*
2. *Faculty member of Restoration & Conservation of Cultural Heritage, Islamic Azad university, Central Branch, Tehran, Iran.*
3. *Faculty member of cultural heritage university, Tehran, Iran.*

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 floresance (XRF) and inductively coupled plasma - optical emission spectroscopy (ICP-OES) . The color 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 clarified by ICP, then analysis results of Persepolis glazes was compared with Susa glaze samples of Apadana palace and Elamite glaze samples of Tchogha Zanbil ziggurat.

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286. Investigation of early Chinese Faience

Hu Yuan[1], Katherine Eremin[2], Richard Newman[3] and Andrew Shortland[4]

1. *Independent scholar.*
2. *Harvard Art Museums, Cambridge, USA.*
3. *Museum of Fine Arts, Boston, USA.*
4. *Cranfield University, Shrivenham, UK.*

Faience is increasingly being recognized as a significant component of the wide assemblage of grave goods found in burials from China. This material has been little studied compared to the better known faience from Egypt, the Aegean and the Near East and there is scant information on the materials or technology used. A number of faience beads dated to the first millennium BCE were studied using scanning electron microscopy with energy and wave length dispersive microanalysis to determine the composition and structure of the material. These included both excavated beads and those from a private collection and ranged in date from the 10th to 1st century BCE.

Analysis showed that beads from different sources and dates formed distinct groups based on the composition of the glass phase and glaze present:

- Tubular and rounded beads from Shaanxi, 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 low soda and very low calcium.
- Tubular and ring beads from Shaanxi, later West Zhou, 9th to 8th century BCE: potash glass with high calcium and low soda and containing abundant inclusions of calcium phosphate.
- Tubular and ring beads from Gansu, Sichuan and Shandong, Warring State to Han period, 5th to 1st century BCE: copper-lead-barium glass with complex internal structure and abundant crystalline phases.

This paper will concentrate on the composition and structure of excavated beads from the 10th to 8th century BCE and comparison of these to each other and faeince from Egypt and the Near East. It is suggested that calcium phosphate was deliberately added to some Chinese faience in the 9th to 8th century to increase the stability of the material.

Metals and Metallurgical Ceramics

287. The role of brass, and its use as surface plating of copper alloys

Arne Jouttijärvi

Heimdal-archaeometry, Skovledet 30, 2830 Virum, Denmark

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 silvergild platings. 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 women was in possession of two brooches made at the same time and probably cast from the same crucible of metal, 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 I graves in which the presence of silver brooches or tutulus 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

Arne Jouttijärvi

Heimdal-archaeometry, Skovledet 30, 2830 Virum, Denmark

Finds 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 large crucibles made from ordinary clay. Impressions in the clay shows that it was applied as a lining within a kind of basket made from iron, and the vitrification of the surface reveals that they were heated from above. The remains are interpreted as a kind of ladle described by Biringuccio in De la Pirotechnia, published in 1540. The ladle served both as a container for the molten metal and as a sort of furnace.
All of the examined fragments of Biringuccio type ladles have been shown to having been used for the casting of a bronze with a fairly low tin content and a high content of antimony. Some of the bronzes were heavily leaded. Bronze of this composition was primarily used for casting of relatively large objects as pots, mortars and church fixtures such as baptismal fonts. The tradition of Biringuccio-style casting apparently also included the use of a rather specific alloy.
In some finds including fragments of hessian crucibles, 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.

289. Counting hammerscale - The systematic sampling of workshop remains, developments in methods and results

Arne Jouttijärvi

Heimdal-archaeometry, Skovledet 30, 2830 Virum, Denmark

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 tree 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

290. Iron Age Metallurgy of Jerusalem

Brett Kaufman

Cotsen Institute of Archaeology, UCLA

Excavations of the foundation layers of the Large Stone Structure at Jerusalem have shown that the first occupation horizon is comprised of metallurgical production activities. Generally accepted as King David's palace, this structure is the earliest monumental Judean architecture dating to the Iron Age I/Iron Age IIA transition (~1000 BC). The metallurgical material culture is comprised of tuyères, crucibles, slag, ore, and alloys and corrosion products. Microstructural and compositional analyses have revealed that the materials include bronze melting slags, iron ore, and all the known contemporary metals of copper, tin, lead, iron, gold, and silver. Known as the Crucibles Layer, this phase represents scrapping and melting practices of material used for the erection of the structure and organized centrally by the nascent state elites who commissioned the construction. Analytical techniques utilized were light optical metallographic microscopy, portable X-ray fluorescence spectroscopy, and scanning electron microscopy coupled with energy dispersive X-ray spectroscopy.

291. Han Dynasty metal production in Southeastern China: copper smelting and bloomery iron

David Larreina Garcia[1], Marcos Martinón-Torrres[2] and Yangxian Li[3]

1. *UCL Institute of Archaeology, London, UK*
2. *UCL Institute of Archaeology, London, UK*
3. *Institute of Historical Metallurgy and Materials, USTB Beijing, PRC*

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 (6th 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 tonnes 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, dendritic 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.

292. An Scientific Study of Copper Smelting Slag from Yujialing Site, Wenxi County, Shanxi Province in Central China

Jianxi Li[1], YanxiangLi[1] and XiangmingDai[2]

1. *Institute of the History of Metallurgy and Materials, University of Science and Technology Beijing, China.*
2. *Research Center of Field Archaeology, National Museum of China, Beijing, China.*

As the only huge resource of copper and other metals, the area of Zhongtiao Mountain is one of the key regions for the origins of Chinese Civilization. During the last decades, some bronze artifacts and casting remains but not mining and smelting remains from this region were studied. In one archaeological investigation at Yujialing site in this area, archaeologists found over ten pounds of slag in a pit. 45 pieces of slag were analyzed with scanning electron microscope combined energy dispersive spectrometer. The result indicates that secondary sulfide ore or oxide ore contained sulfide was smelted, which produced copper with trace impurities. The lead isotope analysis proposes some possible ore resources in Zhongtiao Mountain. However, we cannot clearly point out the export area of the product copper because of the lack of lead isotope data of early bronze in neighboring regions.By 14C dating of 3 pieces of charcoal from the slag and 1 piece of associated bone, the slag was dated to the first half of second millennia BC, which is the earliest so far as we know of central China. The latest investigation reveals more smelting sites in this area, which will give us a new perspective and further understanding of the development of early bronze civilization in China.

293. Comparative study of furnace material used for cast iron smelting and melting in ancient China

Haifeng Liu[1], Wei Qian[2] and Jianli Chen[3]

1. *Institute of Historical Metallurgy and Materials, University of Science and Technology Beijing, China.*
2. *Institute of Historical Metallurgy and Materials, University of Science and Technology Beijing, China.*
3. *School of Archaeology and Museology, Peking University, 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 Na20, 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, Shuiquangou site, Dongpingling site, Qigucheng site, Jiudian site.

294. Revisiting Free Silica Slag

Siran Liu[1] and David Larreina Garcia[1]

1. *UCL Institute of Archaeology, London, UK*

'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 undecomposed 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 intense aggregation of bulky (~1-3 cm) chunks of quartz.. The second case regards to lead/silver smelting slag 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 increased the porosity of the charge and allowed liquid matte to drain at a relatively low temperatures. Conversely, in the Chinese case, silica fragments were used to prevent the draining of matte. Here, metallic iron was used as a reductant 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)

Fabio Lopes[1], Carlos R. Appoloni[1], Roberto Cesareo[2], Marcia Rizzutto[3]

1. *Departamento de Física/CCE, Universidade Estadual de Londrina; Caixa Postal 10.011, CEP 86057-970, Londrina, Paraná - Brasil.*
2. *Università degli Studi di Sassari, 07100 Sassari - Italia.*
3. *Instituto de Física, Universidade de São Paulo, CEP 05508900, São Paulo, Brasil.*

A Pre-Columbian metal vessel belonging to the collection of Enrico Poli Museum in Lima was analyzed with a portable X-Ray Fluorescence (XRF) 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 in 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 on gold 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 about 500 µm Si, 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 voltage and current. Standard 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 ± 4.1), Ag (91.9 ± 0.3), Cu (1.9 ± 0.3) and Pb (0.13 ± 0.03). The Ag-thickness determination was performed using the methodology of the altered differential attenuation of Silver (Kα / Kß) and

Copper (Kα / Kß)-lines. An “equivalent thickness” of gold of approximately 1.4 µm was determined.

296. Chemistry and Mineralogy of Slags from the Three-Stage Iron and Steel Production Process from the Southern Highlands of Tanzania

Edwinus C. Lyaya[1], Thilo Rehren[2], and Bertram B. Mapunda[1]

1. *Department of Archaeology and Heritage, University of Dar es Salaam, Tanzania.*
2 *University College London Qatar (QUCL), Hamad bin Khalifa University, Doha.*

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). Macroscopically, 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 verified 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, indicated 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.

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297. Preliminarily Investigation of the Sri Lankan Copper-alloy Statues

K. A. Anusha Kasthuri[1]

1. *Department of Archaeology, Colombo, Sri Lanka*

Sri Lankan works of art are generally attributed to one of four historical major periods: Anuradhapura (ca. 269 B.C–993 A.D.), Pollonnaruwa (993–1235), Divided Kingdoms (AD 1232–1597), and Kandyan (AD 1480–1815). 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 Ultraviolet light, 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 illogical in at least one further aspect. 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 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 w/o 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

Blanca Maldonado[1], Carlos Morales-Merino[2], Hans-Joachim Mucha[3], Hans-Georg Bartel[4], Thilo Rehren[5]

1. *Centre for Archaeological Studies, El Colegio de Michoacán, A.C., La Piedad, Mexico.*
2. *Rathgen-Forschungslabor, Staatliche Museen zu Berlin, Berlin, Germany.*
3. *Weierstraß-Institut für Angewandte Analysis und Stochastik Berlin, Berlin, Germany.*
4. *Institut für Chemie, Humboldt-Universität zu Berlin, Berlin, Germany.*
5. *UCL Qatar, Hamad bin Khalifa University, Doha, Qatar.*

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, artifactual studies, experimental approaches and analytical 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 sampling of 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 Nuzi

Elisa Maupas[1], Sarah Dillis[1], Patrick Degryse[1], Philippe Muchez[1], Katherine Eremin[2] and Frank Vanhaecke[3]

1. *Department of Earth and Environmental Sciences, K.U.Leuven, Celestijnenlaan 200E, B-3001 Leuven, Belgium.*
2. *Harvard University Art Museums, 32 Quincy Street, Cambridge, MA 02138, USA.*
3. *Department of Analytical Chemistry, U. Ghent, Krijgslaan 281-S12, B-9000 Ghent, Belgium.*

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 overlap exists between different areas (Gale & Stos-Gale 1982, Yener et al. 1991, Stos-Gale et al. 1997, Rehren & Pernicka 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 other 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 aim to reconstruct the trade of Copper in the ancient Near East, the present paper focus on the applicability of a combined isotopic approach to trace the

provenance of Copper alloys artifacts from the Late Bronze Age city of Nuzi.
The site of Nuzi in ancient Northern Mesopotamia presents one of the largest metal Late Bronze Age metal assemblages for the Near East, dating to the middle of second millennium BC and consisting mainly of Copper alloys artifacts. While minerals resources occur widely in the neighbouring regions, Mesopotamia had no mineral sources of its own. As a consequence, the local metal production was based on import from the surrounding cupriferous areas rich in native copper and copper ore deposits, such as Anatolia and the Iranian Plateau (Avilova 2009, Moorey 1994). Preliminary results for isotopic and trace element analysis obtained by MC-ICP-MS and electron microprobe will provide insight of the use and trade of Copper during the Mitanni period in Northern Mesopotamia.

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300. ADVANCE RESULTS OF ARCHEOMETRY INVESTIGATIONS ABOUT A TREASURE FROM BODROGOLASZI, HUNGARY

Nagy, Zsolt Dezső[1], Fintor, Krisztián[2], Tóth, Mária[3] and Révész, László[4]

1. *Department of Archaeology, University of Szeged, Szeged, Hungary.*
2. *Department of Mineralogy, Geochemistry and Petrology, University of Szeged, Szeged, Hungary.*
3. *Institute for Geological and Geochemical Research, Research Centre of Astronomy and Earth Sciences, Hungarian Academy of Sciences, Budapest, Hungary.*
4. *Department of Archaeology, University of Szeged, Szeged, Hungary.*

The treasure from Bodrogolaszi (Borsod-Abaúj-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 numismatic 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 fillip). During the analysis of images about cut and broken surfaces, we discovered darker 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 Nagyszeben), but copper enrichment should be located to German speaking areas (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 heterogeneous archaeological metals

Matthew Nicholas[1], Panagiota Manti[1]

1. *Department of Archaeology and Conservation, Cardiff University, UK.*

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 (HHpXRF) 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 HHpXRF 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 HHpXRF 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 Eriswell, 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 HHpXRF data with that acquired using different techniques will also be examined. The paper contributes to continuing discussions on the role of HHpXRF 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

Eric Nordgren[1], Ian Dennis[1] and Niall Sharples[1]

1. *Department of Archaeology and Conservation, School of History, Archaeology and Religion, Cardiff University, John Percival Building, Colum Drive, Cardiff, CF10 3EU*

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 (Sharples 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 provided new details on the methods of production. 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 of 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 with 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

María Teresa Plaza[1] and Marcos Martinón-Torres[2]

1. *Institute of Archaeology, University College London, London, United Kingdom.*
2. *Institute of Archaeology, University College London, London, United Kingdom.*

The Aconcagua Valley (Central Chile) is located in the southernmost limit of the Tawantinsuyu or Inka territory. In this area, some indicators of the Inka influence such as architecture, the Inka road, rock art and pottery have been largely studied, suggesting that the Inka developed a symbolic strategy to incorporate this area into the state. However, these studies have not considered the metallic and metallurgical evidence, which is both key in the Inka ideology, politics and expansion, and very distinctive of the Inka or Late Period in Central Chile.

Considering that technology is culturally determined, this research uses an approach based on the analysis of the technical aspects of the metals and metallurgical ceramics to reveal important insights about the cultural choices and social dynamics of the groups using and/or producing metals in the area, and the influence of the Inka in those technologies.

For this purpose, metallic artefacts and technical ceramics from two sites in the valley, Cerro La Cruz and Los Nogales, were subjected to analyses using SEM-EDS, optical microscopy, petrography, XDR and FTIR. These analytical techniques allowed to identify manufacturing techniques, raw materials, recipes and the extent of use of the metallic artefacts and technical ceramics.

The results suggest that both sites represent different technological traditions. At Cerro La Cruz, the predominance of typologies and techniques rooted in the indigenous Diaguita Culture and the scarcity of bronze, indicate a conservatism that may reflect a cultural resistance to the Inka domain. Conversely, at Los Nogales, the presence of typical Inka perforated crucibles lined with bone ash, together with the use of bronze, point to a tradition closely related to the Inka expansion, also documented in north-western Argentina, which would reflect a cultural receptivity from some local groups towards new technologies and their associated values.

These differences support the proposition that the Inka domination in the valley was heterogeneous and culturally contingent, and suggest a closer relationship between the state and some local groups, not previously identified.

304. Methodological Issues in Understanding Ancient Crucible Metallurgy

Frederik Rademakers[1] and Thilo Rehren[2]

1. *UCL Institute of Archaeology, London, United Kingdom.*
2. *UCL Qatar, Doha, Qatar.*

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

I. Saprykina[1], L. Pelgunova[2], V. Rodinkova[1], D. Stolyarova[1], A. Chugaev[3]

1. *The Institute of Archaeology of Russian Academy of Sciences (IA RAS), Moscow.*
2. *A. N. Severtsov Institute of Ecology and Evolution of Russian Academy of Sciences, Moscow.*
3. *The Institute of Mining Geology, Petrography, Mineralogy and Geochemistry of Russian Academy of Sciences, Moscow.*

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 jewelry and standing out against poor settlement culture of the early Slavic population happened. The unexpected appearance of these hoards together with the same 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 – from 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 c. 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 Kursk oblast on the border with the Ukraine in the cluster 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 jewelry pieces (items which had been used or 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 c. The complex also contains about 50 items made of silver alloys dated from the late Roman period to the 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 "marks" has special significance for identifying the source of these works. Dish fragments have been studied with stereomicroscope Stemi 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 Tornado (Bruker). To identify possible area of silver works development the analysis has been done with the help of the high-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

Rebecca Scott[1], Kim Eekelers[1], Lander Fredericks[1] and Patrick Degryse[1]

1. *Division Geology, KU Leuven, Celestijnenlaan 200E, 3000 Leuven, Belgium.*

In 1989, Helmig 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 Sagalassos region of south-west Turkey. Although previously samples of the slag material had been exported from the country for the purposes of analysis, a method of analysing

the materials in-situ was required. It was decided that the best technique for achieving 'in-the-field' results would be with HH-XRF. A series of laboratory based tests were first performed in order to determine the ideal working parameters for the HH-XRF. Then various different methods of preparing the slag were tested to see which gave the best results. One of the biggest challenges with using HH-XRF for the analysis of slag is the heterogeneous nature of the material. Therefore, sampling and preparation methods needed to homogenise the material in a reliable way. The results of the laboratory tests showed that the best method of preparing the samples was powdering. The analyses were performed at two energy settings 40kV, 10.9µA for the full range of elements present in the sample and 9kV, 20µA to interrogate the light elements. The laboratory tests indicated that the precision of the HH-XRF was very good and that different slag (i.e. Ti-rich/poor) could clearly be distinguished.

The first challenge in the field involved finding a method to powder the slag; the method chosen, although not ideal, did yield enough sample to perform qualitative analyses. A total of 45 metal slag were analysed in order to see whether the slag could be qualitatively characterised based on provenance and/or function. The results of the field study indicated two principle groups (a high Ti-Zr group and a low Ti-Zr group). The Ca also split the data into two groups but these were not consistent with the previous Ti-Zr groups. The data could be explained both by provenance (based on the find location of the slag) and function (tap slag, furnace cooled slag etc).

Despite the better resolution and improved portability of the HH-XRF, the ideal methodology for analysing metal slag in the field remains much the same. The biggest challenges still involve sample preparation, quantity of powdered material and the accurate determination of light elements in the samples.

Reference

Helmig, D., Jackwerth, E., Hauptmann, A., 1989. Archaeometallurgical Fieldwork and the use of a Portable X-Ray Spectrometer. Archaeometry 31, 181–191.

307. pXRF 'In-the-Field' Fluctuations

Rebecca Scott[1], Kim Eekelers[1], Lander Fredericks[1], Dennis Braekmans[2,3], and Patrick Degryse[1]

1. *Division Geology, KU Leuven, Celestijnenlaan 200E, 3000 Leuven, Belgium.*
2. *Materials in Art and Archaeology, Laboratory of Materials Science, Delft University of Technology, Mekelweg 2, NL-2628CD Delft, The Netherlands.*
3. *Laboratory for Ceramic Studies, Faculty of Archaeology, Leiden University, Reuvensplaats 3-4, 2311 BE Leiden, The Netherlands.*

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 literature supplied with the pXRF recommends that the ambient temperature be kept below 115oF (46oC). It was noted that the ambient temperature increased by an average of 4oF, 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 (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. 4oF 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 70-93oF (21-34oC), 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 if 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?

308. The mystery of the lead disc: accidental survival or ritual deposition?

Rebecca Scott[1], Kim Eekelers[1] and Patrick Degryse[1]

1. *Division Geology, KU Leuven, Celestijnenlaan 200E, 3000 Leuven, Belgium.*

While developing a methodology for the analysis of Roman metal slag in the field, an unusual discovery was made; one slag was found to contain a metal disc. Further analyses in the field with a pXRF, of both the disc and the slag, revealed that the disc was made of Pb with a Cu attachment and traces amounts of Au. The slag was found to be Fe-rich with traces of Cu and Pb present from the corrosion of the disc. Although the conservation team were able to lift the disc from the slag, only a limited amount of 'cleaning' could be performed and the exact nature of the disc is, as yet, unknown. Aside from the obvious question of what is/was it; a number of other questions are raised by this find, such as, how did it end up in a metal slag? Speculation ranges from the disc being a Roman coin which formed a votive offering in the new hearth, to the disc being part of a bigger statue which was in the process of being re-melted. This case study uses a combination of scientific analysis and archaeological study to determine whether we have an accidental survival from Roman metal production, and therefore an insight into the physical production process. Or a deliberate offering to ensure the good working of a new hearth and an insight into the mind of the Roman metal worker.

309. Copper Smelting Technologies at Nahal 'Amram, Southwest 'Araba Valley, Israel

S. Shilstein[1], S. Shalev[2], U. Avner[3]

1. *Weizmann Institute of Science, 76100 Rehovot, Israel.*
2. *Haifa University, 31905 Haifa, Israel.*
3. *'Arava-Dead Sea Science Center, 8814402, Eilat.*

Copper mines dug into sandstones were first surveyed at Nahal 'Amram by N. Glueck in the 1950s, by B. Rothenberg in the 1960s and by L. Willies in the late 1980s. A recent detailed survey, by U. Avner, R. Shem-Tov and B. Langford, discovered many more mines of various periods, as well as other related sites. From a large miners' camp located next to the mines, samples of copper slag were collected from each cluster of dwelling structures. The chemical composition of slag is currently under an extensive study, using a non-destructive X-ray fluorescence method. Many slag fragments are analyzed and several XRF readings are taken from each piece, to determine the slag content and level of homogeneity. Presently, four different technologies are identified from the older periods (later ones are not mentioned here):

a) Small furnace slag dated to the Chalcolitic-Early Bronze Age (5th-3rd millennia BC). The slag is inhomogeneous, containing up to 10% Cu and ca. 2% Fe. The Cu/Fe ratio is close to that of the local copper ore, so no intentional addition of flux is recognized.

b) Small furnace slag dated to the Late Bronze and Iron Age (13th-9th centuries BC). The slag is still inhomogeneous, containing several percent of Cu and 15%-20% Fe. The higher content of Fe indicates deliberate addition Fe as flux, most probably hematite (Fe2O3) which is common in this area.

c) Small furnace slag also dated to the Late Bronze and Iron Age. The slag is more homogeneous containing only 0.2%-0.6% Cu, 20%-30 Fe and a small amount of Mn. The homogeneity and chemical composition indicate well controlled addition of flux.

d) Small slag fragment, probably a result of initial tapping dated to the same period (13th-9th centuries BC). Slag is homogeneous, containing up to 30% Mn, only ca. 1% Fe and ca. 0.3% Cu. The slag represents an advanced technology, based on Mn fluxing. The only known source of Mn in the region is the northern Timna Valley, 25 km to the north by trails.

Preliminary conclusions:

The XRF chemical analyses of slag indicate several different technologies of smelting in the earlier periods of copper production, possibly with chronological development. With the progress of the study, we intend to present the chemical composition of slag from many more sites. Based on 14C dates we hope to reach a detailed sequence of technological progress through the history of the 'Araba Valley.

310. Metal Objects in the Paolo Orsi Museum (Siracusa, Italy): Non-Destructive Compositional Analysis

Robert H. Tykot[1], Andrea Vianello[2], Anita Crispino[3]

1. *Department of Anthropology, University of South Florida, Tampa, FL 33620 USA.*
2. *Oxford University, England, OX1 2JD, United Kingdom.*
3. *Museo Archeologico Regionale Paolo Orsi, 96100 Siracusa, Italy.*

A large number of copper-based and other metal artifacts in the Paolo Orsi Museum in Siracusa, southeast Sicily, were analyzed to determine their elemental 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, bowls, 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

Lente Van Brempt[1] and Vasiliki Kassianidou[2]

1. *Archaeological Research Unit, Department of History and Archaeology, University of Cyprus, Nicosia, Cyprus.*
2. *Archaeological Research Unit, Department of History and Archaeology, University of Cyprus, Nicosia, Cyprus.*

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 Cyprus likely existed as a collection of regional polities in which different settlement types took part in an economical and socio-political network. These regional networks may have been defined by the transhipment 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 neighbouring sites of Maroni-Vournes and Maroni-Tsaroukkas, 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 Kalavassos-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.

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312. Iron on the Imperial Frontier: Evidence from Angkorian Period (9th-15th Century AD) Iron Smelting Sites in Lao PDR and Thailand

Pira Venunan[1], Thomas Oliver Pryce[2], Marcos Martinón-Torres[1]

1. *UCL Institute of Archaeology, London, UK.*
2. *Centre National de la Recherche Scientifique, UMR 7055 Préhistoire et Technologie, Nanterre, France.*

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 contemporary fringe populations of multiple ethnicity produced iron, arguably for consumption by the Khmer core. Despite the expectedly high demand 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 contemporary iron production. The first cluster of smelting sites is, 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 smelters 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 that the production 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 PRELIMANARY STUDY ON A BRONZE INCENSE BURNER DATED TO THE EASTERN JIN DANASTY (317-420A.D.) IN NANJING CITY, CHINA

Wang Xiaoqi[1], Chen Dahai[2], Wang Hong[2] and Huang Xiaojuan[3]

1. *Division of Archaeology, Department of History, Nanjing University, Nanjing, China.*
2. *Division of Archaeology, Nanjing Municipal Museum, Nanjing, China.*
3. *Conservation Lab, Archaeological Institute of Shaanxi Province, Xi'an, China.*

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 beeswax, 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 x-ray fluorescence, μ x-ray fluorescence, metallographic microscopy, as well as scanning electron microscopy coupled with EDS to determine the composition, structure and manufacturing technology.

The semi-quantitive 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 metallographic observation unveiled a typical dendritic casting microstructure, but dendritic segregation was unobvious because of low tin content. The results conducted by scanning electron microscopy equipped with EDS were in consistent with metallographic 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 opinion, which was inclined to be an artifact made of pure copper, referenced from a historical record written by contemporaneous alchemists, one of whom was mostly presumed to be the potential tomb owner. However, deep investigation needed to be performed on diverse parts of 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

Xiaogang Yang[1], Houxi Zou[1], Xiaoyong Huang[2], Yongwei Wang[3], Pujun Jin[4]

1. *Chongqing Cultural Heritage Research Institute, Chongqing, China.*
2. *Kainxian County Bureau of Culture, Broadcasting, Television, Chongqing, China*
3. *Kainxian County Historic Relic Administration Chongqing, China.*
4. *School of Materials Science and Engineering, Shaanxi Normal University, Xi'an,China.*

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 vimineous 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.

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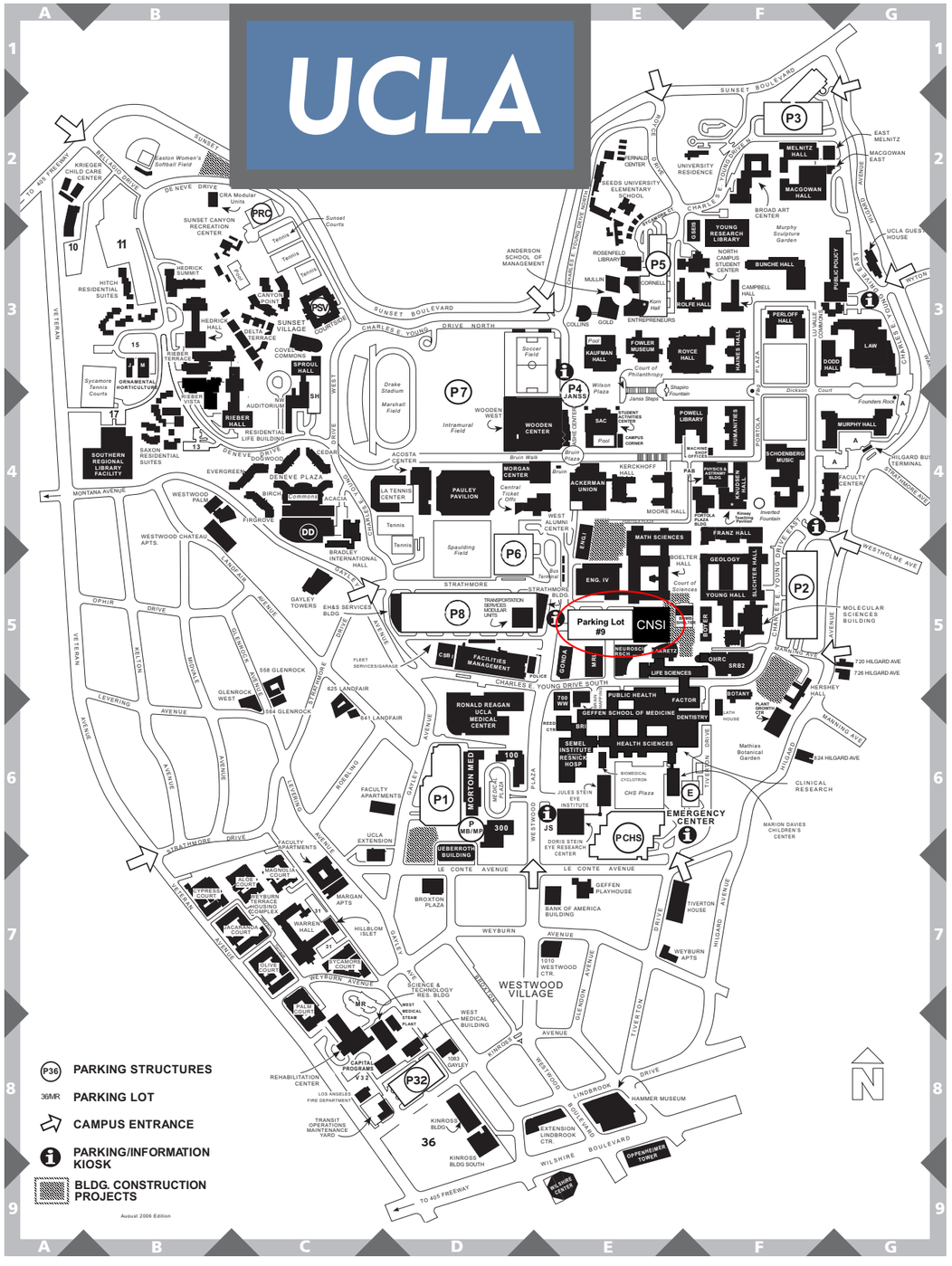

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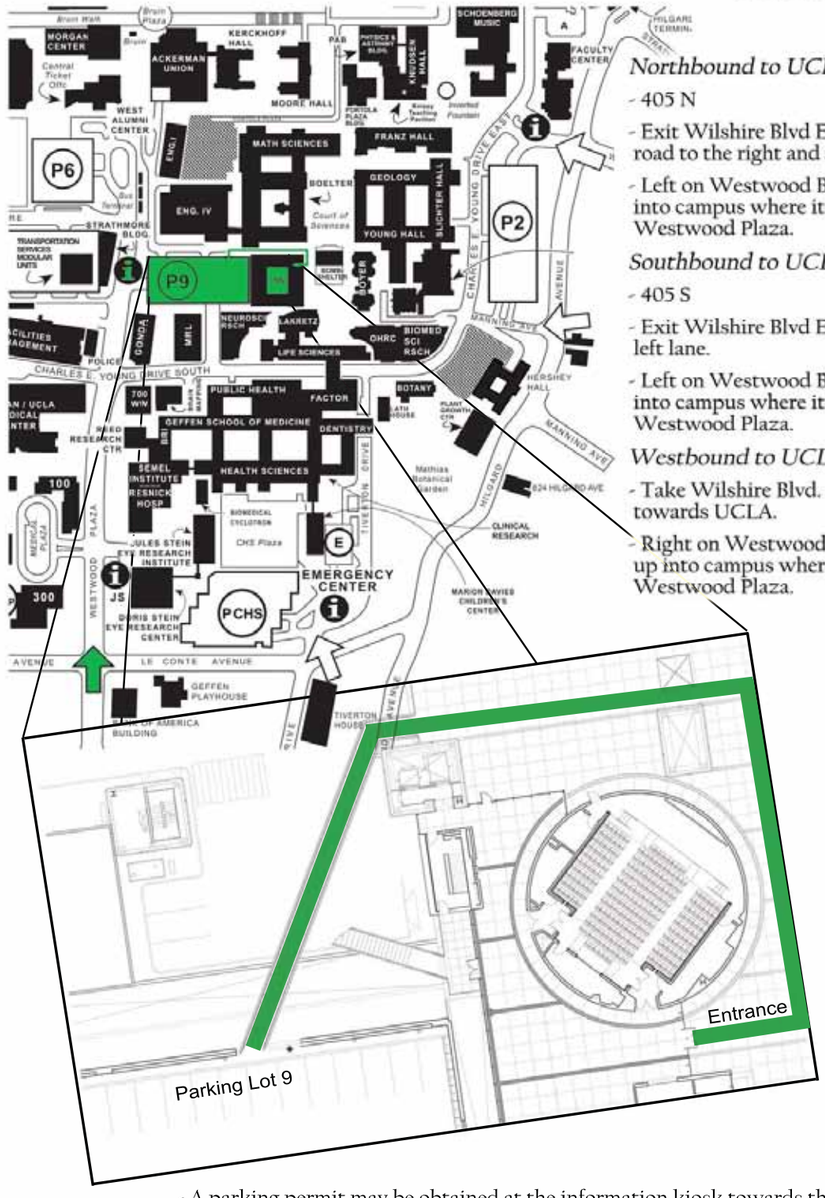

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ISA 2014 MASTER PARTICIPANT LIST

Abd El Salam, Safaa
University of Alexandria
saas17@yahoo.co.uk

Abdel-Ghani, Mona
Cairo University
mabdelghani@yahoo.com

Aguayo, Tomás
Universidad de Chile
tomas.eaa@ug.uchile.cl

Ahmed, Harby
Cairo University
harbyezzeldeen@yahoo.com

Alipour, Rahil
UCL Qatar
rahil.alipour.09@ucl.ac.uk

Amicone, Silvia
University College London
silvia.amicone@ucl.ac.uk

Ankjaergaard, Christina
Wageningen University
christina.ankjaergaard@gmail.com

Appoloni, Carlos
State University of Londrina
appoloni@uel.br

Argote-Espino, Denisse
INAH
efenfi@gmail.com

Armitage, Ruth Ann
Eastern Michigan University
rarmitage@emich.edu

Arvaniti, Theodora
NCSR “Demokritos”
Tarvan@physics.auth.gr

Asandulesei, Andrei
University of Isai
andrei.asandulesei@yahoo.com

Ashkanani, Hasan
University of South Florida
hasan@mail.usf.edu

Avlonitou, Lydia
Université Paris - Nanterre
lydia.avlonitou@mae.u-paris10.f

Azémard, Clara
Avignon University - UFR Sciences
clara.azemard@gmail.com

Babini, Agnese
University of California Los Angeles
agnesebabini@libero.it

Badillo Sanchez, Diego Armando
Universidad de Los Andes
da.badillo10@uniandes.edu.co

Barba, Luis
UNAM
lubarba@me.com

Barbi, Nick
PulseTor
nbarbi@pulsetor.com

Barca, Donatella
University of Calabria
donatella.barca@unical.it

Bassiakos, Yannis
NCSR, “Demokritos”
bassiakos@ims.demokritos.gr

Bearman, Gregory
greg@aneimage.com

Beck, Lucile
CEA
lucile.beck@cea.fr

Benzonelli, Agnese
University College London
agnese.benzonelli.12@ucl.ac.uk

Berenbeim, Jacob
UC Santa Barbara
jberenbeim@chem.ucsb.edu

Blinman, Eric
Museum of New Mexico
eric.blinman@state.nm.us

Blomme, Annelore
KU Leuven
annelore.blomme@ees.kuleuven.be

Boccia-Paterakis, Alice
Scripps College
alicepaterakis@yahoo.com

Boehnke, Patrick
University of California Los Angeles
pboehnke@gmail.com

Bonnerot, Olivier
University of Cyprus
bonnerot.olivier@ucy.ac.cy

Boscher, Loic
UCL Qatar
loic.boscher.09@ucl.ac.uk

Bougarit, David
Getty Conservation Institute
dbougarit@getty.edu

Bracci, Susanna
ICVBC-CNR
s.bracci@icvbc.cnr.it

Braekmans, Dennis
Leiden University
d.braekmans@tudelft.ul

Bravo, Jorge Aurelio
Universidad Nacional de San Marcos
jbravo8@hotmail.com

Brems, Dieter
KU Leuven
dieter.brems@ees.kuleuven.be

Brennan, Brian
Macquarie University
brianbrennanaust@gmail.com

Brown, Keri
Manchester Institute of Biotechnology
keri.brown@manchester.ac.uk

Brown, Terry
Manchester Institute of Biotechnology
terry.brown@manchester.ac.uk

Bugini, Roberto
CNR
buginl@icvbc.cnr.it

Burke, Aaron
University of California Los Angeles
burke@humnet.ucla.edu

Burr, Betsy
University of California Los Angeles
betsyburr@ucla.edu

Burton, James
University of Wisconsin-Madison
jhburton@wisc.edu

Butt, Darryl
Boise State University
janehokanson@boisestate.edu

Cannavo, Valentina
University of Modena and Reggio Emilia
valentinacannavo@gmail.com

Capek, Alexandra
Cal State Northridge
alexandra.capek.165@my.csun.edu

Caro, Federico
Metropolitan Museum of Art
federico.caro@metmuseum.org

Carpenter, Tony
FEI
Tony.Carpenter@fei.com

Cartwright, Caroline
British Museum
CCARTWRIGHT@britishmuseum.org

Cattin, Florence
University of Burgundy
florence.cattin@u-bourgogne.fr

Cavallo, Giovanni
University of Pavia
giovanni.cavallo01@ateneopv.it

Ceglia, Andrea
Vrije Universiteit Brussel
aceglia@vub.ac.be

Chan, Michelle
California State University Northridge
michelle.chan.513@my.csun.edu

Charalambous, Andrea
University of Cyprus
anchar@ucy.ac.cy

Chatr Aryamontri, Deborah
Montclair State University
aryamontrid@mail.montclair.edu

Chau, Amanda
Buffalo State College
amanda.g.chau@gmail.com

Chen, Hong
Zhejiang University
hollychen@zju.edu.cn

Chen, Tsai-wei
National Prehistory Museum Taiwan
b00204020@ntu.edu.tw

Chiarelli, Nicoletta
University of Florence
chiarelli_nicoletta@alice.it

Chipman, Matthew
EDAX
Matthew.Chipman@ametek.com

Christodoulakis, Ioannis
NCSR “Demokritos”
physjohn@yahoo.gr

Cianchetta, Ilaria
Getty Conservation Institute
lcianchetta@getty.edu

Claes, Pieterjan
National Autonomous University Mexico
pieterjan.claes@fisica.unam.mx

Clinch, Robyn
City of Port Phillip and University of Melbourne
rjclinch@yahoo.com

Cockrell, Bryan
University of California Berkeley
bryan.cockrell@berkeley.edu

Colombini, Maria Perla
ICVBC-CNR
maria.perla.colombini@unipi.it

Conejo Barboza, Geraldine
University of Costa Rica
cbgeraldine@gmail.com

Conger, Laura
University College London
lconger@gmail.com

Considine, Brian
J. Paul Getty Museum
bconsidine@getty.edu

Constantinescu, Bogdan
National Institute for Nuclear Physics and Engineering
bconst@nipne.ro

Conte, Sonia
University of Modena and Reggio Emilia
sonia.conte@unimore.it

Correa Ascencio, Marisol
University of Bristol
chmca@bristol.ac.uk

Custance-Baker, Alice
Getty Conservation Institute Consultant
a.custance-baker@outlook.com

Daghmehchi, Maria
Tehran University Institute of Archaeology
maria.daghmehchi@yahoo.com

Daniel, Floréal
IRAMAT
floreal.daniel@u-bordeaux3.fr

Davidson, Ted
University of Pennsylvania Museum
chem367@yahoo.com

Davies, Nathan
Bruker
nate@kivatech.com

Day, Peter
University of Sheffield
p.m.day@sheffield.ac.uk

Degryse, Patrick
KU Leuven
patrick.degryse@ees.kuleuven.be

De Langhe, Kaatje
Ghent University
kaatje.delanghe@ugent.be

Del Solar, Nino
IRAMAT-CRP2A
nvdelsolarve@u-bordeaux3.fr

Demesticha, Stella
University of Cyporus
demesticha@ucy.ac.cy

Derr, K D
Carl Zeiss Microscopy
KD.Derr@zeiss.com

Devulder, Veerle
KU Leuven
veerle.devulder@ees.kuleuven.be

Dias, M. Isabel
C2TN
isadias@ctn.ist.utl.pt

Dirix, Katrijn
KU Leuven
katrijn.dirix@ees.kuleuven.be

Dodd, Lynn
University of Southern California
swartz@usc.edu
Domoney, Kelly
Cranfield University
k.domoney@cranfield.ac.uk

Donais, Mary Kate
Saint Anselm College
mdonais@anselm.edu

Douglas, Janet
Smithsonian Institution, Freer/Sackler Galleries
douglja@si.edu

Driesler, Chuck
Allied High Tech
csdriesler@alliedhightech.com

Dussubieux, Laure
The Field Museum
ldussubieux@fieldmuseum.org

Eekelers, Kim
KU Leuven
kim.eekelers@ees.kuleuven.be

Eremin, Katherine
Harvard Art Museums
katherine_eremin@harvard.edu

Evershed, Richard
University of Bristol
R.P.Evershed@bristol.ac.uk

Feng, Nan
Jilin University
fengnan@jlu.edu.cn

Fenn, Thomas
Yale University
tfenn@email.arizona.edu

Filippaki, Liana
NCSR “Demokritos”
lfilip@ims.demokritos.gr

Fischer, Christian
University of California Los Angeles
cfischer@ucla.edu

Fornacelli, Cristina
Université degli Studi di Siena
fornacelli@unisi.it

Franke, Kristina
University College London
kristina.a.franke@gmail.com

Fraser, Daniel
Lourdes University
dfraser@lourdes.edu

Freestone, Ian
University College London
i.freestone@ucl.ac.uk

Freund, Kyle
McMaster University
freundkp@mcmaster.ca

Fukakusa, Shunsuke
Nara Women’s University
s-fukakusa@cc.nara-wu.ac.jp

Galindo Cruz, Rafael
Universidad Nacional de Colombia
rrgalindoc@unal.edu.co

Gambardella, Alessa
Getty Conservation Institute
agambardella@getty.edu

Ganio, Monica
Northwestern University
monica.ganio@northwestern.edu

Gariani, Gianluca
University of Torino
gariani@gianluca1@gmail.com

Garrett, Simon
California State University Northridge
simon.garrett@csun.edu

Gaudenzi-Asinelli, Mainardo
University College London
m.asinelli@ucl.ac.uk

Gay, Marine
UPMC - CNRS
marine.gay@upmc.fr

Georgakopoulou, Myrto
UCL Qatar
m.georgakopoulou@ucl.ac.uk

Gerling, Claudia
Free University Berlin
claudia.gerling@topoi.org

Giannattasio, Caterina
DICAAR Università di Cagliari
cgiannatt@unica.it

Giannini, Rita
Cranfield University
r.giannini@cranfield.ac.uk

Gilberg, Mark
Los Angeles County Museum of Art
mgilberg@lacma.org
Gill, Maninder Singh
UCL Qatar
maninder.gill.11@ucl.ac.uk

Gliozzo, Elisabetta
University of Siena
gliozzo@unisi.it

Godos González, Fernando
INAH
fgodos@gmail.com

Golubovic, Snezana
Archaeological Institute Belgrade
arheosneska@gmail.com

Grammatikakis, Giannis
University of Crete
ggrammat@chemistry.uoc.gr

Greene, Alan
Stanford University
afgreene@stanford.edu

Grillo, Silvana Maria
DICAAR Università di Cagliari
grillo@unica.it

Grupe, Gisela
Ludwig-Maximilian-University Munich
g.grupe@lrz.uni-muenchen.de

Guo, Yi
Zhejiang University
guoyi10@zju.edu.cn

Gutierrez Garcia-M., Anna
IRAMAT-CRP2A
anna.gutierrez@u-bordeaux3.fr

Guzman, Amanda
UC Berkeley
amanda.j.guzman@berkeley.edu

Hall, Gretchen
University of Pennsylvania
ghall2@comcast.net

Hancock, Ron
McMaster University
ronhancock@ca.inter.net

Hawash, Mohamed
Cairo University
hawash2009@hotmail.com

Hawkinson, Gary
FEI
Gary.Hawkinson@fei.com

Helman-wazny, Agnieszka
University of Arizona
agniwaz@email.arizona.edu
Hendrickson, Mitch
University of Illinois
mjhend@uic.edu

Heron, Carl
University of Bradford
c.p.heron@bradford.ac.uk

Höflmayer, Felix
University of Chicago
fhoeflmayer@uchicago.edu

Holk, Gregory
California State University Long Beach
gregory.holk@csulb.edu

Holmqvist-Saukkonen, Elisabeth
University of Helsinki
elisabeth.holmqvist-saukkonen@helsinki.fi

Howarth, Philly
Linacre College
philippa.howarth@linacre.ox.ac.uk

Hseih, Ellen
University of California Los Angeles
ellenhsieh9999@gmail.com

Hunt, Alexandria
University of Technology, Sydney
alexandria.m.hunt@student.uts.edu.au

Iassonova, Maria
Ridgeview Classical School
crdil@yahoo.com

Iles, Louise
University of York
louise.iles@york.ac.uk

Ioannidis, Dimitrios
University of Cyprus
dimio87@gmail.com

Jacobsen, Dan
Ametek
dan.jacobsen@ametek.com

Jackson, Marie
University of California Berkeley
mdjjackson@gmail.com

Jeberien, Alexandra
University of Applied Sciences Berlin
alexandra.jeberien@htw-berlin.de

Jessen, Catherine
The National Museum of Denmark
catherine.jessen@natmus.dk

Jia, Lijiang
Northwest University Xi'an
jialj@nwu.edu.cn

Jin, Pujun
School of Materials Science Xi'an
jinpj@snnu.edu.cn

Joannes-Boyau, Renaud
Southern Cross University
renaud.joannes-boyau@scu.edu.au

Jouttijärvi, Arne
Heimdal-archaeometry
heimdal@archaeometry.dk

Kaiser, Bruce
Bruker
bruce.kaiser@Bruker-elemental.net

Kakoulli, Ioanna
University of California Los Angeles
kakoulli@ucla.edu

Karamad, Zahra
Eram High Educational Institute
zahra.karamad@gmail.com

Kassianidou, Lina
University of Cyprus
v.kassianidou@ucy.ac.cy

Kasthuri Arachchilage, Anusha
Sri Lanka Department of Archaeology
anusha.kasthuri@gmail.com

Kaufman, Brett
University of California Los Angeles
bkaufman@ucla.edu

Kazantzaki, Maria
National Technical University of Athens
kazantzaki.mar@gmail.com

Keutgens, Karin
Ghent University
viering@telenet.be

Khramchenkova, Rezida
Tatarstan Academy of Sciences
rezidahram@mail.ru

Kilikoglou, Vassilis
NCSR "Demokritos"
kilikog@ims.demokritos.gr

Killick, David
University of Arizona
killick@email.arizona.edu

King, Andrew
Renishaw
Andrew.King@Renishaw.com

Knapp, Bernard
University of Glasgow
Bernard.Knapp@glasgow.ac.uk

Korać, Miomir
Archaeological Institute Belgrade
misko@mi.sanu.ac.rs

Krivanek, Roman
Institute of Archaeology AS CR
krivanek@arup.cas.cz

Kulick, Rachel
University of Toronto
rachel.kulick@gmail.com

Lailson, Becket
UASLP
lailsontb@gmail.com

Lankton, James
UCL Qatar
jamesyuri@gmail.com

Lanoue, Mark
PhiLumina, LLC
techexec@philumina.com

Lapatin, Kenneth
J. Paul Getty Museum
klapatin@getty.edu

Larreina-garcia, David
University College London
d.larreina@ucl.ac.uk

LaRussa, Mauro Francesco
University of Calabria
mlarussa@unical.it

Lauffenburger, Julie
The Walters Art Museum
jlauffenburger@thewalters.org

Le Bourdonnec, François-Xavier
Université Bordeaux Montaigne
Francois-Xavier.Le-Bourdonnec@u-bordeaux-montaigne.fr

Le Carlier, Cécile
CNRS
cecile.lecarlier@univ.rennes1.fr

Lee, Andrew
EDAX
andrew.lee@ametek.com

Leonova, Tatiana
Bashkortostan Pedagogical University
leonotan@mail.ru

Leroy, Stéphanie
MLMC-IRAMAT
stephanie.leroy@cea.fr

Levi, Sara Tiziana
University of Modena and Reggio Emilia
saratiziana.levi@unimore.it

Levy, Thomas
University of California San Diego
tlevy@ucsd.edu

Li, Jianxi
University of Science Beijing
jesselee8361@sian.com

Li, Weidong
Chinese Academy of Sciences
liwd@mail.sic.ac.cn

Licenziati, Francesca
Université Paris Ouest
francesca.licenziati@mae.u-paris10.fr

Lin, Kuei-chen
University of California Los Angeles
kueichenlin@gmail.com

Litty, Susanne
HTW University of Applied Sciences
Susanne.litty@gmail.com

Liu, Haifeng
University of Science Beijing
ustb_liuhaifeng@hotmail.com

Liu, Siran
University College London
driverliu1987@gmail.com

Liu, Yu
Institute of Archaeology CASS
liuyu89@126.com

López-Garcia, Pedro
ENAH
dplopez14@gmail.com

Lubritto, Carmine
University of Naples
carmine.lubritto@unina2.it

Lucejko, Jeannette
University of Pisa
jlucejko@gmail.com

Lyaya, Edwinus
University of Dar es Salaam
edwinusl@yahoo.com

Maccarelli, Laura
Los Angeles County Museum of Art
lmaccarelli@lacma.org

Madkour, Fatma
Minia University
fatma_madkour@yaho.com

Maldonado, Blanca
El Colegio de Michoacán
bmaldon369@yahoo.com

Maltoni, Sarah
University of Padova
sarah.maltoni@gmail.com

Maniatis, Yannis
NCSR, “Demokritos”
maniatis@ims.demokritos.gr

Manrique-Ortega, Mayra Dafne
National Autonomous University Mexico
mayma@fisica.unam.mx

Martinez-Ferreras, Veronica
University of Barcelona
vmartinez@ub.edu

Martinon-Torres, Marcos
University College London
m.martinon-torres@ucl.ac.uk

Martirosyan-Olshansky, Kristine
Cotsen Institute of Archaeology
kristineolsh@ucla.edu

Mattison, Gary
Getty Conservation Institute
gmattison@getty.edu

Maupas, Elisa
KU Leuven
elisa.maupas@ees.kuleuven.be

Maurer, Christopher
State of Washington Dept. of Ecology
cmau461@ecy.wa.gov

McGlynn, George
SAPM
gc.mcglynn@extern.lrz-muenchen.de

Middleton, William
Rochester Institute of Technology
wdmgss@rit.edu

Mileto, Simona
Freie Universitat Berlin
simona.mileto@gmail.com

Minina, Elena
The Pushkin State Museum of Fine Arts
e_minina@mail.ru

Miramontes-Mercado, Ana Bertha
INAH
anabmm@gmail.com

Mishra, Kulbhashan
Indian Archaeological Society
mishra90@gmail.com

Monette, Yves
Canadian Museum of History
yves.monette@museedelhistoire.ca

Möncke, Doris
Friedrich-Schiller-University
doris.moenke@uni.jena.de

Mrđić, Nemanja
Archaeological Institute Belgrade
nemanjamrdjic@gmail.com

Muros, Vanessa
UCLA/Getty Conservation Program
vmuros@ucla.edu

Nagy, Zsolt
University of Szeged
zsoltdezsonagy@gmail.com

Nakazawa, Takashi
Nara Women’s University
t.nakazawa@cc.nara-wu.ac.jp

Neff, Hector
California State University Long Beach
hector.neff@sculb.edu

Neyt, Bert
KU Leuven
bert.neyt@ees.kuleuven.be

Nicolopoulos, Stavros
Appfive
info@nanomegas.com

Niespolo, Elizabeth
California State University Long Beach
eniespolo@gmail.com

Nikoei, Zahra
Islamic Azad University of Beyza
z7nikoei@gmail.com

Nöller, Renate
BAM
re.noeller@web.de

Nordgren, Eric
Cardiff University
nordgrenea@cardiff.ac.uk

Oikonomou, Artemios
School of Technological Applications
artemoikonomou@gmail.com

Oras, Ester
University of Cambridge
ester.oras@gmail.com

Owens, Shawn
University of Californa Santa Barbara
sowensis@gmail.com

Pääkkönen, Mirva
University of Turku
mirva.paakkonen@utu.fi

Pacheco, Claire
CR2MF
claire.pacheco@culture.gouv.fr

Pacheco, Gianella
Universidad Nacional Mayor de San Marcos
gianellap1982@hotmail.com

Palamara, Eleni
University of Peloponnese
el.palamara@gmail.com

Pecci, Alessandra
University of Calabria
alepecci@gmail.com

Perez-Arantegui, Josefina
Universidad de Zaragoza
jparante@unizar.es

Pernicka, Ernst
University of Heidelberg
ernst.pernicka@cez-archaeometrie.de

Perucchetti, Laura
Oxford University
laura.perucchetti@rlaha.ox.ac.uk

Pesce, Giovanni Luca
University of Bath
g.l.a.pesce@bath.ac.uk

Phelps, Matt
University College London
felpsy21@hotmail.com

Photos-Jones, Effie
Analytical Services for Art and Archaeology
effie@sasaa.co.uk

Piros, Réka ágnes
University of Szeged
pirosreka@hotmail.com

Plaza, Maria Tereza
University College London
tereplazacalonge@gmail.com

Pollard, Mark
RLAHA, University of Oxford
mark.pollard@rlaha.ox.ac.uk

Posadas, Lylliam
University College London
lylliam.posadas.12@ucl.ac.uk

Potts, Timothy
J. Paul Getty Museum
tpotts@getty.edu

Pozo, Iago
Getty Conservation Institute
ipozo@getty.edu
Preusser, Frank
Los Angeles County Museum of Art
fpreusser@lacma.org

Price, Capri
Portland State University
capprice@pdx.edu

Prikhodko, Sergey
University of California Los Angeles
sergey@seas.ucla.edu

Prior, Christine
Rafter Radiocarbon Lab
c.prior@gnc.cri.nz

Prochaska, Walter
University of Leoben
walter.prochaska@unileoben.ac.at

Prudencio, M. Isabel
C2TN
iprudenc@ctn.ist.utl.pt

Pryce, Thomas
Université Paris Ouest
opryce@gmail.com

Rabin, Ira
BAM
ira.rabin@bam.de

Rademakers, Frederick
University College London
frederik.rademakers@gmail.com

Radivojevic, Milana
University College London
m.radivojevic@ucl.ac.uk

Rainer, Leslie
Getty Conservation Institute
lrainer@getty.edu

Rambaldi, Diana
Los Angeles County Museum of Art
diana.rambaldi@gmail.com

Raturi, Shilpa
Metropolitan Museum of Art
Shilpa.Raturi@metmuseum.org

Regert, Martine
CEPAM-CNRS
martine.regert@cepam.cnrs.fr

Reiche, Ina
University of Paris 6
ina.reiche@upmc.fr
Renson, Virginie
University of Missouri
rensonv@missouri.edu

Rhodes, Edward
University of California Los Angeles
erhodes@ucla.edu

Ricci, Chiara
Universita di Torino
cricci@getty.edu

Rosenstein, Dana Drake
University of Arizona
ddr@email.arizona.edu

Ruffolo, Silvestro
University of Calabria
silverstro.ruffolo@unical.it

Sakai, Sachiko
University of California Santa Barbara
sachikosak@gmail.com

Saprykina, Irina
Institute of Archaeology RAS
dolmen200@mail.ru

Sarrazin, Philippe
SETI Institute
psarrazin@seti.org

Sasani, Anahita
University of Ferrara
anahita.sasani@student.unife.it

Scott, Becki
KU Leuven
becki.scott@ees.kuleuven.be

Shackley, Steve
University of California Berkeley
shackley@berkeley.edu

Shcherbakov, Nikolai
Bashkortostan Pedagogical University
sherbakov@rambler.ru

Shilstein, Sana
Weizmann Institute of Science
sana.shilstein@weizmann.ac.il

Shortland, Andrew
Cranfield University
a.shortland@cranfield.ac.uk

Shugar, Aaron
SUNY-Buffalo State
shugaran@buffalostate.edu
Shuteleva, Lia
Bashkortostan Pedagogical University
sherbakov@rambler.ru

Singh Farswan, Yogambar
H.N.B. Garhwal University
farswanys@yahoo.co.in

Skinner, Anne
Williams College
anne.r.skinner@williams.edu

Sokolov, Stanislav
All-Russian Scientific-Research Institute
vims-sokol@mail.ru

Soleimani, Parvin
ART University of Isfahan
soleimani.parvin@yahoo.com

Solongo, Saran
Mongolian Academy of Sciences
saransolongo@yahoo.com

Song, Guoding
Chinese Academy of Sciences
guodings@ucas.ac.cn

St. George, Ina
Linacre College
ina.stgeorge@arch.ox.ac.uk

Stanish, Charles
Cotsen Institute of Archaeology
stanish@ucla.edu

Sternberg, Rob
Franklin & Marshall College
rob.sternberg@fandm.edu

Stroud, Robert
Appfive
robert@appfive.com

Stuart, Barbara
University of Technology, Sydney
barbara.stuart@uts.edu.au

Teutonico, Jeanne Marie
Getty Conservation Institute
jteutonico@getty.edu

Tihanyi, Balazs
University of Szeged
balazs0421@gmail.com

Ting, Carmen
Universiteit Leiden
k.y.c.ting@arch.leidenuniv.nl
Tite, Michael
RLAHA, University of Oxford
michael.tite@rlaha.ox.ac.uk

Tohsaku, Carol
San Diego State University
ctohsaku@mail.sdsu.edu

Tonioke, Yukiko
Yale University
yukiko.tonoike@yale.edu

Trentelman, Karen
Getty Conservation Institute
ktrentelman@getty.edu

Tsakalos, Evangelos
NCSR, “Demokritos”
tsakalos.e@gmail.com

Twilley, John
Independent Conservation Scientist
jtwilley@sprynet.com

Tykot, Rob
University of South Florida
rtykot@usf.edu

Valiulina, Svetlana
Kazan Federal University
svaliulina@inbox.ru

van Brempt, Lente
University of Cyprus
van-brempt.lente@ucy.ac.cy

Venunan, Pira
University College London
pira.venunan.10@ucl.ac.uk

Waksman, Yona
CNRS, UMR 5138
yona.waksman@mom.fr

Wallis, Neill
University of Florida
nwallis@flmnh.ufl.edu

Walton, Marc
Northwestern University
marc.walton@northwestern.edu

Wang, Changsui
University of Chinese Academy of Sciences
cswang@ucas.ac.cn

Wang, Kuan-wen
University of Sheffield
kw.wang@sheffield.ac.uk

Wang, Rong
Fudan University
rongwang1980@gmail.com

Wang, Xiaoqi
Nanjing University
wangxiaoqiarch@163.com

Watson, Judy
University of Bristol
jw12854@bristol.ac.uk

Watson, Mary
grb329@yahoo.com

Wei, Shuya
University of Science and Technology Beijing
sywei66@hotmail.com

Wen, Rui
Northwest University Xi'an
rwen80@163.com

Whelton, Helen
University of Bristol
Helen.whelton@bristol.ac.uk

Wilke, Detlef
Dr. Wilke Management and Consulting GmbH
wilke@xrfarchaeometrics.com

Woodruff, Patrick
University of South Florida
pwoodruff@mail.usf.edu

Wright, Véronique
Institut Francais d'Etudes Andines
veronique.wright@ifea.org.pe

Wynn, Laura
Aristotle University
Lwynn@otenet.gr

Yang, Hsiao-Chin
National Prehistory Museum Taiwan
hcyang@nmp.gov.tw

Yang, Xiaogang
Chongqing Cultural Heritage Research Inst
654318159@qq.com

Yousefnejad, Soodabeh
Tehran University of Art
syousefnezhad@yahoo.com

Zacharias, Nikolaos
University of Peloponnese
zacharias@uop.gr

Zhao, Congcang
Northwest University Xi'an
zcc88886666@126.com

Zhu, Lizheng
New York University
lizheng.zhu@nyu.edu

Zipkin, Andrew
The George Washington University
amzipkin@gwmail.gwu.edu

Renishaw Inc
5277 Trillium Blvd
Hoffman Estates
Illinois IL 60192

T +1 847 286 9953
F +1 847 286 9974
E usa@renishaw.com
www.renishaw.com

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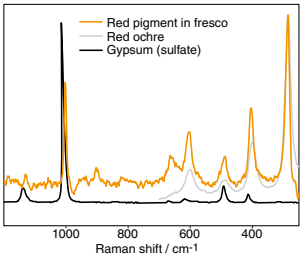
Identify pigments



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 mm^2) 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