

## **CERAMICS MATTER: 16<sup>TH</sup> EDITION OF THE EUROPEAN MEETING ON ANCIENT CERAMICS – EMAC 2023 & 1<sup>ST</sup> EMAC SCHOOL**

RANERI S.

Italian National Research Council, Institute of Chemistry and OrganoMetallic Compounds, Pisa,  
simona.raneri@pi.iccom.cnr.it

The European Meeting on Ancient Ceramics (EMAC) is a biennial conference convening scholars and young researchers with diverse academic backgrounds from both the humanities and sciences. The meeting aims to promote interdisciplinary and integrated studies of ancient ceramics, covering various aspects ranging from production, dissemination, and use to post-depositional alteration and conservation. Methodological developments, new approaches, and scientific advances are presented in terms of analytical and measuring techniques, data processing, and interpretation.

After two years of postponement, the 16<sup>th</sup> edition the European Meeting on Ancient Ceramics 2023 is back as in-person conference in Italy, which was the very first venue of EMAC. The 16<sup>th</sup> edition of the EMAC conference was initially expected for 2021, when it was postponed due to the pandemic; to keep active the community and promote the scientific discussion, in July 2021 a three-day online event - WAITING FOR EMAC2023@Pisa - offered the opportunity discussing recent research and future prospective on ancient ceramics studies, also favoring the participation of PhD students, post-doc, young researchers.

Organized by CNR-ICCOM-Pisa, in collaboration with the Dept. of Civilizations and Forms of Knowledge and Dept. of Chemistry of the University of Pisa, the 16<sup>th</sup> edition of EMAC Conference is introduced - for the first time - by a two-day School hosted by the University of Pisa in the amazing frame of the Collection of Plaster Casts and Antiquities and focused on the application of portable, non-destructive, non-invasive methods for the study of archaeological ceramics. Theoretical sessions given by scholars from different countries and research fields will introduce practical workshops.

During EMAC 2023 conference, researchers from both European and not-European countries will entail discussions on different topics, casting a glance over recent advances in ancient ceramics studies. To join the 2023 celebration of benefits and success of Open Science, a special session on Digital archaeology and pottery studies will introduce the Plenary session, set to be a fascinating exploration of the implications of Open Science and Open Data for ceramics studies.

This year, the collaboration with Siriusgame offered the opportunity for an epistemological reflection over our discipline, getting a glimpse of themes related to inclusion and democratization of science within the traditional EMAC scientific session; highlight the role of women in the production of ceramics, de-colonise the study of ceramics, discuss ethical issues in working with minorities and underrepresented communities, promote an inclusive research design through a continuous dialogue with expert whose work is committed to promotion of D&I, are some of the inspirations proposed.

The high quality of received contributes – included in this special edition of Plinius - enabled to build a rich scientific program, embellished by glamour social activities in the frame of the vivid city of Pisa.

The support of the Italian Society of Mineralogy and Petrology (SIMP) to the 1<sup>st</sup> edition of EMAC School and the 16<sup>th</sup> edition of EMAC Conference is acknowledged.

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The 16<sup>th</sup> European Meeting on Ancient Ceramics is organized by ICCOM-CNR-Pisa (Italian National Research Council, Institute of Chemistry and OrganoMetallic Compounds), in collaboration with the Dept. of Civilizations and Form of Knowledges and the Dept. of Chemistry and Industrial Chemistry of the University of Pisa.

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**INDEX****Plenary session**

Ancient ceramics meets open science J. Richards	11
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**School lectures**

Archaeology matters. New analytical methods for old research questions C. Sciuto	12
The new challenges of digital applications to archaeological pottery G. Gattiglia	13
Rendering visible patterns and non visible data of archeological potteries: from 2D to 3D imagery R. Chapoulie	14
Ceramic inside out: the portable (XRF) way V. Palleschi	15
Applying Roman spectroscopy in archaeometry research P. Vandenabeele	16
Using pXRF on archaeological ceramics in practice: a case study from 2 <sup>nd</sup> millennium CE Uganda H. Page	17
Analyzing ceramics: portable, mobile, and flexible methods in archaeology K.P. Schneider, R. Tagle, M. Gerken, M. Girona, F. Reinhardt, C. Hirschle, A. Menzies	18

**Scientific session*****S1. Digital archaeology and potteries studies***

Micro-CT scanning of minoan vases from Phaistos, Crete. Preliminary results on ceramic forming techniques of the Middle Bronze Age I. Caloi, F. Bernardini	19
Maiolica seen by Vis-NIR Hiperspectral Imaging: the application of an ultraportable camera at the Museo Nazionale del Bargello F. Galluzzi, M. Puntin, R. Manca, C. Sciuto, D. Paghi, M. Benvenuti, R. Chapoulie	20
Fabrics of ancient ceramics in the Mediteranean: the FACEM online database C. Hasenzagl, B. Borgers	21
Studying ancient ceramics in the Mediterranean with the FACEM database C. Hasenzagl, B. Borgers, V. Gassner, B. Bechtold	22
On group of 9 “Campana” reliefs in european museum collections T. Ilyina, E. Boyko, E. Minina, Yu. Svoyskiy	23
Creating ceramic typologies with network analysis. The hellenistic pottery from Sirkeli Höyük S. Marxer	24
Categorizing the visible and invisible attributes of ceramic pastes: a database for archaeometry M. Puntin	25

From sherds to web: the be-archaeo experience Y. Santos, M. Labate, M. Magalini, G. Pellis, P. Davit, N. Matsumoto, T. Nozaka, A. Seike, J. Ryan, J. Mitsumoto, V. Lombardo, A. Lo Giudice, E. Tema, M. Gulmini	26
<b>S2. Experimental archaeology, technological traces, use wear and organic residues</b>	
Influence of clay composition and firing temperature on pore formation of model pottery samples J-M. Cayme, R. Palm, P. Somelar, S. Vahur, I. Leito, E. Oras	27
The transformation of spathic calcite inclusions during the firing process of ancient calcite temper ceramics C. Lupi, F. Grazi, P. Pallecchi	28
Potsherds from “Cantiere delle Navi Antiche di Pisa”: extraction and analysis of the organic remains F. Nardella, M. Mattonai, J. La Nasa, A. Giannaccini, G. Pace, A. Camilli, E. Ribechini	29
A glimpse into the culinary practices of the Indus Valley Civilisation: A pottery case study from Bagasra (Gola Dhoru) S. Sarkar, S. Boyatzis, N. Zacharias	30
Developing new procedures for measuring pottery manufacturing traces through Laser Scanning Confocal Microscope. A pilot study from EBA Sicily S. V. Todaro, F. Giacoppo, G. Calandra	32
Reconstructing Judean iron Age Cooking pot production employing experimental archaeology L. Tramer	33
Experimenting variables in pottery manufacture within an ethnoarchaeological context, Paros Greece A. Tsoupra, V. Politakis, P. Barrulas, P. Moita, J. Mirao	34
Early neolithic pottery decorations: new insight from Rio Tana (AQ, Abruzzi, Italy) A. Vassanelli, A. Terranova, C. Petrinelli Pannocchia, P. Cignoni, M. Callieri	35
<b>S3. Raw materials ecologies and provenance</b>	
A history of Rhodian amphorae producers based on the chemical and mineralogical composition of stamped handles M. Abdelgawad, A. Bahnasy, N. Cantin, J. Empereur	36
Production and consumption of pottery in Coptos between the 1 <sup>st</sup> and 2 <sup>nd</sup> centuries AD A. Bahnasy, M. AbdelGawad, N. Cantin, D. Dixneuf	37
Glaze raw materials exploration and commercialization in Western Iberia during the Islamic period (10 <sup>th</sup> -13 <sup>th</sup> centuries) M. Beltrame, P. Barrulas, A. Tsoupra, J. Mirão, L. Dias, C. Vela	38
What Makes a Classic? Continuity of raw material procurement and ceramic fabrics in Pheneos, From the Bronze Age to the Classical Period C. Burke, V. Testolini, V. Xanthopoulou, I. Iliopoulos	39
Investigating the chemical composition of Roman fine ware from the area of East Locris and East Phokis: a comparison with clayey raw materials K. Christodoulou, A.-M. Pollatou, D. Grigoropoulos, A. Hein	40
Chemical Characterization of Bronze Age Nile clayey ceramics from northern Sudan - is it really all the same? G. D’Ercole, J.H. Sterba, J. Budka	41

Raw material and technology of production of Recent Neolithic pottery at Travo Sant'Andrea (Piacenza) G. Eramo, I.M. Muntoni, M. Bernabò Brea, M. Maffi	42
Archaic Amphorae from Vulci: an Archaeometric Approach C. Fornacelli, M. Giamello, D. Magrini, S. Rojo Muñoz, A. Zifferero	43
Sugar production in Cape Verde: archaeometrical characterization of Trindade sugar pots L. Gondim, J.G. Iñáñez, J. Monteiro, M. Almeida, J.B. Torres, G. Arana, A. Teixeira	44
Sancti Spiritus and around: indigenous ceramics and interactions from the first Spanish settlement in Argentina J. Iñáñez, A. Azkarate Garai-Olaun, I. Sánchez-Pinto, J. Solaun, S. Escribano, G. Cocco, G. Arana	45
Cultural Interaction between Naju and Jeju Island through Scientific Analysis of Pottery from Bogam-ri, Naju at the Iron Age of Southern Korea H. Jin, M.S. Lee, S. Jang	46
Red Slip Roman jugs from Cyprus: a question of provenance M. Kajzer, E. Marzec, E. Kiriati	47
From Byz with Wine: Archaeometric analysis of medieval amphorae from Poland A. Korokhina, S. Waksman, M. Auch, M. Tymoshenko, M. Trzeciński, N. Khamaiko, M. Woloszyn	48
Distribution in Gaul of amphorae produced in Fondi / Southern Latium in the Second Iron Age S. Lemaître, G. Thierrin-Michael, V. Thirion-Merle	49
Ceramic imitations of metalware in the late Hellenistic and early imperial Greek world : Mapping production centers using fabric provenance analysis F. Liard	50
Pottery of Argive provenance in coastal Thessaly during the Late Bronze Age according to Neutron Activation Analysis B. Lis, A. Batziou, J. Sterba, H. Mommsen	51
Locally made or imported: the archaeometric analysis of the ceramic materials from the Meroitic site of Sedeinga (northern Sudan) L. Maritan, M.E. Mascaro, C.N. Mc Carthy, D. Pasqual, R. David, C. Rilly	52
Hellenistic pottery from the Cyclades: provenance of epidote-rich cooking fabric E. Marzec, M. Kajzer	53
Ceramic production and raw materials in the Tuscan-Ligurian region: an archaeological and petrographic approach in a diachronic perspective S. Menchelli, C. Capelli, E. Starnini, R. Cabella, M. Piazza	54
Characterising pottery production and importation in Early Bronze Age Poliochni-Lemnos (Northeast Aegean): petrographic and geochemical analysis S. Menelaou, O. Kouka, E. Kiriati, N. Müller, C. Gardner	55
Neolithic and Bronze Age pottery consumption at Agriomernos Cave, Samos (Greece): compositional analysis and provenance determination S. Menelaou, E. Marzec, F. Georgiadis, S. Katsarou, A. Siros, A. Darlas	56
Petrographic and geochemical analyses of potsherds from Wadi Tanuf, Oman: Approaching pottery production in southeastern Arabia during the second and first millennia BCE T. Miki, T. Kuronuma, B.L. MacDonald, M. Glascock, Y. Kondo	57

The diffusion of Black Gloss pottery in the Western Mediterranean: archaeometry and data visualization C. Ortega Palacios, M. Madrid i Fernández, A. G. Sinner	58
Looking at the iron age in the interior Iberia and the mediterranean influences: ceramics from the archaeological site of “El pueyo de Marcuello” (Huesca, Spain) J. Pérez-Arantegui, P. Lapuente, J. Fabre, M.J. Arbués	59
Study of Ochre based pigment on Archaeological objects from different sites in Sicily for a possible provenance attribution G. Politi, S.V. Todaro, D. Gulli, Q. Lemasson, B. Moignard, C. Pacheco, L. Pichon, A.M. Gueli	60
Tracing the Cultural and Trade Relations of the Spanish Empire and the Lesser Caribbean Antilles in the 16 <sup>th</sup> and 17 <sup>th</sup> centuries through ceramic analysis S. Pujals, J. Buxeda i Garrigós, R. Montesana	61
The bell beakers of Cardim 6 and Porto Torrão (Southern Iberia): provenance of raw materials and circulation of “idea” A. L. Rodrigues, R. Marques, M. Dias, M. Prudêncio, A. Valera, K. Gméling	62
What is ‘La Hoguette’? A new methodological approach (p-XRF) to a familiar issue M. Schauer	63
Neolithic and Chalcolithic pottery from Ogliastritto (Italy): assessing raw materials procurement and paste preparation by petrographic analysis D. Serino, V. Cannavò, G. Ferraro, G. Verbicaro, S.T. Levi, A. Vanzetti, S. Marino	64
Chalcolithic and Bronze Age ceramics from Peñón de La Zorra (Alicante, Spain). Raw materials choice and technological change I. Serna Martínez, M. del Pino Curbelo, G. García Atiénzar, J. Buxeda Garrigos	65
Characterization of the Gemer whiteware (S Slovakia): first steps for the implication of a traceable folk pottery material type to the archaeological data V. Szilágyi, G. Vida	66
Medieval to early Modern Age (12 <sup>th</sup> – 18 <sup>th</sup> c.) whiteware on the Hungarian Plain (Alföld, E Hungary): a foreign material group in the pottery record V. Szilágyi, E. Simonyi, G. Tomka, M. Wolf, Z. Kovács, P. Kónya, K. Gméling, A. Kreiter	67
<b>S5. Technology and production</b>	
Insights into the Chupicuaro ceramic production during the Formative Period in Mesoamerica F. Alloteau, A. Ben Amara, N. Cantin, H. Cabadas Baez, S. Sedov, G. Ibarra, A. Castañeda, V. Darras	68
Unveiling technological traditions of Early Iron Age potters in Villanovan communities of Etruria (Central Italy) S. Amicone, L.F. Morandi	69
Archaeometric characterization of Italian Terra Sigillata fragments from Rome: preliminary data E. Arbolino, C. Germinario, G. Soricelli, G. Ricci, S. Morretta, C. Grifa	70
Archaeometric study of tin-glazed ceramics from Anabaptist pottery production centres in Moravia B. Bajnóczi, M. Szabó, G. Nagy, M. Tóth, Z. May, J. Pajer, A. Ridovics	71
Understanding technological choices in the production of early medieval marble tempered coarse wares in Pannonia K. Bajnok, Z. Kovács, B. Dönczö, M. Rigo, L. Maritan, Gy. Szakmány Gy.	72

The colours of Portuguese azulejos. A multi-analytical characterisation of decorated tiles and the replication of historical pigment recipes M. Bandiera, U. Veronesi, M. Manso, A. Pais, E. Esteves, A. Ruivo, M. Vilarigues, S. Coentro	73
Technologies and Traditions of Pottery and Plaster Production at Neolithic Makri, Thrace, Greece A. Barouda, P. Quinn, N. Efstratiou	74
Production Centers and Technology of Cooking Pots in Iron Age Judah D. Ben-Shlomo, L. Bouzaglou	75
Cooking Ware as indicator for Regional Trade and Exchange. A view from 4 <sup>th</sup> –1 <sup>st</sup> centuries BC southern Lazio (Italy) B. Borgers	76
Compositional and Technological Characterisation of Medieval Pottery Production at Utrecht, the Netherlands B. Borgers, E. Travé Allepuz, B. Bajnóczi, A. Griffioen	77
Historical recipes to produce blue As-free pigments by roasting minerals: use of Erythrite and Clinosafflorite to yield cobalt blue L. Bruzzone, L. Gaggero, A. Zucchiatti, J. Molera	78
An investigation on provenance and manufacturing technology of architectural terracottas from the Athenaiion in Castro (Apulia, Italy) E. Cantisani, S. Vettori, M. Franceschini, E. Fantechi, T. Ismaelli	79
Characterization of ancient ceramics and clay deosits from Battifratra Cave, Italy S. Capriotti, E. Chiarabba, N. Marconi, C. Conati Barbaro, L. Medeghini	80
Early ceramic technologies and traditions in the Edom Lowlands region of southern Jordan from a diachronic perspective S. Carrion Anaya, P.S. Quinn, M.M. Burton, M.D. Howland, A. Gidding, M. Najjar, T.E. Levy	81
Potters and Painters: Application of LIBS and LA-ICP-MS analysis on decorated fine Hellenistic tableware M. Charlton, M. Miše, J. Jovanović	82
How was it made? Studying the technology of Portuguese faience from the 16 <sup>th</sup> to the 18 <sup>th</sup> century S. Coentro, M. Bandiera, U. Veronesi, A.N. Pais, A. Castro, S. Pires, I. Coutinho, M.J. Cândido, J.M. Mimoso	83
Potters' technological choices in the Neolithic site of La Vela (north-eastern Italy) G. Deimichei, S. Amicone, A. Pedrotti	84
Copy and paste: Mediterranean imports and local ceramic production at the site of La Fonteta (Alicante, Spain) during the Early Iron Age (8 <sup>th</sup> –6 <sup>th</sup> centuries BC) M. del Pino Curbelo, I. Vinader Anton, E. López Rosendo, A.J. Lorrio Alvarado, M. Torres Ortiz	85
Local production of Ionian pottery at Cumae: the contribution of archaeometric analyses E. di Virgilio	86
Celadon Characterization by Synchrotron Radiation-Based XRD and Cathodoluminescence Microscopy M. Emami, R. Chapoulie, M. Abdellatif, Ph. Hans, M. Montazerzohouri	87
Compositional, textural and microstructural features of the pithoi produced from the VI to the IV century B.C. in the rural settlement of Jazzo Fornasiello near Gravina in Puglia (Apulia) G. Eramo, I.M. Muntoni, C. Lambrugo, A. Lojacono	88

Architectural Clay from the Oenotrian Settlement at Incoronata Greca (Pisticci, Matera): a Contextual and Technological Re-appraisal C. Germinario, S. Pagano, M. Mercurio, F. Izzo, E. Cantisani, S. Savelli, S. Todaro, S. Pope, C. Grifa	89
Human mobility and technological transfer between Greece and Southern Italy: the cases of Pithekoussai and Cumae. Project outline M. Giobbe, E. Kiriati, I. Lemos, N. Müller, M.A. Di Vito, S. De Vita, T.E. Cinquantaquattro, M. D'Acunto	90
From Jerez to the Atlantic: first archaeometric approach to Southwestern Andalusian ceramic trade containers production S. Guerrero-Rivero, J. Iñáñez, F. Amores-Carredano, G. Arana	91
Manufacturing Characteristics of Plant-Tempered Pottery in Jeju Island, Neolithic Korea: Insights from Fabric Microstructure and Mineral Phase Analysis S. Jang, H. Jin, H. Kim	92
Copy and Paste. Technological choices and skills adaptation in Pheneos, Arcadia R. Klöckl, V. Testolini	93
From macro to micro: advanced and experimental methods for the analysis of finishing techniques and post-firing treatments on ancient ceramics E. Koutouvaki, M. Vidale, S. Amicone, E. Aloupi, L. Maritan	94
Reconstruction of firing conditions of archaeological ceramics based on the identification of clay and index minerals K. Králová, R. Thér, A. Kloužková, M. Kolářová	95
Technical and stylistic specificities of incised glazed ceramics from Takht-e Soleyman using dark-coloured clay layers (Iran, 12 <sup>th</sup> /13 <sup>th</sup> Century CE) K. Kunst, F. Alloteau	96
Microstructure Analysis and Coloring Mechanism of the Black-Glazed Tea Bowls from the Jian Kiln of China W. Li	97
The early days of ceramic lead-glazing in the Ancient Mediterranean : Unravelling technological practices at Lesbos, central Greece, and central Italy F. Liard, A. Ben Amara	98
New Research on Shang Period Bronze Casting Ceramic Technology from Anyang, Henan Province, China S. R. Lin, J. Chen, P. S. Quinn, D.M. Kong	99
Fingerprinting ceramics from the Chalcolithic Santa Vitória enclosure (SW Iberia) R. Marques, A.L. Rodrigues, M.I. Prudêncio, M.I. Dias, A.C. Valera, A.C. Basílio, K. Gméling	100
Compositional study, provenance and circulation of Chalcolithic Bell beakers and Penha-type ceramics (NW Portugal) R. Marques, A.L. Rodrigues, D. Russo, M.I. Prudêncio, A.C. Valera, A.C. Basílio, R. Ramos, M.I. Dias, I. Harsányi, Z. Kasztovszky, V. Szilágyi, K. Gméling, I. Kovács, Z. Szókefalvi-Nagy	101
Technological Characterization of Production of Inka-Style Pottery in the Southern Border of Tawantinsuyu (Inka Empire) A. Martínez, P. Quinn, B. Sillar, S. Amicone	102
Lying on the seabed: modelling post-depositional alteration of pottery in marine environments M. E. Mascaró, R. Auriemma, R. Chapoulie, C. Mazzoli, H. Pezeshkanjalili, L. Maritan	103



The production of terra sigillata in Arezzo, central Italy: An archaeometric investigation M.E. Mascaro, E. Cantisani, M. Ricci, P. Pallecchi, S. Vilucchi, D. Pasqual, L. Maritan	104
Technological features of the Late Bronze Age pottery identified at Topolița (Neamț county), eastern Romania F. Matau, I. Breaban, M. Pintilei, O. Chiscan, V. Diaconu, A. Stancu	105
Modelling alteration processes experienced by Roman amphorae from Cratian underwater sites M. Mise, P. Quinn, M.E. Mascaro, L. Maritan	106
Iron and iron-manganese crystalline phases as tracers of ancient lead glaze production techniques J. Molera, E. Salinas, M. Colomer, O. Vallcorba, T. Pradell	107
A multi-analytical approach to investigate pottery manufacture and production at Helawa (Kurdistan Region of Iraq) during the Chalcolithic period (c. 5300-3800 BCE) G. Morabito, A. Vacca, L. Peyronel, G.D. Gatta	108
Revealing the know-how – integrated studies on cooking pottery manufacturing traditions from the 3 <sup>rd</sup> - 7 <sup>th</sup> centuries CE. A case study from Nea Paphos, Cyprus K. Nocoń, E. Marzec, E. Kiriati	109
Cooking ware at prehistoric Toumba Thessaloniki: an indicator of continuity in potting tradition and culinary practice T. Ogawa, S. N. Müller, H. Procopiou, S. Triantafyllou, S. Andreou, E. Kiriati	110
The origin of the lead used in the production of glazes: the case of maiolica made in the Florentine area between the 15 <sup>th</sup> and 19 <sup>th</sup> century D. Pagni, R. Manca, M. Casalini, L. Chiarantini, A. Bragagni, S. Tommasini, M. Benvenuti	111
Ychsma pottery production: Experimental archaeology to recreate the firing conditions D. Pareja, J. Iñáñez, R. Chapoulie, A. Ben Amara, L. Días	112
The neolithic pottery of Rio Tana (Central Italy, Abruzzo): new data from the archaeometric investigations G. Russo, C. Petrinelli Pannocchia, A. Vassanelli, L. Medeghini, S. Capriotti, S. Mignardi	113
Coiling your way up: New visual evidence of early Mesoamerican (Capacha) pottery forming techniques C. Salgado-Ceballos, Ó de Lucio Morales, A. Mitrani	114
Preliminary study on late roman pottery from Kyparissia, Peloponnese, Greece V. Valantou, E. Palamara, N. Zacharias	115
Exploring early mediaeval Cyprus through its cooking pots. Some preliminary remarks T.K. Vasileiou, A.K. Dr Vionis	116
<b>S.6 Theory and Methods</b>	
Representativeness of a ceramic assemblage - Significance and Confidence in relation to sample size A. Hein, J. Buxeda i Garrigós, V. Kilikoglou	117
Neutron activation analysis of archeological ceramics: an approach to creation of reference groups W. Badawy, A. Yu Dmitriev, V. Yu. Koval	118
Architectural and Hydrographic Reuse of Ceramics in Late Antique Ascalon S. Ehrlich	119

Investigating pottery forming techniques through the application of non-destructive small-angle neutron scattering (SANS) J. Gait, K. Bajnok, N. Hugot, G. Pépy, A. Len	120
Identifying the use of Iron age pottery from Tepe Sagzabad (Iran): Results from the first analysis of pottery residues M. Ghaleh, N. Eftekhari, M. Depahlavan, E. Marrocchino, C. Vaccaro	121
The archaeometry of ceramics: a quantitative review of the literature by bibliometric C. Grifa, C. Germinario	122
Comparison of rapid preparation methods for lead isotope analysis of high-lead ceramic glazes – A case study of the late medieval ‘Besztercebánya/Banská Bystrica-type’ stove tiles A. Horváth, B. Bajnóczi, D. Györkös, L. Palcsu	124
Discovering peoples, cultures, and technologies: development of a non-invasive approach on S’Arcu ‘e is Forros amphora (Sardinia) G. Morabito, N. Marinoni, C. Colombo, M. Catrambone, T. Pedrazzi, G.D. Gatta	125
Towards realistic phase analysis of low-fired ceramics: new experimental and micro-analytical approaches K.G. Nickel, A. Flicker, C. Berthold	126
Ceramic chronology by luminescence dating - a tool for a better understanding of infill dynamics in negative archaeological structures A.L. Rodrigues, R. Marques, M. Dias, M. Prudêncio, A.C. Valera	127
What has p-XRF ever done for us?! How statistical procedures can help to overcome prejudices against an analytical method M. Schauer	128
Sample preparation for Neutron activation analysis - pitfalls and best practices J.H. Sterba, M. Nemetz, M. Foster	129

## Plenary session

### ANCIENT CERAMICS MEETS OPEN SCIENCE

RICHARDS J.

Department of Archaeology, University of York, [julian.richards@york.ac.uk](mailto:julian.richards@york.ac.uk)

Open Science and Open Data are becoming increasingly prevalent in the Sciences and the Arts and Humanities. Funders requires it, publishers expect it, and colleagues applaud it. What does it mean for data sharing amongst pottery specialists?

This presentation will examine the implications of the FAIR Principles (Findable, Accessible, Interoperable and Reusable) for ceramics studies. It will highlight examples of good practice and consider both the challenges and opportunities of sharing ceramics data.

## School lectures

### **ARCHAEOLOGY MATTERS. NEW ANALYTICAL METHODS FOR OLD RESEARCH QUESTIONS**

SCIUTO C.

Department of Civilization and Form of Knowledge, University of Pisa, Italy, [claudia.sciuto@cfs.unipi.it](mailto:claudia.sciuto@cfs.unipi.it)

The recent development of portable instrument for carrying on non-destructive analysis on archaeological materials has fostered a paradigm shift in archaeometry. This also applies to archaeological pottery, for which -for example- the introduction of portable spectroscopic techniques has led to a multiplication of provenance studies. Non-destructive methods can be used extensively for characterising the materials, but the procedure should always be controlled to avoid problems with data processing. The evaluation of an artefact's characteristics and research goals are fundamental to planning data acquisition campaigns. Moreover, an adequate sampling strategy is crucial in order to gather relevant information for outlining the context.

The choice of methods and sampling is not only technical but represents a theoretical dilemma, because by selecting variables to record and items to measure, archaeologists are influencing the questions that could be posed to materials. The development of scientific applications must be grounded in a theoretical reflection on the implications of these practices for the interpretation of archaeological records.

## THE NEW CHALLENGES OF DIGITAL APPLICATIONS TO ARCHAEOLOGICAL POTTERY

GATTIGLIA G.

Department of Civilization and Form of Knowledge, University of Pisa, Italy, [gabriele.gattiglia@unipi.it](mailto:gabriele.gattiglia@unipi.it)

Digital technologies have certainly changed the way we do archaeology. The digital turn in the study of archaeological pottery has embraced quantitative and qualitative methods, statistical approaches, applied computational technologies, 3D models, GIS, spatial analysis, software and hardware development, sharing, openness, interoperability, and, more recently, AI.

Today, archaeologists are entangled, dependent, and even entrapped by the digital, but it is yet unclear how this is redesigning archaeological hermeneutics in this field of study. This contribution does not suggest focusing on the critique of one or more single digital applications or methods, rather on understanding how digital tools as an apparatus determine or make possible or allow us to study pottery, and in which way.

## **RENDERING VISIBLE PATTERNS AND NON VISIBLE DATA OF ARCHEOLOGICAL POTTERIES: FROM 2D TO 3D IMAGERY**

CHAPOULIE R.

Archéosciences Bordeaux /UMR 6034 CNRS, Université Bordeaux Montaigne, France, [chapouli@u-bordeaux-montaigne.fr](mailto:chapouli@u-bordeaux-montaigne.fr)

Highlighting the invisible and mapping the spectral signatures of selected targets is a quite intriguing question in ancient ceramics studies, especially in the recognition of specific decorative patterns. Among methods suitable for the scope, hyperspectral imaging stands out as a widespread non-destructive analytical imaging technique. In archaeology, it has been mostly applied for remote sensing satellite imagery to disclose information about features that are hidden undergrounds. Recent advances in portable instrumentation have led to the development of small and rugged cameras that can be used directly in the field or in museums where ceramic is commonly presented. Examples will be presented on the way of getting - in a very practical way - hyperspectral images in controlled and in uncontrolled external environment in a relatively short time. If the spatial resolution does not allow sharp details to be analyzed (decoration profiles), the spectral resolution is good enough to achieve automatic pattern recognition or detect fakes from large collections.

In the field of imagery, the integration of the whole of the analytical data collected on objects in 3D models is becoming an essential tool of research, especially meeting the needs of valorization (publication, museography). Specifically, the increased 3D imagery allows the complete exploration of the analytical results, by supporting the most accomplished knowledge of an object. A successfully set of examples is presented with a new computerized system which provides a Referenced Information System in 3D (RIS3D, ©Archeovision), a computer framework for storing, accessing, and displaying data related to positions on 3D models. It is related to geographical information systems but adapted to the specificities of 3D models as well as the required extended genericity due to the multiplicity of potential objects that can be addressed. Challenging and opportunity in building databases are discussed and a new vision in organizing database content is shown, with a peculiar attention on ceramic objects.

## **CERAMIC INSIDE OUT: THE PORTABLE (XRF) WAY**

PALLESCHI V.

Italian National Research Council, Institute for the Chemistry of OrganoMetallic Compounds, CNR-ICCOM Pisa, Italy,  
[vincenzo.palleschi@cnr.it](mailto:vincenzo.palleschi@cnr.it)

Energy-Dispersive X-Ray Fluorescence (ED-XRF) is a powerful elemental analytical technique that is mostly used for in-situ applications that need to use portable instruments. The non-destructive characteristics of ED-XRF and the possibility of working on samples without any pre-treatment make the technique especially interesting for the study of archaeological samples. In this lecture, we will discuss some practical aspects of the use of ED-XRF portable instrumentation for the analysis of ancient ceramics. We will highlight the advantages, but also the possible issues related to its use for the analysis of archaeological samples. Examples will be given of how to use ED-XRF spectra to find out the composition of ceramic samples or to classify them using the Graph Clustering method.

The lecture is a prerequisite for the Practical Workshop on ED-XRF, which will be held in the afternoon.

## APPLYING RAMAN SPECTROSCOPY IN ARCHAEOLOGY RESEARCH

VANDENABEELE P.

Department of Archaeology, Ghent University, Belgium, [Peter.Vandenabeele@UGent.be](mailto:Peter.Vandenabeele@UGent.be)

Over the last few decades, Raman spectroscopy has established itself as a highly regarded analytical technique in cultural heritage research due to its capability for non-destructive analysis of a wide range of materials. It is a powerful analytical tool that provides molecular spectroscopic information about the samples being studied. It is highly valued for its ability to rapidly acquire spectra from small organic and inorganic particles, down to approximately 1µm in size, without the need for extensive sample preparation. The method is also non-destructive, provided the laser power is kept low, which preserves the samples for further analysis. Raman spectroscopy even enables identification of products through packaging, offering applications such as the identification of counterfeit medicine through blister packaging. Today, various portable Raman systems are available commercially, enabling on-site, in situ measurements.

Raman spectroscopy's non-destructive nature is useful in the field of art analysis. By studying small paint samples, it helps detect fake artifacts, supports conservation, and determines the artifact's origin. The use of mobile instruments also adds value, allowing non-destructive, on-site analysis of valuable artifacts. When studying ceramics artefacts, a non-destructive approach can be used by focussing the laser to the surface of the object. Thus, it is possible to study the glaze composition or the pigments that are present. This approach was applied for the non-destructive analysis of porcelain. Moreover, if it is possible to work on embedded samples, the different layers can be studied, including the ceramics body. Thus, its mineral composition can be determined, shedding light on the production process of the fabric.



## **USING PXRF ON ARCHAEOLOGICAL CERAMICS IN PRACTICE: A CASE STUDY FROM 2<sup>ND</sup> MILLENNIUM CE UGANDA**

PAGE H.

Department of Civilization and Form of Knowledge, University of Pisa, Italy, [h.page@alumni.ucl.ac.uk](mailto:h.page@alumni.ucl.ac.uk)

This lecture presents a case study using pXRF in practice on a large assemblage of archaeological ceramics from the early 2nd millennium CE site of Ntuusi in western Uganda. This lecture will present a realistic view of the performance, issues, and practicalities of using pXRF on archaeological ceramics from the planning stage to data interpretation. This will include an examination of the practicalities of data collection in different working environments, the sampling of geological material, issues encountered with data transformation and processing, and the use of statistical software. Within data processing, a number of aspects including using geological standard data for precision and accuracy measurements, deciding on statistical transformation methods, and employing data analysis approaches including descriptive and multivariate statistics such as principal components analysis will be discussed. In particular, the case study will also discuss issues relating to the archaeological interpretation on pXRF ceramic data, in this case specifically the issue of relative geochemical homogeneity within the ceramic assemblage.

## ANALYZING CERAMICS: PORTABLE, MOBILE, AND FLEXIBLE METHODS IN ARCHAEOLOGY

SCHNEIDER K.<sup>1,\*</sup>, TAGLE R.<sup>1</sup>, GERKEN M.<sup>1</sup>, GIRONDA M.<sup>1</sup>, REINHARDT F.<sup>1</sup>, HIRSCHLE C.<sup>1</sup>,  
MENZIES A.<sup>1</sup>

<sup>1</sup>Bruker Nano Analytics, Am Studio 2D, 12489 Berlin

\*[kathrin.schneider@bruker.com](mailto:kathrin.schneider@bruker.com)

Portable X-ray fluorescence (XRF) spectrometers have developed over the last year to become a valuable tool in archaeological research, providing a range of features that extend beyond their portability. In this presentation, we will explore the features of portable XRF that make it a valuable tool for material research, with a particular focus on the analysis of ceramics. We will consider the potential limitations of this technique as well as best practices for real-world applications, whether in a laboratory environment or at an archaeological site.

Ceramics are the most commonly found artifacts in archaeological excavations and represent a precious cultural heritage that spans thousands of years. These finds range from everyday utensils used for cooking to transportation, storage, and even writing substrates. Hence, ceramics record human travel and cultural exchange like no other material.

Provenance analysis, or ceramic characterization, has typically been done geochemically, as well as petrographically and mineralogically. These invasive analytical methods are time-consuming and limit the number and choice of samples that can be analyzed, as unique cultural heritage objects are often too precious and therefore not available for invasive analysis. Non-invasive XRF-based elemental analysis offers a solution to this dilemma.

Portable XRF instruments are known to have one of the lowest limits of detection among all XRF instruments, easily reaching down to single-digit ppm for a vast number of elements. This feature rests in the ideal geometry of the instrument, where the detector is extremely close to the sample at a large solid angle. The range of detectable elements can even go down to Fluorine in certain models of TRACER if a helium purge is used. However, the limiting factor of analysis of light elements like F is not the detection limit but it's relevance for the analytical question, sample homogeneity, and sample preparation under real-life conditions.

However, applying XRF to ceramics presents a major challenge that is often overlooked. The main chemical components of ceramics, i.e., Na, Mg, Al, Si, K, Ca, and Fe, are considered relatively light elements in XRF analysis and have a low information depth of less than 50  $\mu\text{m}$  in a sample. This results in sample-related analytical uncertainty, as the composition of the surface of the object might not be representative of the bulk sample due to coating processes or contamination during use and subsequent ground deposition, which can strongly affect analytical outcomes.

To address this issue, an analytical solution is to focus on elements with fluorescence in a higher energy range, such as Rb, Sr, Y, Zr, and Nb, which can achieve higher information depths of several hundred micrometers. We will present results obtained using Bruker's portable XRF instrument TRACER 5g to demonstrate that XRF is a powerful tool for quantification of ceramics even at low elemental concentrations. We will show that using elements of the higher energy range provides more robust and reproducible results compared to the complete range of detectable elements. Additionally, we would like to suggest a measurement protocol for a ceramic provenance study based on portable XRF, taking into consideration not only the instrument's analytical capabilities but also the nature of the sample to be analyzed.

## SCIENTIFIC SESSIONS

### S1. Digital archaeology and potteries studies

#### MICRO-CT SCANNING OF MINOAN VASES FROM PHAISTOS, CRETE. PRELIMINARY RESULTS ON CERAMIC FORMING TECHNIQUES OF THE MIDDLE BRONZE AGE

CALOI I.<sup>1,\*</sup>, BERNARDINI F.<sup>1</sup>

<sup>1</sup>Dipartimento di Studi Umanistici, Università Ca' Foscari Venezia, Fondamenta del Malcanton, 30100 Venezia, Italy,

\*[icaloi@unive.it](mailto:icaloi@unive.it)

Keywords: micro-CT scanning, forming techniques, Minoan Crete

This paper aims to provide preliminary results of X-ray computed micro-tomography (micro-CT) scanning of vases from the Minoan palatial site of Phaistos (Crete), dating to the Protopalatial period, corresponding to Middle Minoan IB-MM IIB (1900-1700 BC). The micro-CT scanning has allowed to visualize the inner micro-structure of the vases both in 2D and 3D, to analyze the orientation of voids and inclusions, and to estimate joins and cracks. These elements have helped in identifying the construction units of the vases, mainly layers or clay lumps, and in decoding the sequential gestures of the potters, while building the roughouts of the vessels, shaping/finishing or throwing the pots on the wheel. The preliminary results of this work will be presented showing the three main forming techniques identified: the layer-building technique, which is mainly adopted to construct middle-sized jugs in semi-fine fabrics; the combination of the layer-building technique and the wheel, used to produce both middle-sized and small vessels; the wheel-throwing technique, which is adopted only for small and miniature open vessels, mostly cups. The use of micro-CT scanning, first applied on Minoan vases from Protopalatial Phaistos, has confirmed some of the results obtained through macroscopic analyses, such as the almost total absence of coils in the Protopalatial vases from Phaistos, the extensive adoption of the layer-building technique, both with or without wheel, and the large adoption of combining different, separately produced, parts of a vase on the wheel.

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## MAIOLICA SEEN BY VIS-NIR HYPERSPECTRAL IMAGING: THE APPLICATION OF AN ULTRAPORTABLE CAMERA AT THE MUSEO NAZIONALE DEL BARGELLO

GALLUZZI F.<sup>1\*</sup>, PUNTIN M.<sup>2</sup>, MANCA R.<sup>3</sup>, SCIUTO C.<sup>2</sup>, PAGHI D.<sup>3</sup>, BENVENUTI M.<sup>3</sup>, CHAPOULIE R.<sup>1</sup>

<sup>1</sup> Archéosciences Bordeaux /UMR 6034 CNRS, Université Bordeaux Montaigne, France

<sup>2</sup>MAPPA Lab, Department of Civilizations and Forms of Knowledge, University of Pisa, Italy

<sup>3</sup>Dipartimento di Scienze della Terra, Università degli Studi di Firenze, Italy

\*[francesca.galluzzi@u-bordeaux-montaigne.fr](mailto:francesca.galluzzi@u-bordeaux-montaigne.fr)

Keywords: hyperspectral imaging, glazed pottery, Museo Nazionale del Bargello

Collections of glazed ceramics in museums represent a key resource for the study of the manufacturing techniques and materials used, as well as the evolution of museography and restoration strategies over time. The investigation of museum objects, however, can be challenging since it often requires the use of non-invasive techniques and ultraportable instruments. Hyperspectral Imaging (HSI) presents several advantages in this context since it i) allows to perform non-invasive and contactless analysis; ii) can be performed with highly portable cameras; iii) does not provide health and safety constraints linked to ionizing radiation; iv) is fast and easy for data acquisition, thus allowing the screening of large areas and/or a high number of objects (Sciuto et al., 2022).

In this study, we propose the use of an ultraportable HSI camera (IQ-SPECIM) operating in the Vis-NIR range (400-1000 nm) for the study of a selection of tin-glazed pottery (maiolica) of the Museo Nazionale del Bargello in Florence (Italy). The study aimed to acquire information on original Renaissance maiolica, 19th-century forgeries and pastiches of authentic and forged/restored parts, distinguishing between them. Multivariate statistical modelling such as PCA (Principal Component Analysis) and SAM (Spectral Angle Mapper) led to clear analytical discrimination and exact localization of the restored/forged areas and the original ones in the objects under study. Through multivariate modelling, it was also possible to identify outlier pixels due to scattering effects. Moreover, HIS and XRF mappings (Manca et al., 2019) proved to be complementary in identifying colouring agents and, in some cases, in highlighting differences between glazes with similar colours but slightly different compositions; for example, different types of cobalt-based blues were recognized.

In conclusion, this study showed that ultraportable HSI cameras can be a powerful tool for a fast and straightforward screening of museum collections to discriminate between different types of glazes and pigments in maiolica wares and verify their authenticity. The acquisition of a more extensive HSI database is therefore suggested.

### ACKNOWLEDGEMENTS

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## FABRICS OF ANCIENT CERAMICS IN THE MEDITERRANEAN: THE FACEM ONLINE DATABASE

HASENZAGL C. <sup>1,\*</sup>, BORGERS B. <sup>2</sup>

<sup>1</sup>Department of Archaeology, Ghent University, Ghent, Belgium

<sup>2</sup>Department of Classical Archaeology, University of Vienna, Vienna, Austria

\*[Carina.Hasenzagl@UGent.be](mailto:Carina.Hasenzagl@UGent.be)

Keywords: fabric studies, pottery provenance, data sharing

The FACEM online database ([www.facem.at](http://www.facem.at)) brings together thousands of high-resolution fabric images of Greek, Punic, and Roman ceramics in the Mediterranean, making them openly available to everyone, from pottery specialists to students. FACEM's research methodology combines the examination of pottery at a macro- and microscopic level with thin-section petrography and chemical analyses as a means to identify the production technology, provenance, and distribution of ceramic finds essential for the reconstruction of broader socio-economic evaluations and ancient trade networks. In addition to data on the petrographic and chemical fabric composition, information on vessel typo-chronology and archaeological contexts is also included. So far, the evidence has been drawn from more than 50 archaeological sites in the Mediterranean.

With its headquarters at the University of Vienna and many international research partners, FACEM supports interdisciplinary scholarship and ceramic data sharing. Since its first release in 2011, it has grown into a well-known research community, especially on amphorae and black-glazed wares from the 6th to the 2nd c. BC. On behalf of FACEM's founders and the editorial board, we are proud to announce the launch of the 9<sup>th</sup> release, extending the chronological and geographical scope that will open new pathways for investigating a wide range of pottery wares produced in the Mediterranean between the 6th c. BC and the 7<sup>th</sup> c. AD. This paper provides a brief overview of FACEM's database and website structure. It will introduce the repertoire of included pottery wares and demonstrate how the database can be used, highlighting the potential and benefits of digital records in querying and comparing data as well as communicating and visualizing results.

## STUDYING ANCIENT CERAMICS IN THE MEDITERRANEAN WITH THE FACEM DATABASE

HASENZAGL C.<sup>1,\*</sup>, BORGERS B.<sup>2</sup>, GASSNER V.<sup>2</sup>, BECHTOLD B.<sup>2</sup>

<sup>1</sup>Department of Archaeology, Ghent University, Belgium

<sup>2</sup>Department of Classical Archaeology, University of Vienna, Austria

\*[Carina.Hasenzagl@UGent.be](mailto:Carina.Hasenzagl@UGent.be)

Keywords: fabric studies, pottery provenance, data sharing

Are you searching for freely accessible high-resolution fabric images and constantly updated data to compare your ceramic finds and share your expertise on pottery provenance?

Then, the FACEM Project might be what you have been looking for.

FACEM (= Fabrics of Ancient CERamics in the Mediterranean) is an online collection of fabrics of Greek, Punic, and Roman ceramics (e.g., Black Glazed Wares, Transport Amphorae, Coarse Wares, ceramic building materials, terra sigillata) produced between the 6th century BC and the 7<sup>th</sup> century AD in different Mediterranean workshops. Designed for pottery specialists and researchers worldwide, it follows pioneering scholarship and provenance studies by offering a web-based information system committed to the open-access publication of results. Founded in 2011 at the University of Vienna, FACEM has grown into an interdisciplinary research community sharing ceramic data as a means to identify the production technology, provenance, and distribution of ceramic finds essential for the reconstruction of broader socio-economic evaluations and ancient trade networks. After more than a decennium of fabric studies, Facem provides thousands of macro photographs in different magnifications with zoom-in options on the clay matrix and temper, as well as data on the petrographic fabric composition, vessel typo-chronology, and archaeological context.

We are happy to announce the 9th release of FACEM, which has also welcomed new research partners. This updated database will include new ceramic classes for investigating an even wider range of ceramic classes (e.g., African Red Slip Ware) produced in the Mediterranean.

## ON GROUP OF 9 “CAMPANA” RELIEFS IN EUROPEAN MUSEUM COLLECTIONS

ILYINA T.<sup>1</sup>, BOYKO E.<sup>1-2,\*</sup>, MININA E.<sup>1</sup>, SVOYSKIY YU.<sup>2-3</sup>

<sup>1</sup>The Department of Art and Archeology of the Ancient World, the Pushkin State museum of Fine Arts, Russia

<sup>2</sup>Centre of Classical and Oriental Archaeology, Institute for Oriental and Classical Studies, National Research University, Higher school of economics, Russia

<sup>3</sup>Laboratory RSSDA

\* [muhobojko@gmail.com](mailto:muhobojko@gmail.com)

Keywords: architectural terracotta, 3d-modelling, museum collections

The Department of Art and Archeology of the Ancient World of Pushkin Museum has two terracotta slabs attributed to the group of "Campanian reliefs". These reliefs depict a woman's head in profile (inv. II 1a 209, 210). They are absolutely identical to each other, as well as to two slabs from the Louvre (inv. 3874.1-2; 3875.1-2) and, probably, four slabs from the Ny Carlsberg Glyptothek and one – in Berlin Antikensammlung.

Both Moscow ones are glued together from similar fragments with significant plaster additions; on their surface they are tinted in the color of clay. The provenance of the Moscow and Danish plates are associated with Wolfgang Gelbig (1890-1900-s), but the first appearance of such a reliefs is related with Giampetrino Campana and his collection in Rome in 1840-s.

In 2020, in the catalogue of exhibition dedicated to the Campana collection refers to the Louvre relief as a 19th-century reproduction. Also, we drew attention to the absence of other similar exhibits, both in its entirety and in fragments, in world collections; their antique origin; as well as iconographic and stylistic features, we have doubts about the authenticity of this type of reliefs in general.

The closest analogue for this group is the matrix from the Vatican Museums (inv. MF.14070), originating from the Stanisław Poniąkowski collection: it reproduces only a quarter of the relief. The reliefs differ from the Vatican Matrix only in the absence of a rosette in the upper right corner, also in the different materials. We carefully examined the reliefs and found some differences between them. Together RSSDA laboratory we prepared a 3d models of 2 Moscow slabs to find the differences and common places between them. The report will be devoted to the origin of the reliefs and the technology of their production.

## CREATING CERAMIC TYPOLOGIES WITH NETWORK ANALYSIS. THE HELLENISTIC POTTERY FROM SIRKELI HÖYÜK

MARXER S.

Institut für Archäologische Wissenschaften, Universität Bern Archäologisches Seminar, Philipps-Universität Marburg, Switzerland, [sophia27@live.de](mailto:sophia27@live.de)

Keywords: Network Analysis, Hellenistic Pottery, Sirkeli Höyük

The presented project is part of my PhD thesis «Material Culture on the Move. The Transition from the Late Iron Age to the Hellenistic Period on Basis of the domestic pottery in Cilicia», which I have been writing since October 2021 at the University of Bern (Switzerland) in Near Eastern Archaeology and since October 2022 in the framework of a Cotutelle (binational promotion) at the University of Marburg (Germany) in Classical Archaeology.

### *Data*

The main material basis is formed by the finds from the excavations at Sirkeli Höyük. Sirkeli Höyük is one of the largest settlement mounds in Cilicia and is located 40 kilometers east of Adana. Sirkeli Höyük is about 350 meters by 300 meters and consists of an oval main mound and a flat terrace in front to the north, which form an 8 hectares citadel that was located on the north side of the walled city of over 20 hectares. The site was inhabited from the Chalcolithic throughout the Bronze Age and Iron Age until the Hellenistic Period (Novák et al., 2020). So far, in cooperation with the excavation team of the Sirkeli Höyük Project, I was able to add 8.709 Hellenistic pottery fragments to the project database, of which 2.887 pieces were examined by me in more detail. The documentation is completed by drawings and photographs of the sherds as well as fracture photographs for macroscopic examinations of the fabric.

### *Research Questions*

The main question of my poster is: How does the Hellenistic pottery in Sirkeli Höyük look like? What are the most common wares, fabrics, decorations, surface treatment and shapes? Which of these occur together? Do we see any difference in the ceramic from the various excavation areas? To answer these questions, I'm using the program Nodegoat to run network analysis and visualize data (Knappett, 2015; Peeples, 2019; Van der Leeuw – Sander, 2013). I made an own Nodegoat project and added all my data from the excavation from Sirkeli Höyük. With different query I was not only able to update the typology of the Hellenistic pottery but also to answer all my research questions and beyond. Because of my own ground-breaking results, I want to present this new easy method to analyse ceramic data and create typologies.

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## CATEGORIZING THE VISIBLE AND INVISIBLE ATTRIBUTES OF CERAMIC PASTES: A DATABASE FOR ARCHAEOOMETRY

PUNTIN M.

Department of Civilizations and Forms of Knowledge, University of Pisa, Italy, [massimiliano.puntin@gmail.com](mailto:massimiliano.puntin@gmail.com)

Keywords: database, archaeometry, ceramic pastes

Recently, digital and methodological progress has modified archaeological research methods, both in field and in laboratory. The shift concerns processes of data acquisition, preservation, processing, analysis and sharing. For the study of ceramic artifacts, methodological experimentation is increasingly being combined with typological and archaeometric study of materials in order to clarify the dynamics of production. Diagnostic and archaeometric techniques, primarily minero-petrography, are quite used during these studies, however results are often not provided as raw data and are hardly reusable by other users.

Considering the large amount of data produced by these methods, it seemed necessary to create a database to store and interrogate information. It is composed of three entities connected to each other that allow to view contextual, physical, compositional information. This system archives previous and recently acquired data, and searches through queries the characteristics in common between the individual samples and ceramic pastes. That's possible thanks to open *thesauri*, created by referring to the bibliography, that facilitate the compilation of the database through lexical uniformity (Gattiglia, 2018).

Another aim of the database is to describe ceramic pastes in the most objective way using software pipelines to determinate the percentage of inclusions and porosity and surface colour. The database allows to enter data from petrographic, chemical and physical analysis in specific fields and upload files.

It is possible to enter information on ceramic pastes from previous studies, normalizing terminology where possible, and allowing them to be compared with data obtained from the analysis of samples.

The database, released as open data, is applicable to every ceramic category. By coupling analytical data and visual observations, it becomes possible to classify ceramic pastes and compare their characteristics with those from other literature.

The identification of ceramics with similar properties allows to cluster raw materials, characterize production techniques, and determine artifacts' provenance.

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## FROM SHERDS TO WEB: THE BE-ARCHAEO EXPERIENCE

SANTOS Y.<sup>1,\*</sup>, LABATE M.<sup>1</sup>, MAGALINI M.<sup>2</sup>, PELLIS G.<sup>1</sup>, DAVIT P.<sup>1</sup>, MATSUMOTO N.<sup>3</sup>, NOZAKA T.<sup>4</sup>, SEIKE A.<sup>5</sup>, RYAN J.<sup>3</sup>, MITSUMOTO J.<sup>5</sup>, LOMBARDO V.<sup>6</sup>, LO GIUDICE A.<sup>2</sup>, TEMA E.<sup>7</sup>, GULMINI M.<sup>1</sup>

<sup>1</sup>Department of Chemistry, University of Torino, Italy

<sup>2</sup>Department of Physics & INFN, University of Torino, Italy.

<sup>3</sup>Research Institute for the Dynamics of Civilizations, Okayama University, Japan.

<sup>4</sup>Department of Earth Sciences, Okayama University, Japan.

<sup>5</sup>Faculty of Humanities and Social Sciences, Okayama University, Japan.

<sup>6</sup>Department of Computer Sciences, University of Torino, Italy.

<sup>7</sup>Department of Earth Sciences, University of Torino, Italy.

\*[yuri.leitesantos@unito.it](mailto:yuri.leitesantos@unito.it)

Keywords: Database, semantic web, data curation

During the last decades, the number of archaeometric investigations carried out on pottery sherds from archaeological excavations and museum collections is exponentially increasing, offering precious information for better understanding their technology, provenance, and use. Digital items (data files, pictures, etc.) produced through various archaeometric techniques carry specific information that, once interpreted, produces new knowledge, enriching the archaeological inferences. However, in most cases, only the final data interpretation is available, published in specialized journals or disclosed in excavation reports. The access to digital data in different stages of analysis remains therefore difficult for the international scientific community, preventing future developments and new interpretations. Archaeometers are now called upon to overcome these limits by playing an active role in tailoring the structure of databases, providing computer scientists with the expertise to design suitable tools that make data accessible to both scholars and the general public. In this framework, the semantic database developed within the BE-ARCHAEO project (H2020-MSCA-RISE n. 823826), called BeA, implements an encompassing integration of archaeological and archaeometric knowledge (Lombardo et al., 2022). Digital items from archaeological and archaeometric investigations have been organized according to a four-step digital data curation approach: 1) data acquisition, to record raw data from the stratigraphic units and the archaeological findings; 2) data processing and modelling, to document data treatments; 3) data interpretation, to yield the information about a specific sherd/observation and 4) publication, which displays such information in a variety of ways, from scientific papers and websites to mobile applications and/or virtual reality tools.

In such procedure, data encoding plays a key role in stimulating reflectivity allowing the scientist (and user) to record (and follow) the procedure at different steps, from raw data to knowledge. Moreover, the availability of data from different instrumental techniques makes the comparison of the multi-disciplinary outcomes challenging but necessary to support a transdisciplinary approach. This presentation demonstrates the strengths of the BeA approach for the interpretation of archaeological findings by presenting, as a case-study, the multi-technique archaeometric analyses of sherds from the Tatetsuki burial mound, a 2<sup>nd</sup> century CE tomb in Soja city (Okayama prefecture, Japan). The results are currently available as a website (<https://bearchaeo.unito.it/omeka-s/s/bearchaeo-resources-site/page/welcome>).

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## S2. Experimental archaeology, technological traces, use wear and organic residues

### INFLUENCE OF CLAY COMPOSITION AND FIRING TEMPERATURE ON PORE FORMATION OF MODEL POTTERY SAMPLES

CAYME J.-M.<sup>1,\*</sup> PALM R.<sup>1</sup>, SOMELAR P.<sup>2</sup>, VAHUR S.<sup>1</sup>, LEITO I.<sup>1</sup>, ORAS E.<sup>1-3</sup>

<sup>1</sup>Institute of Chemistry, University of Tartu, Estonia

<sup>2</sup>Department of Geology, University of Tartu, Estonia

<sup>3</sup>Department of Archaeology, University of Tartu, Estonia

\*[jan-michael.cayme@ut.ee](mailto:jan-michael.cayme@ut.ee)

Keywords: porosity, clay, archaeological pottery

The porosity of unglazed pottery has been seen as a crucial characteristic for the adsorption and retention of food residues in ancient ceramics. These pores protect the organic biomolecules against microbial degradation and water leaching during the deposition (Oras et al., 2017; Drieu et al., 2019). The role of the clay matrix's physical and chemical properties in producing these pores, particularly the nano-sized pores, is not fully understood. This study attempts to describe the formation of nano-sized pores in different clay model samples patterned according to the characteristics of archaeological pottery.

Different mass ratio combinations of local Estonian clay (i.e., illite-smectite type) and a commercial kaolinite clay, and tempers consisting of crushed rocks and CaCO<sub>3</sub> to mimic the addition of shells, were experimentally produced and fired separately in a furnace at 600°C and 800°C, respectively. The mineral composition was investigated using X-ray Diffraction (XRD), and the resulting nano-sized pores were evaluated using a nitrogen (N<sub>2</sub>) porosimeter, identifying the changes in the micropore and mesopore ranges. Results show that there is a good correlation ( $R^2 > 0.90$ ) between the amount of clay and the total pore volume ( $V_{TOT,41\text{ nm}}$ ) and pore surface area ( $S_{BET}$ ) with crushed rock and CaCO<sub>3</sub> temper. Specifically, as the clay component increases,  $V_{TOT}$  and  $S_{BET}$  increase as well. Relative to the amount of CaCO<sub>3</sub> added, the pore characteristics decrease as the amount of added CaCO<sub>3</sub> increases. However, for kaolinite-derived samples fired at 800°C, it was observed that correlations decreased ( $R^2 < 0.50$ ), which is due to the formation of larger grain-sized post-firing mineral phases. The results of this work will further contribute to providing background information for predicting organic (lipid) preservation and selecting pottery samples for organic residue analysis (ORA).

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## THE TRANSFORMATION OF SPATHIC CALCITE INCLUSIONS DURING THE FIRING PROCESS OF ANCIENT CALCITE TEMPER CERAMICS

LUPI C.<sup>1,\*</sup>, GRAZZI F.<sup>2</sup>, PALLECCHI P.<sup>3</sup>

<sup>1</sup>External collaborator, Soprintendenza Archeologia Belle Arti e Paesaggio per la città metropolitana di Firenze e le province di Pistoia e Prato, Italy

<sup>2</sup>Consiglio Nazionale delle Ricerche, Istituto di Fisica Applicata 'Nello Carrara', Italy

<sup>3</sup>Soprintendenza Archeologia Belle Arti e Paesaggio per la città metropolitana di Firenze e le province di Pistoia e Prato, Italy

\*[caterinalupi98@gmail.com](mailto:caterinalupi98@gmail.com)

Keywords: calcitic temper, firing process, experimental archaeology

One of the main ceramic pastes that has been produced since the Neolithic period is characterized by the intentional addition to clay, of crushed spathic calcite as temper.

Our work aims to increase the knowledge concerning the use of this raw material and its behavior during the ceramic firing, to provide an indication of the original firing temperature of the artefact. To achieve this, an analysis of the characteristics of spathic calcite crystals was carried out on nine prehistoric ceramic samples found in Neolithic contexts in Tuscany.

In order to have a comparison, a study was conducted to investigate the behavior on single calcite crystals and a clayey mixture with calcite temper. This paste was prepared in the laboratory according to the compositional aspects obtained from the examination of the forementioned prehistoric samples. The samples were cooked in a muffle furnace at a temperature ranging from 650° C to 900°C, at temperature intervals of 50°C, in an oxidizing environment.

Overall, the samples subjected to analysis were twelve, six with the same ceramic paste cooked at different temperatures and six calcitic elements at the same particle size of those contained in the ceramic paste.

All the samples underwent a mineralogical analysis by X-ray diffraction and morphological analysis by scanning electron microscope, while the Raman spectroscopy enabled to investigate the development of calcination at a microscopic level. A petrographic analysis was also conducted on thin sections by polarizing microscope.

Results on single calcite crystals indicate an initial transformation into calcium hydroxide at 750°C, while transformation into calcium oxide begins at 800° C and ends at 900°C.

SEM studies reveal that calcite crystals present microcracks already at 700°C and an evident morphological modification at a higher temperature. In ceramic pastes transformations start at higher temperatures and occur principally on the external surfaces of the artefact. The laboratory-prepared specimens show textural modifications and morphological changes of the calcite crystals at 750°C and their complete destruction at above 900°C. By comparing these variations to the characteristics of the calcite inclusions observed in the archaeological samples, we obtained a better evaluation of the firing temperature and the manufacturing techniques of the archaeological artefacts analysed.

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## POTSHERDS FROM “CANTIERE DELLE NAVI ANTICHE DI PISA”: EXTRACTION AND ANALYSIS OF THE ORGANIC REMAINS

NARDELLA F.<sup>1,\*</sup>, MATTONAI M.<sup>1</sup>, LA NASA J.<sup>1</sup>, GIANNACCINI A.<sup>1</sup>, PACE G.<sup>2</sup>, CAMILLI A.<sup>2</sup>,  
RIBECHINI E.<sup>1</sup>

<sup>1</sup>Department of Chemistry and Industrial Chemistry, University of Pisa, Italy

<sup>2</sup>Museo delle Navi Antiche di Pisa, Italy

[\\*federica.nardella@dcci.unipi.it](mailto:federica.nardella@dcci.unipi.it)

Keywords: ceramic, chromatography, mass spectrometry

This work describes the research carried out within ARCANA (Archaeometry investigations at the Cantiere delle Navi Antiche di Pisa) project funded by the Tuscany region and aimed at the development and optimization of analytical methods mainly based on chromatography and mass spectrometry to study organic residues in archaeological ceramic. The archaeological site of “Cantiere delle Navi Antiche di Pisa” located in Pisa, was the ancient commercial harbor which disclosed a series of ship wreckages and their loads of commercial items in an excellent state of preservation. Among these, ceramic artefacts were the more numerous. Ceramic has been one of the most common materials used for preparation, storage, cooking and transport of numerous products since ancient times. Potsherds can preserve organic substances over time and the organic residue analysis can provide several information on ancient populations (Heron & Evershed, 1993; Blanco-Zubiaguirre et al., 2018). The characterization and the consequent identification of the uses of the ceramic remains is very complex because of the compositional modification incurred by the original material at molecular level.

Within ARCANA project, innovative methods to extract the samples were settled in order to improve the recovery of the analytes of interests maximizing the information achievable from a micro-sample. As a preliminary approach, the research was focused on food residue with particular attention to lipids. Experimental design strategies were employed starting from the study of reference samples. The mockups, prepared by spiking virgin ceramic with standard solutions of triacylglycerides and oils, were subjected to artificial aging with the attempt of recreating the reactions occurred in the original material. The optimized methods will be adopted to investigate the archaeological findings collected from the site. The obtained analytical data will be combined with the other characteristics of the samples such as origin and morphology and correlated with the archaeological background.

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## A GLIMPSE INTO THE CULINARY PRACTICES OF THE INDUS VALLEY CIVILISATION: A POTTERY CASE STUDY FROM BAGASRA (GOLA DHORO)

SARKAR S.<sup>1,\*</sup>, BOYATZIS S.<sup>2</sup>, ZACHARIAS N.<sup>1</sup>

<sup>1</sup>Laboratory of Archaeometry, Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese, Greece

<sup>2</sup> Department of Conservation of Antiquities and Works of Art, University of West Attica, Greece

\*[sarkar.siddhant@gmail.com](mailto:sarkar.siddhant@gmail.com)

Keywords: Indus Valley Civilisation, Pottery, Organic Residue Analysis

The Indus Valley Civilization (3300 BCE to 1500 BCE) site of Gola Dhoro or Bagasra (Gujarat, India) is located 1 km from the Gulf of Kachch and links the three different and culturally rich regions of Gujarat- Kutch, Saurashtra, and North Gujarat, making it a significant site in the broader region. Concomitantly, four phases were stratigraphically recorded, with sufficient evidence of interaction with other contemporary Chalcolithic Cultures. The present study focuses on the analysis of a pottery assemblage of 72 samples from the site using LED, SEM/EDS, and FTIR to investigate pottery manufacturing techniques and dietary practises. The analysis allowed us to determine the relationship between different wares and shapes, the nature of organic residues and best practises for their study, the relationship between organic residues and vessel typology (i.e., preference of a particular vessel for a specific dietary component), and its distribution in time (different phases) and space (inside and outside the fortification wall). Ultimately, the present project aims to facilitate the synthesis of existing knowledge about the Indus Valley Civilization's ceramic technology and dietary practises with that of the present study to create a new narrative. A total of 72 samples of varying typologies (main wares: Red Ware, Coarse Red Ware, Buff Ware, Black and Red Ware; & main shapes: small-medium pots, goblets, storage jars, bowls, cooking/serving vessels, and black slipped jar), dating to 3 phases of the excavation (Phase I = 22 samples, Phase II = 24 samples, and Phase III = 26 samples), were initially examined with the help of an LED microscope in order to form preliminary groups. 34 representative samples were selected for further investigation with the help of SEM/EDS to study their manufacturing technology. Of the above, ca. 21 samples were selected and analysed in powder form with FTIR to assess their chemical components and characterise the most likely candidates for preserving organic residues. The SEM/EDS analysis indicated the presence of four chemical and technological groups, contributing to understanding their manufacturing process. A correlation was observed between the chemical composition of bowls, goblets, large/storage jars, and cooking vessels, suggesting the use of a similar pottery manufacturing technique temporarily, regardless of the presence of multiple cultures. Conversely, the lack of any clear correlation among the small-medium-sized pots from different phases could either be indicative of the absence of a uniform manufacturing technique or the result of intercultural interactions. Similarly, FTIR analysis of the samples after extraction with suitably selected solvents showed organic residues in the majority of sherds, of which at least one shows a strong indication of a fatty substance, while the majority possibly suggest dairy products. In the upcoming step, GC-MS analysis will be conducted for stronger evidence, which is expected to help in determining the nature of the fatty substances.

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## **DEVELOPING NEW PROCEDURES FOR MEASURING POTTERY MANUFACTURING TRACES THROUGH LASER SCANNING CONFOCAL MICROSCOPE. A PILOT STUDY FROM EBA SICILY**

TODARO S.V.<sup>1,\*</sup>, GIACOPPO F.<sup>2</sup>, CALANDRA G.<sup>2</sup>

<sup>1</sup>Department of Humanities, University of Catania, Italy

<sup>2</sup>Department of Humanities, University of Catania, Italy

[\\*svtodaro@unict.it](mailto:svtodaro@unict.it)

Keywords: ceramics, EMAC2023

In the past 20 years pottery specialists have tackled the study of forming and finishing techniques with various approaches integrating macroscopic and microscopic examination of archaeological materials and have corroborated their results with experimental reproduction of forming and finishing sequences. As a contribution to this field, the research unit of pottery specialists at Catania University undertook and completed a three-year project to test the potential of Laser Scanning Confocal Microscopy (LSCM) for analyzing pottery surfaces and discriminating wear traces from manufacturing and finishing traces (Giacoppo, 2022). This microscope offers several advantages over conventional optical tools: it is completely non-destructive; it permits the acquisition of high-resolution and high-contrast images, from which detailed qualitative and quantitative data can be obtained; it allows a three-dimensional reconstruction of the micro-topography of objects - thus tracing the palimpsest of actions stratified on surfaces.

Building on the results of that project, this paper aims to propose a procedure for the study of manufacturing techniques of two classes of EBA pottery from eastern Sicily, that integrates macroscopic and microscopic examination of archaeological materials with microscopic assessment of experimental replication of the traces observed. More specifically, it aims to compare and contrast - in qualitative and quantitative terms - the traces reproduced with different tools and different techniques on experimental samples made with clay and temper mined locally at the sites under study and tools found at EBA archaeological sites.

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## RECONSTRUCTING JUDEAN IRON AGE COOKING POT PRODUCTION EMPLOYING EXPERIMENTAL ARCHAEOLOGY

TRAMER L.

Institute of Archaeology, Ariel University, Israel, [leah.tramer@gmail.com](mailto:leah.tramer@gmail.com)

Keywords: ceramics, EMAC2023, Iron Age, Cooking pots, Judah, experimental archaeology

Cooking pots are one of the most important elements of ancient material cultures, shedding light on ancient society through the functionality of food preparation. Due to their function, cooking pots require special technical qualities. They must be resistant to thermal shocks and withstand high heat for a long time. Various technological studies of cookware in Judea (modern Israel) during the Iron Age II (ca. 1000-586 BC) have shown that cooking pots were mostly produced in regional specialized workshops and distributed to various sites in the region. Moreover, the vast majority of the cooking pots analyzed were made only of 'terra rossa' type clay with tempering of calcite or quartz and were fashioned by coiling technique. Ethnographic studies from the same region show also specialized production of cooking pots in several areas of the central hills using similar clay types, tempers and techniques.

The study presented here focuses on the reconstruction of various aspects of the 'Chaîne Opératoire' of these vessels by experimental archaeology and is part of a more comprehensive study of the technology and typology of cooking pots in Judea during the Iron Age.

The main research question is whether the specialized workshops using specific raw materials, and in particular terra rossa type clay, as well as specific clay recipes and tempering, managed to produce superior quality cooking pots in comparison to those produced differently in the same region. Therefore, in the framework of this study cooking pots following Iron Age II types and production techniques were made from various local soils collected in the vicinity of the ancient Iron Age sites, as alluvial, loess, grumusol and terra rossa soils. The clay was prepared with various quantities and types of temper. The different pots (those surviving firing) were then used for repeated cooking in open fire and their durability and efficiency was examined.

The initial results of this ongoing experimental study indicated that many of the soils collected in the vicinity of the ancient sites were not suitable for pottery making or for creation of cooking pots enduring open fire without cracking. In addition, the amount of calcite temper may have a significant influence on the durability of the cooking vessels in repeated usage and thermal shocks.

## EXPERIMENTING VARIABLES IN POTTERY MANUFACTURE WITHIN AN ETHNOARCHAEOLOGICAL CONTEXT, PAROS GREECE

TSOUPRA A.<sup>1,\*</sup>, POLITAKIS V.<sup>2</sup>, BARRULAS P.<sup>1-3</sup>, MOITA P.<sup>1-4</sup>, MIRAIO J.<sup>1-4</sup>

<sup>1</sup>HERCULES Laboratory, University of Évora, Portugal

<sup>2</sup>Spirit of Greece-Ceramics by Vassilis Politakis, Greece

<sup>3</sup>Department of Chemistry and Biochemistry, University of Évora, Portugal

<sup>4</sup>Geosciences Department of School of Sciences and Technology, University of Évora, Portugal

[\\*atsoupra@gmail.com](mailto:atsoupra@gmail.com)

Keywords: traditional ceramics; raw materials; ceramic technology

Present-day behavior and choices can be used to gain insights into the practices and expressions followed by ancient cultural groups. The creation of analogies between the past and the present can, therefore, provide new data on which archaeological theories can rely.

This study aims to contribute to a better understanding of archaeological ceramics by relying on the active collaboration between scientists and a traditional potter. Here, we present the analytical data of a sample-set of traditionally-made ceramics and their respective raw materials, applying a multi-analytical methodological approach that combines petrography, XRD, VP-SEM-EDS and XRF. Through the determination of the mineralogical and geochemical composition of the raw material samples, we intend to explore their relevant suitability for the manufacture of specific pottery styles. Raw material processing is reflected on the mineralogical compositions. Deviations in the geochemical compositions among the ceramics manufactured with clay collected from the same geological source appear to be related to manipulation processes undertaken during the production of the objects and correspond to the use of a different grain size of the raw materials. Elemental distribution maps illustrate these variations among the samples of each location, revealing the impact of technological choices on the analytical data.

## EARLY NEOLITHIC POTTERY DECORATIONS: NEW INSIGHT FROM RIO TANA (AQ, ABRUZZI, ITALY)

VASSANELLI A.<sup>1</sup> \*, TERRANOVA A.<sup>1</sup>, PETRINELLI PANNOCCHIA C.<sup>1</sup>, CIGNONI P.<sup>2</sup>, CALLIERI M.<sup>2</sup>

<sup>1</sup>Department of Civilizations and Forms of Knowledge, University of Pisa, Italy

<sup>2</sup>ISTI – CNR, Pisa, Italy

\*[alice.vassanelli@phd.unipi.it](mailto:alice.vassanelli@phd.unipi.it)

Keywords: pottery decorations, 3D imaging, experimental protocols

This study aims to present a morphological and technological analysis of the pottery decorations from the Early Neolithic site of Rio Tana (AQ, Abruzzi, Italy; Petrinelli Pannocchia et al., 2022). The archaeological evidence links the pottery assemblage to the cultural complex of the Impresa Ware Culture (Bagolini & Von Eles, 1978), which spread across the Adriatic coast from the first half of the 6<sup>th</sup> millennium BC.

A specific experimental program was developed to investigate the gestures and choices made by the earliest craftspeople to manufacture the various decorations. The possible influence of different parameters, among which the ceramic body composition, the drying stage, and the presence of surface treatments were considered during our experimentation.

The experimental data, compared with the archaeological evidence, together with observations under the microscope and digitized surveys of the surfaces (3D surface imaging), allowed us to shed new light on the decorative choices and the meaning they had for the earliest Neolithic groups in central Italy.

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### S3. Raw materials ecologies and provenance

#### A HISTORY OF RHODIAN AMPHORAE PRODUCERS BASED ON THE CHEMICAL AND MINERALOGICAL COMPOSITION OF STAMPED HANDLES

ABDELGAWAD M.<sup>1</sup> \*, BAHNASY A.<sup>1</sup>, CANTIN N.<sup>1</sup>, EMPEREUR J.-Y.<sup>2</sup>

<sup>1</sup>Centre d'Études Alexandrines, UAR 3134 CNRS/IFAO, Egypt

<sup>2</sup>Directeur de Recherche, Émérite au CEAlex, membre de l'Institut

\*[mai.abdelgawad@cea.com.eg](mailto:mai.abdelgawad@cea.com.eg)

Keywords: Stamped-amphorae, Fabricants, Raw materials

During the Hellenistic period (4th BC to 1st BC), Rhodes was one of the most important Greek cities for the production of stamped amphorae, which were exported to the far reaches of the Mediterranean and beyond. The stamps printed on the two handles of the amphorae are the markers of their origin and the witness of the long distance transport and trade of agricultural products, particularly wine.

The Rhodian stamps indicate the year and even the month, providing the archaeologist with exceptionally accurate chronological tracers (Finkielstejn, 2001). Moreover, they contribute to a better understanding of the political, economic and social organization of Greek cities (Badoud and Marangou, 2019). Currently, more than two hundred thousand amphora stamps were documented (Cankardeş-Şenol, 2015-2017).

The fabricants on Rhodes Island were grouped into "houses", representing the production centers. Stylistic studies revealed that the amphorae workshops were managed by dynasties of manufacturers of the same family.

A preliminary study (Emperor & Abdel Gawad, 2020) on three houses had already highlighted compositional variations. The present study goes further, and is based on the selection of a total of 680 amphora handles from the collections of Alexandria, Delos and Athens. These handles were attributed to 36 fabricants, belonging to 13 houses between the 3<sup>rd</sup> and 1<sup>st</sup> centuries BC. The entire collection was analyzed using pXRF, with a parallel petrographic study on half of the collection, providing us with a reference for the Rhodian material and its variability over time.

The objective is to see if the chemical and mineralogical compositions can highlight the evolution of the production of these amphorae, especially in the selection of raw materials, along with their preparation. In fact, if it has been possible through the previous study to differentiate Rhodian productions from those of Knidos, can we go further to differentiate between the various fabricant houses? Furthermore, do the variations in the composition of each house allow us to locate these workshops on the island?

This large-scaled study sets the foundation for a more detailed approach based on a large corpus of samples and, beyond that, initiates a broader review of amphorae production strategies in the Aegean Sea.

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## PRODUCTION AND CONSUMPTION OF POTTERY IN COPTOS BETWEEN THE 1<sup>ST</sup> AND 2<sup>ND</sup> CENTURIES AD

BAHNASY A.<sup>1, \*</sup>, ABDELGAWAD M.<sup>1</sup>, CANTIN N.<sup>1</sup>, DIXNEUF D.<sup>2</sup>

<sup>1</sup>Centre d'Études Alexandrines, CNRS/IFAO (CNRS – UAR5134), Egypt

<sup>2</sup>Aix Marseille Univ, CNRS, LA3M, Aix-en-Provence, France

[\\*assem.bahnasy@cea.com.eg](mailto:*assem.bahnasy@cea.com.eg)

Keywords: Petrography, pXRF, Raw materials

The site of Coptos, the current city of Qouft, is located a few kilometers south of Qena city, Egypt, a place where the Nile forms a loop towards the East, approaching as close as possible to the shores of the Red Sea. Since 2005, the collaboration between the French Institute of Oriental Archeology in Cairo (IFAO), HiSoMA laboratory (CNRS, UMR 5189), and University of Lumière-Lyon 2 has resumed the excavations at Coptos, under the direction of Laure Pantalacci.

The excavation carried out in 2009 revealed reddened and ash layers including elements of kiln-like structures, which can clearly be attributed to a ceramic production area. These stratifications also yielded consumption ceramic products, such as amphorae, cooking ware, and fineware.

According to the ceramological study, conducted by Delphine Dixneuf, the functioning of this potential production area is significantly questioned. Was this workshop able to produce such a diversity of ceramic products?

Chemical analyses using a portable X-ray fluorescence spectrometer and petrographic approach, of macro and microscopic studies, were carried out on 130 ceramic fragments of different typologies, at the Center of Alexandrian Studies (CEAlex) and the French Institute of Oriental Archeology (IFAO). In general, the conducted studies made it possible to identify the clay raw materials selected for the fabrication of these types of ceramics, in addition to shedding the light on the characteristics of the prepared clay paste used in their manufacturing.

The elucidated results, from both the chemical and petrographic studies, discuss the possibility of having a ceramic production at the excavated area, and checking the ceramological hypotheses related to the fabricated typologies. The studies resulted in the classification of 4 petrographic and 3 chemical compositional groups, covering all the different forms. In fact, the variance between the two results, represented by the additional petrographic group, seems to delineate a specific functionality related to the typology (notably water storage). Nevertheless, two compositional groups that represent the majority of the sherds, confirm the presence of local production according to their compatibility with the surrounding geological environment. On the other hand, some fabrics appeared to have been imported to the site, although they were supposed to be from the same workshop.

In conclusion, the cross-correlation between the archaeometric and ceramological studies refines and clarifies the establishment of coherent fabrics and typological assemblages. Although this multidisciplinary study aided in confirming the hypothesis about the existence of local production in the vicinity of the excavated site, it also marked the usage of another clay raw material than the widely used Nile deposits, despite their proximity to the supposed workshop.

## GLAZE RAW MATERIALS EXPLORATION AND COMMERCIALIZATION IN WESTERN IBERIA DURING THE ISLAMIC PERIOD (10<sup>TH</sup>-13<sup>TH</sup> CENTURIES)

BELTRAME M.<sup>1</sup>, BARRULAS P.<sup>1</sup>, TSOUPRA A.<sup>1,\*</sup>, MIRÃO J.<sup>1</sup>, DIAS L.<sup>1</sup>, VELA C.<sup>1</sup>  
<sup>1</sup>Hercules Laboratory, University of Évora, Portugal

[\\*atsoupra@gmail.com](mailto:atsoupra@gmail.com)

Keywords: Glaze, raw materials, Islamic period

Since the beginning of the Islamic domination of the Iberian Peninsula (8<sup>th</sup> century AD), new people from the North of Africa and Eastern Mediterranean area settled in the *al-Andalus* (Islamic Iberia), and they brought their culture, habits, know-how, technology, and beliefs, which indelibly characterized Iberian Middle Ages.

In any case, the contact between these two different cultures resulted in the transmission and assimilation of technical expertise that contributes to the production and diffusion of Hispano-Moresque architectural glazed tiles, driven by the introduction and diffusion of the glaze technology by Islamic ceramists.

Thus, there is no doubt that the beginning of the Islamic period in the Iberian Peninsula meant a huge step forward concerning ceramic technology. The introduction of the glaze to decorate/impermeabilize ceramic vessels was surely the most important innovation in addition to the exploitation of the Iberian natural resources connected to its production, in particular, lead ores as the main flux and sand.

So, by studying Islamic glazed decorations different datasets can be extracted using a multidisciplinary approach, combining different disciplines such as archaeology, archaeometry and ore geology. These data can be directly correlated to the glaze technology applied in each place, to the raw material employed, and to its chronological diffusion.

Lead ore provenance, exploration pattern during time, treatment, and eventually its commercialization during the Islamic period can be assessed. In addition, the silica source utilized in glaze production can also be evaluated to verify whether the different raw materials (i.e. sands) were eventually employed in different places in glaze production. This might feed future models regarding the use and commercialization of natural resources during the Iberian Middle Ages.

All these issues will be tackled through the study of mono-chromatic and bi-chromatic Islamic glazed ceramics, recovered in well-contextualized archaeological contexts (9<sup>th</sup> to 13<sup>th</sup> century AD) in the cities of Santerém, Évora, Lisbon and Mértola. To understand the relation between glaze technology and geological resources exploitation an integrated research protocol will be applied including the assessment of the glaze homogeneity by cathodoluminescence, in addition to the analysis of lead isotopes and trace elements by LA-ICP-MS.

## WHAT MAKES A CLASSIC? CONTINUITY OF RAW MATERIAL PROCUREMENT AND CERAMIC FABRICS IN PHENEOS, FROM THE BRONZE AGE TO THE CLASSICAL PERIOD

BURKE C.<sup>1</sup> \*, TESTOLINI V.<sup>2</sup>, XANTHOPOULOU V.<sup>3</sup>, ILIOPOULOS I.<sup>3</sup>

<sup>1</sup>Austrian Archaeological Institute, Austrian Academy of Science, Austria

<sup>2</sup>Institute of Classics, Department of Archaeology, University of Graz, Austria

<sup>3</sup>Department of Geology, University of Patras, Greece

[\\*clare.burke@oeaw.ac.at](mailto:clare.burke@oeaw.ac.at)

Keywords: Petrography, Diachronic, Raw Materials

Although it is well understood that the outward appearance of pottery is more rapidly open to innovation and change than the techniques and raw materials used to produce it, there have been few opportunities in the examination of archaeological pottery from the Greek Peloponnese to investigate production and the utilization of raw material resources from a long diachronic perspective that crosses both prehistory and historical periods at a single site. As such, whilst we have exceptionally detailed studies and valuable data on pottery production for different periods in different areas, it is unusual to have such a long durée view of pottery production and consumption that covers different socio-economic and political circumstances of a site. Such a broad diachronic perspective could certainly offer important insights into the degree to which such social systems impacted raw material procurement and pottery circulation at different times.

This paper presents the results of an integrated program of analysis, that includes archaeological and geological techniques to examine the raw materials and technological practices used to make ceramics found at the site of Pheneos in the Peloponnese of mainland Greece. Thin section analysis of pottery from the Early Bronze Age through to Classical and Hellenistic periods (c. 2100-100BC) has revealed the presence of a number of low-grade metamorphic fabrics that are consistent with local geology, which along with kiln fragments testifies to local production with the same clay types and general fabric recipes for approximately 2000 years. These include the use of both calcareous and non-calcareous types, probable clay mixing, and the adaptation of paste recipes in relation to the types of shapes being made. Whilst notable differences are apparent between the prehistoric and historic pottery in terms of general pottery fineness, the proportions of different pastes, and respective imports, the analysis also testifies to long held relationships with important regional potting centers that include suspected Corinthian imports in both the Bronze Age and Classical periods.

## INVESTIGATING THE CHEMICAL COMPOSITION OF ROMAN FINE WARE FROM THE AREA OF EAST LOCRIIS AND EAST PHOKIS: A COMPARISON WITH CLAYEY RAW MATERIAL

CHRISTODOULOU K.<sup>1,2</sup>, POLLATOU A-M.<sup>1,3</sup>, GRIGOROPOULOS D.<sup>4</sup>, HEIN A.<sup>1,\*</sup>

<sup>1</sup> Institute of Nanoscience and Nanotechnology, N.C.S.R “Demokritos”, Greece,

<sup>2</sup> Department of History and Archaeology, National and Kapodistrian University of Athens, Greece

<sup>3</sup> Department of Geology, University of Patras, Greece

<sup>4</sup> Deutsches Archäologisches Institut, Abteilung Athen, Greece

\* [a.hein@inn.demokritos.gr](mailto:a.hein@inn.demokritos.gr)

Keywords: Roman Pottery, clayey raw materials, East Locris and East Phokis, chemical synthesis, pEDXRF, XRPD, NAA

The present study attempted to shed light on the chemical characterization of ancient Roman ceramics and twelve selected clayey material from the area of East Phokis (Kalapodi, Elateia, Exarchos) and the ancient Opous in East Locris (modern town of Atalanti). The investigation of the aforementioned areas relies on the notion that these regions comprise an important network of pottery production centers from the Hellenistic era and onwards (Zachos 2018). Pottery kilns have been documented in both Elateia and the modern town of Atalanti (Hein & Grigoropoulos 2019). The Roman pottery assemblage consists of 316 fragments of fine decorated, cooking and transport wares. Most of the samples (215) derive from the Phocian sanctuary of Kalapodi and dates between the late 1st c. BC and the 6th c. AD (Niemeier 2016), while few (16) were chosen from the western cemetery of Hyampolis in the valley of Exarchos. The cemetery ranges chronologically between the late 1st and the early 2nd c. AD. Another 22 sherds were collected from the multi-phase building at Sklavopigado, dating to Hellenistic and Roman times. Lastly, 53 samples were selected from the so-called eptagonal building in Atalanti, dated to the late 2nd until 4th century A.D. As the focus of the study concerns questions related to the exploitation of specific raw material sources and the organization of local pottery manufacture, characteristic pottery sherds and local clays were analyzed using handheld portable energy-dispersive X-ray fluorescence analysis (XRF) and neutron activation analysis (NAA) to determine and compare their elemental composition. In addition, considering the mineralogical composition of clayey raw materials, briquettes were formed and fired under controlled temperatures (700°C, 850°C, 950°C, 1050°C) in a laboratory kiln. The 950°C briquettes were examined through X-ray Powder diffraction (XRPD) to interpret the crystallographic structure. Interesting conclusions were raised from the examination of raw materials collected in the vicinity of the four sites, Atalanti, Exarchos, Kalapodi and Elateia. XRPD analysis displayed a similar mineralogical and elemental composition of the four sites, which is compatible with the local geological background. Nevertheless, XRF and NAA clustering groups showed a clear distinction of cooking wares, the majority of which proved to be produced in East Phocis, as they lay in the same clusters with the respective clay samples. Moreover, some cooking wares from the area of East Phokis have been produced in Opous since they match with clay sources from this area. Considering fine decorated pottery, the cross-examination between most of the cluster groups and their archaeological context indicates that in all sites both East Phokian and Opountian products were in use. Therefore, a regional network of interaction including the two regions has been detected.

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## CHEMICAL CHARACTERIZATION OF BRONZE AGE NILE CLAYEY CERAMICS FROM NORTHERN SUDAN - IS IT REALLY ALL THE SAME?

D'ERCOLE G.<sup>1,\*</sup>, STERBA J.H.<sup>2</sup>, BUDKA J.<sup>1</sup>

<sup>1</sup>Department of Cultural and Ancient Studies, Ludwig Maximilians-University Munich, Germany

<sup>2</sup>Center for Labelling and Isotope Production, TRIGA Center Atominstitut, Austria

\*[Giulia.Dercole@aegyp.fak12.uni-muenchen.de](mailto:Giulia.Dercole@aegyp.fak12.uni-muenchen.de)

Keywords: Nile clayey ceramics, NAA, Bronze Age, northern Sudan

Ceramics produced with Nile Clay are very commonly found in archaeological excavations of different ages, all along the Nile River from Egypt to northern and central Sudan. The otherwise quite successful application of bulk geochemical analysis (Neutron Activation Analysis or NAA) to establish provenance for ceramic materials is notoriously challenging for this type of sample, being that Nile clayey ceramics are all characterized by a very homogeneous groundmass and a similar framework of mineral inclusions. Using our large database of 200+ samples, spanning several millennia from prehistory to the Late Bronze Age (New Kingdom) as well as material produced over a long stretch of the Nile according to different traditions (i.e., wheel-made Egyptian style and hand-made Nubian style pottery), we aim to investigate minute changes in the chemical composition of Nile clayey ceramics that might help to differentiate their provenance and production technology.

The application of multivariate statistical methods on the dataset produced by Neutron Activation Analysis, guided by macroscopic and petrographic information including typology, dating, fabric type, and use of the vessels leads to a differentiated view on this large volume of data. Comparison to reference collections from literature further extends the material considered.

## **RAW MATERIAL AND TECHNOLOGY OF PRODUCTION OF RECENT NEOLITHIC POTTERY AT TRAVO SANT'ANDREA (PIACENZA)**

ERAMO G.<sup>1</sup>, MUNTONI I.M.<sup>2</sup> \*, BERNABÒ BREA M.<sup>3</sup>, MAFFI M.<sup>4</sup>

<sup>1</sup> Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari "Aldo Moro", Italy.

<sup>2</sup> Soprintendenza Archeologia, Belle arti e Paesaggio per le province di Barletta-Andria-Trani e Foggia, Italy

<sup>3</sup> Museo Archeologico di Travo Piacenza, Italy

<sup>4</sup> già Soprintendenza Archeologica dell'Emilia Romagna, Italy

\*[italomaria.muntoni@cultura.gov.it](mailto:italomaria.muntoni@cultura.gov.it)

Keywords: Neolithic, Petrography, Emilia-Romagna

The multi-layered site of Travo Sant'Andrea was frequented between the late 5th and early 4th millennium BC in the Emilian Recent Neolithic (ERN). The settlement presents considerable complexity in the rectangular household investigated and in the aspects of economic and craft-type activities. The first phase of occupation is dated to 4330-4160 BC cal, with close comparisons to the Chassean groups of Southern France (Provence), while the second phase of occupation is dated to 4230-3990 BC, with more contacts with northeastern European groups (epi-Lengyel, Lasinja).

The archaeometrical studies conducted at the University of Bari Aldo Moro include petrography on thin sections at optical microscope (POM) and scanning electron microscopy (SEM-EDS). The petrographic analysis of 39 potsherds from Travo revealed two main fabrics: 1) Fe-oxide rich clay tempered with spathic calcite; 2) sandy clay with argillaceous rock fragments, altered mafics and volcanics and calcite. The petrofacies are compatible with available local raw materials, where the sandy clay fabric points to unprocessed colluvial and fluvial deposits, whereas a deliberate addition of spathic calcite to a fine clay was inferred. The oxidation patterns, the birefringence of the ceramic body and the microstructures point to open firing with temperatures below 800°C.

**ARCHAIC AMPHORAE FROM VULCI: AN ARCHAEOLOGICAL APPROACH**FORNACELLI C.<sup>1</sup>, GIAMELLO M.<sup>1</sup>, MAGRINI D.<sup>2</sup>, ROJO MUÑOZ S.<sup>3,\*</sup>, ZIFFERERO A.<sup>4</sup><sup>1</sup>Dipartimento Scienze Fisiche, della Terra e dell'Ambiente, Università degli Studi di Siena, Italy<sup>2</sup>Istituto di Scienze del Patrimonio Culturale, Consiglio Nazionale delle Ricerche, Italy<sup>3</sup>Dipartimento di Filologia, Letteratura e Linguistica Università di Pisa Dottorato Pegaso Archeologia, Italy & Facultad de Filosofía y Letras Universidad Autónoma de Madrid, Spain<sup>4</sup>Dipartimento di Scienze Storiche e dei Beni Culturali, Università degli Studi di Siena, Italy\*[sara.rojomunoz@phd.unipi.it](mailto:sara.rojomunoz@phd.unipi.it)

Keywords: Etruscan amphorae, Vulci, archaeometry

The Mediterranean Sea of the 6th century BC was a common space for very different actors—Greeks, Punics, Etruscans, Iberians, Sardinians, etc.—who used the same trading routes. The Battle of the Sardinian Sea (535/540 BC) settled the beginning of a new period in international relations, with a better division of the Mediterranean trading spaces.

Etruscans were also part of this trading system, with their wine, transported in local amphorae, as one of the most successful products. From the end of the 7th century BC they began to arrive to the ports in the Gulf of Lion. Most of the information available nowadays about Etruscan amphorae come, in fact, from the ports and shipwrecks along the coasts of Provence and Languedoc (Py et al., 2002; Long et al., 2002).

The present study focuses on one of the Etruscan amphorae production areas: the Albegna Valley, on the north-western border of Vulci. This area has been identified as an important agricultural district, specialized in wine production, and important concentrations of archaic amphorae and wasters have been found in the lower valley, as well as structures for storage and elaboration of the cultivated goods (Zifferero, 2017).

An archaeometric investigation was carried out on amphorae samples coming from these centres, other areas of the valley, and the ports of Lattara and Emporion. From a morphological point of view, the amphorae from the Albegna Valley can be mainly divided between older types (types A-ETR3A/B) and more recent ones (type A-ETR3C). A chemical investigation of the ceramic pastes, supported by statistical analysis and mineralogical and petrographic investigations, was carried out on 150 amphorae samples together with other local materials from the Albegna Valley for comparison. The aim was to investigate changings in amphorae production between the 6th and the first half of the 5th centuries BC, and to see whether the situation at the Albegna is reflected in the foreign ports.

The results from the archaeometric study showed a changing in composition from the earliest calcareous pastes with quartz-felspathic inclusions toward more recent ferruginous pastes characterized by high amounts of volcanic inclusions, the same as the typical amphorae coming from the main centre of Vulci (types A-ETR1/2 and 5). This suggests a possible shift in production sites, reflecting the new regional organization that follows the Battle of the Sardinian Sea, when Vulci gains full control of its territory and opens its big emporic port at Regisvilla.

These changes had already been observed at the ports of arrival (pâtes 2/5 of the older types and pâte 3 of the recent ones in Sourisseau, 1997), and confirms them on a local-regional scale basis. Thus, we can now better understand the impact of Mediterranean routes restructuration and the establishment of new trade systems impact on one of the most important Etruscan centres in Southern Etruria and how this affected markets and areas of influence.

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## SUGAR PRODUCTION IN CAPE VERDE: ARCHAEOMETRICAL CHARACTERIZATION OF TRINDADE SUGAR POTS

GONDIM L.<sup>1,\*</sup>, IÑÁÑEZ J.G.<sup>1</sup>, MONTEIRO J.<sup>2</sup>, ALMEIDA M.<sup>3</sup>, TORRES J.B.<sup>4</sup>, ARANA G.<sup>5</sup>, TEIXEIRA A.<sup>4</sup>

<sup>1</sup>GPAC -Espacio experimental para la innovación en Patrimonio y Paisajes Culturales, Universidad del País Vasco (UPV/EHU), Spain<sup>2</sup>Instituto do Património Cultural – IPC, Praia, Cabo Verde.

<sup>3</sup>Professional archaeologist.

<sup>4</sup>CHAM, FCSH, Universidade NOVA de Lisboa, Portugal.

<sup>5</sup>IBeA, Facultad de Ciencia y Tecnología, Universidad del País Vasco, Spain

\*[leticia.dasilva@ehu.es](mailto:leticia.dasilva@ehu.es)

Keywords: Sugar, ceramics, colonial

Cape Verde was an uninhabited Atlantic archipelago when it was discovered and occupied by the Portuguese in 1460. During the 15<sup>th</sup> and 16<sup>th</sup> centuries, the Portuguese tried to implement the cultivation of sugarcane in the archipelago, although due to Cape Verde's arid tropical climate, it was not as successful as in Madeira, São Tomé and Brazil. At the same time, Santiago Island was a strategic port due to its geographic location and pivoted its main economy towards the Atlantic slave trade. By the end of the 16<sup>th</sup> century, the island started to lose this commercial role, and the elites increased the agricultural exploration of the territory. Remnants of this period were brought to light at the archaeological site of Trindade, a sugarcane mill located in the interior of Santiago Island. Among other archaeological evidence and written historical documentation, an important set of sugar loaf moulds appeared at the site. These findings enabled dating back the first archaeologically known sugar manufacturing in Cape Verde to the 16<sup>th</sup> and 17<sup>th</sup> centuries (Almeida and Monteiro, 2018).

The present study aims at archaeometrically characterizing the sugar ceramic supply found at Trindade archaeological site. Thus, a set of 30 ceramic loaf moulds was analyzed by means of chemical (ICP-MS), mineralogical (X-ray diffraction) and microscopic (Scanning Electron Microscopy and Optical Microscopy) methods. Preliminary results shed light on the exogenous provenance of these ceramics, the technological know-how used in their manufacturing process, and its relationship with sugar production and colonial trade in Iberian colonial contexts.

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## SANCTI SPIRITUS AND AROUND: INDIGENOUS CERAMICS AND INTERACTIONS FROM THE FIRST SPANISH SETTLEMENT IN ARGENTINA

IÑÁÑEZ J.<sup>1,\*</sup>, AZKARATE GARAI-OLAUN A.<sup>1</sup>, SÁNCHEZ-PINTO I.<sup>1</sup>, SOLAUN J.<sup>1</sup>, ESCRIBANO S.<sup>1</sup>, COCCO G.<sup>2</sup> & ARANA G.<sup>3</sup>

<sup>1</sup>GPAC - Experimental space for innovation in Heritage and Cultural Landscapes, Geography, Prehistory and Archaeology Dpt., University of the Basque Country UPV/EHU, Spain

<sup>2</sup>Museo Etnográfico y Colonial “Juan de Garay”, Argentina

<sup>3</sup>IBeA, Analytical Chemistry Dpt., University of the Basque Country UPV/EHU, Spain

[\\*javier.inanez@ehu.eus](mailto:*javier.inanez@ehu.eus)

Keywords: pottery, colonial, Argentina

The site of Sancti Spíritus Fort (1527-1529), established by Sebastián Gaboto at the confluence of the Carcarañá and Coronda rivers, is the first Spanish settlement in Argentina. The fort was founded on June 1527 and lasted for only two years, until 1529, when it was sacked and fired by the indigenous population in retaliation to the harsh conditions shown by Spaniards. Thus, this event provides archaeologists with the remains of the fort as an exceptional place for studying early colonization processes in South America. The research being developed is making it possible to study one of the first contexts of Hispanic-indigenous interaction in the context of Spanish colonialism in the southern cone of America, being one of the most relevant contributions the finding that the European settlement is located on an indigenous settlement existing at least 100 years before the arrival of the Europeans. The analysis of the different phases of occupation, the different construction techniques, the ceramic artifacts and the identification of the plants used, have provided information on a unique archaeological context that allows us to analyze the interaction of the native societies with the Europeans, in the initial moments of the Spanish colonialism in the La Plata Basin and the previous antecedent to the process of conquest and foundation of cities.

In order to deepen into the understanding of ceramic supply during early contact periods in Argentina by local communities, an archaeometrical characterization of a set of 56 ceramics has been carried out by means of a multi-analytical approach, including chemical analysis by ICP-MS, mineralogical analysis by XRD, and microscopical examinations by OM and SEM-EDS. Their microstructure and elemental composition have been determined and evidence of the influence of the technological choices and raw materials have been assessed.

## CULTURAL INTERACTION BETWEEN NAJU AND JEJU ISLAND THROUGH SCIENTIFIC ANALYSIS OF POTTERY FROM BOGAM-RI, NAJU AT THE IRON AGE OF SOUTHERN KOREA

JIN H.J.<sup>1</sup>, LEE M.S.<sup>1</sup> & JANG S.<sup>1, \*</sup>

<sup>1</sup>National Research Institute of Cultural Heritage, Yuseong-gu, Daejeon, South Korea

[fkite@korea.kr](mailto:fkite@korea.kr)

Keywords: Iron Age, Cultural Interaction, Bogam-ri site in South Korea

The Naju Bogam-ri sites in South Korea have yielded over 32 tombs from the Iron Age to the Three Kingdoms period, along with a diverse array of unearthened relics. The scale of the tomb group and the relics suggests that this was the tomb group of a regional power. During the seventh excavation survey, a quantity of Iron Age pottery was discovered in ditch features presumed to be part of a causewayed enclosure located on the outskirts of the village.

Among them, 1 m-sized jar-type potteries were excavated from No. 13 ditch features, and it is assumed that they came from Jeju Island due to their distinctive shape and surface mineral composition. The geological distribution of the Naju area, where the Bogam-ri site is located, is predominantly granite and andesite, which differs from Jeju Island's basalt rocks. The mineralogical and geochemical properties of the jars suggest that they reflect the geological characteristics of their production place.

This study analyzed and compared the potteries excavated from the Bogam-ri site in Naju using X-ray diffraction analysis, microscopic observation, inductively coupled plasma mass spectrometry, and neutron activation analysis.

As a result, the potteries excavated from Bogam-ri, Naju were divided into two groups. In Group 1, quartz, plagioclase, and pyroxene were identified as the main minerals, and fine-grained minerals including elongated pores and basalts fragments were observed. In group 2, fine-grained quartz and alkali feldspar were found without basalt, indicating a different origin of the clay compared to group 1. Potteries found on Jeju Island show slightly different characteristics in the grain size and content of minerals for each site, but basalt fragments and needle-shaped plagioclase are observed.

Chemical analysis of pottery samples revealed that Group 1 pottery belongs to the basaltic andesite and andesite series, while Group 2 pottery belongs to the andesite and dacite series in the volcanic classification. Pottery samples from Jeju Island are distributed in the same series as Group 1 and are classified into the same group based on trace element distribution.

Therefore, the pottery of Group 1 from Naju Bogam-ri has similar mineralogy and chemical distribution to the pottery of Jeju Island, and it is highly likely that the pottery of Group 1 was made in Jeju Island and imported to Naju during the Iron Age. This suggests an interaction between Naju and Jeju Island during this period and provides valuable insights into the production and distribution of these potteries.

## RED SLIP ROMAN JUGS FROM CYPRUS: A QUESTION OF PROVENANCE

KAJZER M.<sup>1</sup>, \* , MARZEC E.<sup>2-3</sup>, KIRIATZI E.<sup>2</sup>

<sup>1</sup>Institute of Archaeology and Ethnology of the Polish Academy of Sciences, Poland

<sup>2</sup>Fitch Laboratory, British School at Athens, Greece

<sup>3</sup>Institute of Mediterranean and Oriental Cultures of the Polish Academy of Sciences, Poland

\* [gosiakaj@gmail.com](mailto:gosiakaj@gmail.com)

Keywords: Cyprus, Roman period, red slip jugs

The presentation is focused on the red slip jugs from Cyprus, which occur in contexts dated between the early 1<sup>st</sup> and mid-2<sup>nd</sup> century CE. They are characterised by a spherical, bulgy body, a straight, grooved neck and an out-turned rim. Their entire external surface is covered with semi-lustrous or lustrous slip. Such vessels are known from different sites in Cyprus, including Nea Paphos, Palaepaphos, Kourion and Amathus. In the necropolis of Amathus, the red slip jugs formed one-third of all Roman pottery. Due to their significant presence at this site and its vicinity, John Hayes suggested that they originate from the Kourion-Amathus-Limassol area.

The macroscopic examination carried out in the framework of the current research showed that the same type of red slip jugs is also common in Nea Paphos. To investigate their provenance, 14 samples from Nea Paphos and Kourion were selected for thin section petrography and elemental analysis (WD-XRF). The results of the petrographic analysis revealed the presence of two fabric groups (FG 1 and FG 2), showing textural similarities but different in terms of mineralogical composition. Moreover, there is a correlation between the FGs and sites. All samples classified as FG 1 were taken from Nea Paphos, while all FG 2 samples are from Kourion.

These results indicated that different production centres manufactured the red slip jugs and provided new evidence of Early Roman fine ware production in Cyprus.

## FROM BYZ WITH WINE: ARCHAEOMETRIC ANALYSIS OF MEDIEVAL AMPHORAE FROM POLAND

KOROKHINA A.<sup>1-2, \*</sup>, WAKSMAN S.Y.<sup>3</sup>, AUCH M.<sup>4</sup>, TYMOSHENKO M.<sup>5</sup>, TRZECIECKI M.<sup>4</sup>,  
KHAMAİKO N.<sup>1-2</sup>, WOŁOSZYN M.<sup>1-6</sup>

<sup>1</sup>Leibniz Institute for the History and Culture of Eastern Europe (GWZO), Germany

<sup>2</sup>Institute of archaeology, National academy of sciences of Ukraine, Ukraine

<sup>3</sup>CNRS UMR5138 Archéologie & Archéométrie, France

<sup>4</sup>Institute of Archaeology and Ethnology Polish Academy of Sciences, Poland

<sup>5</sup>Museum of Kyiv History, Ukraine

<sup>6</sup>University of Rzeszów, Poland

\*[a.v.korokhina@gmail.com](mailto:a.v.korokhina@gmail.com)

Keywords: amphorae, Early Rus', Middle Ages

The potential of amphorae for the study of trade, cultural links and consumption patterns in the Middle Ages is far from exhausted. In Europe, amphorae of the Günsenin types, indicating the revival of Byzantine long-distance sea trade, appear in considerable amount on the sites of the Early Rus' (Koval 2010), especially in its southern part and Kyiv, one of the main trade hubs of medieval Europe (Barret et al. 2022). The settlements of eastern Poland (the so-called Cherven Towns) are the western periphery of amphorae distribution which could be probably linked to regional differences in patterns of commerce and consumption.

The study deals with the analysis of amphorae from the Czermno hillfort in Eastern Poland (Piotrowski, Wołoszyn 2012). The petrographic and elemental analysis allowed us to distinguish two major compositional groups of amphorae, which shows that they probably came to the region from several centres during the 10-13 centuries. Some of these centers may be identified, thanks to comparisons of the bulk elemental compositions with reference groups for the main types of Middle and Late Byzantine amphorae in the Lyon laboratory database (for the method see: Waksman 2011). Further research involving other Polish sites, as well as the record from Kyiv will help us reconstruct the specifics of regional trade (within Rus'), as well as the links between the Byzantine Empire and its northern periphery. The study was prepared with the financial support of the Volkswagen Foundation.

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## DISTRIBUTION IN GAUL OF AMPHORAE PRODUCED IN FONDI / SOUTHERN LATIUM IN THE SECOND IRON AGE

LEMAÎTRE S.<sup>1</sup>, THIERRIN-MICHAEL G.<sup>2</sup> \*, THIRION-MERLE V.<sup>3</sup>

<sup>1</sup>Département Histoire de l'art et Archéologie, Faculté Sciences Humaines et Arts, Université de Poitiers, France

<sup>2</sup>Department of Geosciences, University of Fribourg, Switzerland

<sup>3</sup>Laboratoire ArAr -UMR 5138, Archéologie et Archéométrie, CNRS - Université Lumière Lyon 2, France.

\*[gisela.thierrin-michael@unifr.ch](mailto:gisela.thierrin-michael@unifr.ch)

Keywords: Amphorae, chemical analysis, petrographic analysis

In the Fondi plain on the Tyrrhenian coast of Italy, several amphora production sites have been discovered in the 1970s and sherds collected in a land survey (Hesnard et al. 1989). As some of the stamps on sherds among the Fondi production were identical to those on amphorae found in the shipwreck La Madrague de Giens off the French Mediterranean Coast, large wine imports to Gaul from the region of Fondi were assumed. 50 sherds of mostly Dr.1 amphorae were analysed chemically (WDS X-ray fluorescence) and petrographically in order to constitute a reference group for comparison with amphorae from consumer sites. However, comparisons to the amphorae from oppida along the Mediterranean coast and those of other late Iron Age and early Roman consumer sites on the Rhone-Rhine axis between Lyon and Basle / Augst did not reveal the expected large numbers of Fondi amphorae. Only recent analyses carried out in the framework of the ITIVIN project concerned with the comparative study of amphorae from sites around Poitiers allowed the discovery of a more significant proportion of amphorae attributable to the Fondi production among the imported amphorae.

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## CERAMIC IMITATIONS OF METALWARE IN THE LATE HELLENISTIC AND EARLY IMPERIAL GREEK WORLD: MAPPING PRODUCTION CENTERS USING FABRIC PROVENANCE ANALYSIS

LIARD F.

Faculté de Philosophie, Lettres et sciences humaines, Université Saint-Louis, Belgium, [florence.liard@usaintlouis.be](mailto:florence.liard@usaintlouis.be)

Keywords: Mould-made bowls, lead-glazed pottery, petrography

This research presents the results of a petrographic analysis of 140 black-glazed “Megarian” bowls from the late Hellenistic period, and 97 lead-glazed skyphoi attributable to the late Hellenistic and early imperial period. The pottery fragments, all mould-made, were discovered in three significant sites of the Aegean region: Athens, Corinth, and Mytilene. The starting point of this research is the apparent inconsistency between the widely shared assertion that Athens and Corinth hosted thriving industries of black-glazed mould-made bowls in the late 3<sup>rd</sup> and at least until the mid- 2<sup>nd</sup> century BC, while mouldmade vessels exhibiting late Hellenistic styles – including decorative patterns that are well-documented in central Greece – and covered with a lead glaze were not produced in mainland Greece, but instead were systematically imported from Mytilene and other industries of western Asia from the 1<sup>st</sup> century BC onwards.

The goal of this research is to clarify the role of mainland Greek craftsmanship in the diffusion of lead-glazed pottery in the ancient Mediterranean world, and to identify continuous traditions of glazed mould-made ware production before and after the Roman conquest of the eastern Mediterranean.

Petrographic analysis confirmed the existence of lead-glazed pottery industry in Mytilene and identified some of its products among the Athenian assemblage. Several Hellenistic bowls sampled at Mytilene turned out to be in the same fabric as the lead-glazed wares, thereby revealing some continuity in technological practice beyond a change in fashions and styles. Lead-glazed skyphoi were identified as being local to Attica and to Corinthia respectively, with two mineralogically-related fabrics identified for each production region. In Attica, at least one of these fabrics was used since the 3<sup>rd</sup> century BC for early types of Megarian bowls, although the texture of the clays – with coarser versions for later types of mould-made wares, then for lead-glazed pottery – suggests a lesser refinement of the sediments through time. In Corinthia, the clays used for black-glazed vessels were strikingly different from those used for lead-glazed vessels, thereby suggesting a technological shift in the production of fine decorated pottery that may coincide in time with the sack of Corinth by the Romans in 146 BC, and the refoundation of the city as a Roman colony under Julius Caesar in 44 BC.

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## POTTERY OF ARGIVE PROVENANCE IN COASTAL THESSALY DURING THE LATE BRONZE AGE ACCORDING TO NEUTRON ACTIVATION ANALYSIS

LIS B.<sup>1,\*</sup>, BATZIOU A.<sup>2</sup>, STERBA J.H.<sup>3</sup>, MOMMSEN H.<sup>4</sup>

<sup>1</sup>Institute of Archaeology and Ethnology, Polish Academy of Sciences, Poland

<sup>2</sup>Ephorate of Antiquities of Magnesia, Greek Ministry of Culture and Sports, Greece.

<sup>3</sup>TRIGA Center Atominstytut, Technische Universität Wien, Austria.

<sup>4</sup>Helmholtz-Institut für Strahlen- und Kernphysik, University of Bonn, Germany.

\*[blis@iaepan.edu.pl](mailto:blis@iaepan.edu.pl)

Keywords: Neutron Activation Analysis, pottery provenance, imports

Pottery produced during the Late Bronze Age (LBA) in the Argolid, associated with the area of Mycenae and Berbati, is very well characterized by Neutron Activation Analysis (Demakopoulou et al. 2017). Beyond Argolid, the so-called MYBE elemental pattern has been detected in numerous samples dating to LBA deriving from the Aegean and Eastern Mediterranean (Jung 2015). Nevertheless, while exports of often elaborately decorated Argive pottery to Cyprus, the Levant, or Egypt are thoroughly investigated, we are lacking such detailed data for many of the regions of the Greek Mainland.

The new program of elemental analyses of LBA pottery from the sites of Pefkakia and Kastro/Palaia located in coastal Thessaly, building upon earlier results from the same area currently under publication (Lis et al. *in print*), aims to fill this gap. With the help of this combined data we are able to discuss imports from the Argolid reaching an important Mycenaean region in a diachronic perspective, from the beginnings of the LBA until ca. 1200 BC.

Comprehensive sampling allows us to consider the range of shapes that was imported to Thessaly during different parts of the LBA, while the good agreement between macroscopic and neutron activation analyses results for pottery produced in the Argolid makes it possible to offer insights into the frequency of such imports.

Our presentation will conclude with thoughts on the interpretation of Argive pottery found in coastal Thessaly.

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## **LOCALLY MADE OR IMPORTED: THE ARCHAEOMETRIC ANALYSIS OF THE CERAMIC MATERIALS FROM THE MEROITIC SITE OF SEDEINGA (NORTHERN SUDAN)**

MARITAN L.<sup>1</sup> \*, MASCARO M.E.<sup>1</sup>, MC CARTHY C.N.<sup>1</sup>, PASQUAL D.<sup>1</sup>, DAVID R.<sup>2</sup>, RILLY C.<sup>3</sup>

<sup>1</sup>Department of Geosciences, University of Padova, Italy

<sup>2</sup>MF Norwegian school of Theology, Norway

<sup>3</sup>Llacan, CNRS, EPHE, France

\* [lara.maritan@unipd.it](mailto:lara.maritan@unipd.it)

Keywords: Meroitic pottery, Northern Sudan, Nile Valley

The strategic geographic location of Sedeinga (northern Sudan) along the Nile between the second and the third Cataract at the crossroad with the desert tracks leading to Darfur, and between the central Nile Valley and the northern territories (present Egypt) makes this Meroitic site important in terms exchanges/importation of materials between areas and possible production centres characterized by different geological settings. The various types of ceramic bodies macroscopically observed among the ceramic repertoire of decorated objects attested at the site (stamped goblets, bowls, cups, bottles and jars), open the important issue on the provenance and production technology, in terms of clay selection, processing and firing. Meroitic ceramics are, in fact, described in terms of the possible raw materials used, as kaolinitic clay-based or Nile clay-based, according to the light-pinkish (buff) or dark brown-intense red colour of their ceramic body, respectively.

With this in mind, an archaeometric analysis of a set of 58 samples, selected to cover the various identified macro-fabrics, was carried out using a multi-analytical approach, consisting in petrographic, mineralogical and geochemical analysis. Samples were divided into homogeneous groups in terms of raw materials used and production recipes. They were compared with both literature data and clay materials collected along the Nile, to define their local origin or the provenance area from which they came from.

The work allows us to properly define the type of raw materials used, petrographically and geochemically, and to constrain their origin in geological terms, thanks to the comparison with a large database of clayey materials collected along the Nile. Comparison also with literature data on ceramics from other sites in northern and central Sudan, disclosed similarities in production recipes and trades on various scales on a wider viewpoint within the ancient Nubia.

## HELLENISTIC POTTERY FROM THE CYCLADES: PROVENANCE OF EPIDOTE-RICH COOKING FABRIC

MARZEC E.<sup>1-2</sup>, KAJZER M.<sup>3</sup> \*

<sup>1</sup>Fitch Laboratory, British School at Athens, Souedias 52, 10676 Athens, Greece.

<sup>2</sup>Institute of Mediterranean and Oriental Cultures of the Polish Academy of Sciences, Poland.

<sup>3</sup>Institute of Archaeology and Ethnology of the Polish Academy of Sciences, Poland

\*[gosiakaj@gmail.com](mailto:gosiakaj@gmail.com)

Keywords: Delos, Hellenistic pottery, cooking fabric

The current paper brings new evidence to the ongoing discussion of pottery production on Delos during the Hellenistic times through integrated macroscopic, elemental and petrographic analyses of ceramic assemblages from Serapieia A, B and C on Delos, combined with geological prospection on the neighboring islands. The macroscopic analysis indicated that various ceramic objects were made of red cooking fabrics. They include chytrai, lopades, lids and braziers, which were used for cooking, as well as lamps, plates, lekanes, jugs, and roof tiles, used for other purposes.

Forty-two samples representing the most numerous macroscopic group made of red cooking fabric were analyzed with thin section petrography and wavelength dispersive X-ray fluorescence spectrometry. The results of petrographic analysis indicated that all of these samples form one compositional group characterized by the abundance of epidote group minerals.

The examination and experimentation carried out on clayey sediments collected on Tinos suggested that this island is a potential source of this group of pottery. This has a profound impact on studies of the consumption of Hellenistic pottery on Delos because most research on pottery from the island has been focused on long-distance trade during the Late Hellenistic period.

This study shows the importance of close-regional connectivity.

## CERAMIC PRODUCTION AND RAW MATERIALS IN THE TUSCAN-LIGURIAN REGION: AN ARCHAEOLOGICAL AND PETROGRAPHIC APPROACH IN A DIACHRONIC PERSPECTIVE

MENCHELLI S.<sup>1\*</sup>, CAPELLI C.<sup>2</sup>, STARNINI E.<sup>1</sup>, CABELLA R.<sup>2</sup>, PIAZZA M.<sup>2</sup>

<sup>1</sup>Department of Civilizations and Forms of Knowledge, University of Pisa, Italy

<sup>2</sup>Department of Earth, Environment and Life Sciences, University of Genoa, Italy

\* [simonetta.menchelli@unipi.it](mailto:simonetta.menchelli@unipi.it)

Keywords: ceramic sourcing; Tosco-Ligurian region; petrographic approach

This contribute focuses on the history of ceramic production of a large geographic area from the archaeological point of view encompassing Liguria and N-W Tuscany and using a petro-archaeometrical approach (essentially based on thin-section analyses of more than a thousand of samples).

The scope of the research is to reconstruct the productive districts combining information from the Prehistory to the late Roman age in a diachronic perspective (Capelli et al. 2006, 2017). The region under study extending from Ventimiglia (in western Liguria) to the Cecina Valley (in central Tuscany) is characterized by a marked geological variability allowing the definition of specific production areas based on mineralogical-petrographic data.

Our research combines information collected from different sources including raw materials and samples of the earliest productions (Neolithic wares) to Roman and Late Roman products (cooking wares: pots, pans, saucepans, lids) and wastes of ceramic workshops identified in the study area (Menchelli et al. 2001, 2011). This diachronic approach allows the definition of subregional productive districts characterized by specific fabrics/mineralogical-petrographic assemblages.

Finally, some case-studies will be presented in detail.

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## CHARACTERISING POTTERY PRODUCTION AND IMPORTATION IN EARLY BRONZE AGE POLIOCHNI-LEMNOS (NORTHEAST AEGEAN): PETROGRAPHIC AND GEOCHEMICAL ANALYSIS

MENELAOU S.<sup>1-2, \*</sup>, KOUKA O.<sup>2</sup>, KIRIATZI E.<sup>1</sup>, MÜLLER N.<sup>1</sup>, GARDNER C.<sup>1</sup>

<sup>1</sup>Fitch Laboratory, British School at Athens, Greece

<sup>2</sup>Archaeological Research Unit, University of Cyprus, Greece

\*[s.menelaou@bsa.ac.uk](mailto:s.menelaou@bsa.ac.uk)

Keywords: Poliochni, Early Bronze Age, ceramic petrography, geochemical analysis

The settlement of Poliochni on the east coast of Lemnos Island (northeast Aegean) has long been considered one of the largest early urban centres of the Early Bronze Age (EBA) and the first city in Europe, owing to its sophisticated planning and richness of material culture (e.g. Doumas & La Rosa). Poliochni, one of the best-known sites of the third millennium BC in the region, has brought to light important evidence that testify to its nodal position and openness to cultural interactions across the Aegean, including craft innovations and the construction of communal, administrative buildings. Previously interpreted as a sea-oriented Anatolian-style community with major contacts with Mainland Greece and the Cyclades, as suggested by potential ceramic imports, Poliochni presents a diverse ceramic assemblage with Aegean and western Anatolian elements.

This paper provides an overview of the analytical results of selected pottery samples from the excavations carried out by the Italian Archaeological School at Athens in the 1930s and 1950s (Bernabò Brea 1964; 1976), covering all phases of the EBA. Thin-section petrography and elemental analysis with WD-XRF of 78 samples have allowed a first characterisation of the local potting traditions and a diachronic understanding of continuity and change in relation to raw materials exploitation. More importantly, this paper adds new data in our knowledge of Aegean exchange networks and connectivity, through the identification of imports from the central Aegean and probably the opposite Anatolian coast.

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## NEOLITHIC AND BRONZE AGE POTTERY CONSUMPTION AT AGRIOMERNOS CAVE, SAMOS (GREECE): COMPOSITIONAL ANALYSIS AND PROVENANCE DETERMINATION

MENELAOU S.<sup>1-2,\*</sup>, MARZEC E.<sup>1</sup>, GEORGIADIS F.<sup>3</sup>, KATSAROU S.<sup>3</sup>, SIROS A.<sup>3</sup>, DARLAS A.<sup>3</sup>

<sup>1</sup>Fitch Laboratory, British School at Athens, Greece

<sup>2</sup>Archaeological Research Unit, University of Cyprus, Cyprus

<sup>3</sup>Ephorate of Palaeoanthropology-Speleology, Greek Ministry of Culture and Sports, Greece

[\\*s.menelaou@bsa.ac.uk](mailto:s.menelaou@bsa.ac.uk)

Keywords: Ceramic Petrography, WD-XRF, Agriomernos Cave-Samos

This pilot study investigates the prehistoric ceramic production and consumption at Agriomernos Cave (Megalo Seitani), a recently-discovered site in northwest Samos, Greece, altering our hitherto idea of a largely uninhabited part of the island during the Neolithic and Bronze Age periods, through recovery of a closed well-dated context. In the framework of a wider project, this paper presents the analytical results through a combination of thin-section petrography and Wavelength Dispersive X-Ray Fluorescence Spectroscopy.

The analytical results, combined with macroscopic and typological data, have revealed a diverse ceramic assemblage in terms of clay composition and provenance. While most of the pottery was produced locally, using a range of different raw material sources, secure intra- and off-island imports have also been identified based on their petrological signature. Agriomernos Cave constitutes a key archaeological site at an area that has largely remain unexplored and it offers a unique opportunity to evaluate a sealed and securely-dated ceramic assemblage with strong typological and stylistic parallels from the nearby islands and western Anatolian littoral.



## **PETROGRAPHIC AND GEOCHEMICAL ANALYSES OF POTSDHERDS FROM WADI TANUF, OMAN: APPROACHING POTTERY PRODUCTION IN SOUTHEASTERN ARABIA DURING THE SECOND AND FIRST MILLENNIA BCE**

MIKI T.<sup>1,\*</sup>, KURONUMA T.<sup>2</sup>, MACDONALD B.L.<sup>3</sup>, GLASCOCK M.<sup>3</sup>, KONDO Y.<sup>2</sup>

<sup>1</sup>The University Museum, The University of Tokyo, Japan

<sup>2</sup>Research Institute for Humanity and Nature, Japan

<sup>3</sup>Archaeometry Laboratory, Research Reactor Center, University of Missouri, U.S.A.

\*[tmiki@um.u-tokyo.ac.jp](mailto:tmiki@um.u-tokyo.ac.jp)

Keywords: Thin-section petrography, INAA, Oman

This presentation explores the petrographic and geochemical characteristics of the pottery collected from two sites in Wadi Tanuf, Oman, the cave of Mugharat al-Kahf belonging to the Middle Bronze Age (Wadi Suq period, c. 2000-1600 BCE), and WTN02 the site of the Early Iron Age (c. 1300-650 BCE).

The aim of this research is to clarify interregional similarities and differences in pottery production techniques in southeastern Arabia and examine the long-distance trade of pottery, thereby exploring mobile communities in these periods. We conducted an analysis by thin-section petrography and instrumental neutron activation analysis (INAA) of ceramic samples from these sites. The petrographic results indicate that various types of clay sources and tempers were utilized in the Middle Bronze Age, while there is a region-wide similarity in the minerals used as temper (from Oman ophiolite) in the Early Iron Age. The geochemical results suggest the difference in clay sources between the Middle Bronze Age and Early Iron Age in Wadi Tanuf, and the unlikeliness of the interregional trade of ordinary pottery throughout southeastern Arabia.

These results will contribute to understand differences in interregional interactions and the knowledge transfer of pottery production techniques between the Middle Bronze Age and Early Iron Age. Furthermore, the differences between these two periods will shed new light on the socio-economic transformation during the second and first millennia BCE.

## THE DIFFUSION OF BLACK GLOSS POTTERY IN THE WESTERN MEDITERRANEAN: ARCHAEOOMETRY AND DATA VISUALIZATION

ORTEGA PALACIOS C.<sup>1,\*</sup>, MADRID I FERNÁNDEZ M.<sup>1</sup>, SINNER A. G.<sup>2</sup>

<sup>1</sup>Cultura Material i Arqueometria UB (ARQUB, GRACPE), Departament d'Història i Arqueologia, Universitat de Barcelona, Spain

<sup>2</sup>Department of Greek and Roman Studies, University of Victoria, Canada

\*[clortegap@ub.edu](mailto:clortegap@ub.edu)

Keywords: Black Gloss pottery, archaeometry, provenance

Black Gloss pottery, also called Campanian pottery, was the first mass-produced tableware in Antiquity. Its appearance must be linked to the Roman expansion and the development of a complex economic and commercial system.

In this paper, we present the archaeometric study of over 350 individuals of Black Gloss pottery from several consumption centres in Western Mediterranean. The study is part of the research project Mediterranean Connectivity: Economy, Trade and Commercial Circuits in the Roman West (2<sup>nd</sup> c. BCE – 1<sup>st</sup> c. CE) (MedConTaCCt) (Madrid and Sinner, 2019; 2021; Pagliantini et al., 2022) and incorporates some results of the Cosa project (Roca et al., 2013). All the samples have been analysed using X-ray fluorescence to address questions about provenance and by X-ray diffraction for the study of the technique used in their production. A subsample has also been selected for a microstructural analysis by means of scanning electron microscopy.

Our research has identified 17 compositional groups that correspond to different ceramic products made in the Italian peninsula, as well as several non-italic groups that have been interpreted as regional/local products, identified for the first time in the ancient Gaul and the Iberian Peninsula.

The results reveal the existence of many workshops and production areas, most previously unknown. With a fast-growing databank, creating data visualization and mapping tools to visualize complex searches and queries has become a core aspect of the project.

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## LOOKING AT THE IRON AGE IN THE INTERIOR IBERIA AND THE MEDITERRANEAN INFLUENCES: CERAMICS FROM THE ARCHAEOLOGICAL SITE OF “EL PUEYO DE MARCUELLO” (HUESCA, SPAIN)

PÉREZ-ARANTEGUI J.<sup>1,\*</sup>, LAPUENTE P.<sup>2</sup>, FABRE J.<sup>3</sup>, ARBUÉS M.J.<sup>4</sup>

<sup>1</sup>Instituto Universitario de investigación en Ciencias Ambientales de Aragón (IUCA), Universidad de Zaragoza, Spain

<sup>2</sup>Petrología y Geoquímica, Departamento de Ciencias de la Tierra, Universidad de Zaragoza, Spain

<sup>3</sup>Museo de Zaragoza, Spain

<sup>4</sup>Museo de Huesca, Spain

\*[jparante@unizar.es](mailto:jparante@unizar.es)

Keywords: Iron Age, Iberian, provenance

The archaeological site called “El Pueyo de Marcuello” (Huesca, Spain) is an Iron Age urban settlement, geographically situated between the Pyrenees and the Ebro Valley and dated to the second half of the first millennium BCE. The nature and manufacture of the archaeological remains found at present allow identifying this site as a contact point for relevant exchanges, which go beyond the so-called prestige items, even their production mechanisms, with remarkable connections with the Central and Western Mediterranean cultures.

These cultural connections and exchanges were investigated through the characterization of the ceramic objects found during the archaeological excavations. In addition to cooking vessels and bowls, several decorated lids and holmoi or ceramic feet were found, especially in an area of the site, proving a singular case of this Iron Age site.

More than forty fragments were studied, especially including some of the most peculiar ceramic types, and analyzed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) and Mass Spectrometry (ICP-MS). The statistical treatment of the chemical data resulted in the identification of two main compositional groups. Both included low-calcareous clay bodies with distinguishing elemental compositions in major, minor and trace elements. These two clusters were also confirmed by the petrographic observations of the thin sections, showing two different ceramic bodies. All these data have allowed making a comparison in order to explain the provenance of the ceramic objects and then, the cultural and commercial contacts of the region with the Mediterranean.

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## STUDY OF OCHRE BASED PIGMENT ON ARCHAEOLOGICAL OBJECTS FROM DIFFERENT SITES IN SICILY FOR A POSSIBLE PROVENANCE ATTRIBUTION

POLITI G.<sup>1</sup> \*, TODARO S.V.<sup>2</sup>, GULLÌ D.<sup>3</sup>, LEMASSON Q.<sup>4</sup>, MOIGNARD B.<sup>4</sup>, PACHECO C.<sup>4</sup>, PICHON L.<sup>4</sup>, GUELI A.M.<sup>1</sup>

<sup>1</sup> Dipartimento di Fisica e Astronomia “Ettore Majorana”, Università di Catania, Italy

<sup>2</sup> Dipartimento di Scienze Umanistiche, Università di Catania, Italy

<sup>3</sup> Soprintendenza per i Beni Culturali e Ambientali di Agrigento, Italy

<sup>4</sup> Centre de Recherche et Restauration des Musée de France, France

\*[giuseppe.politi@ct.infn.it](mailto:giuseppe.politi@ct.infn.it)

Keywords: Ochre Database PIXE

Ochre was largely used in prehistory first in connection with burials and wall paintings, and later on in connection with pottery and architecture decorations. In Sicily, between the end of the V and the beginning of the IV millennium BC, ochre is used to decorate the surface of two categories of pottery that seems to imitate metal vessels in either the profile or for the association with grooved or jabbed decoration.

Interestingly, while in some cases the sources of the ochre so abundantly used are obvious, in other cases they are not; the Sicilian ones for example, have not been characterized and provenanced. In this work we will report on the results obtained with PIXE technique on the elemental composition of some raw materials and of ochre-based pigments on archaeological samples, both coming from various sites in Sicily.

These results on chemical composition, forming the first example of data base for this kind of archaeological objects, will be analyzed with the standard multivariate statistical techniques, to study possible correlation plot and to look for the differences into the same production site and among the different sites. Moreover, a comparison with results obtained on raw materials, if available, will be useful to try a provenance attribution.

## TRACING THE CULTURAL AND TRADE RELATIONS OF THE SPANISH EMPIRE AND THE LESSER CARIBBEAN ANTILLES IN THE 16<sup>TH</sup> AND 17<sup>TH</sup> CENTURIES THROUGH CERAMIC ANALYSIS

PUJALS S.<sup>1,\*</sup>, BUXEDA I GARRIGÓS J.<sup>1</sup>, MENTESANA R.<sup>1</sup>

ARQ|UB (Material Culture and Archaeometry UB) GRACPE (Research Group on the Archaeology of Complexity and the Processes of Social Evolution) Department of History and Archaeology, Prehistory and Archaeology section, University of Barcelona, Spain

[\\*spujalsbl@ub.edu](mailto:spujalsbl@ub.edu)

Keywords: ceramic archaeometry, Spanish Atlantic expansion, cultural contact

The transatlantic trade between the Spanish Empire and America was fundamental in the establishment of the colonies in America. The trade supplied settlers, fleets, and navies with essential goods, including foodstuffs, that were essential for their survival. Written evidence suggests that ceramic transport jars contained liquids and solids, including olive oil, wine, vinegar, honey, butter, olives, and capers. As a ubiquitous and frequently used product, ceramics provide a wealth of information about the manufacturing practices and technological choices of these colonial societies.

This paper explores the trade contact between the Spanish Empire and the Lesser Caribbean Antilles in the 16th and 17th centuries through the study of the ceramic transport containers from the archaeological prospection on the island of Cayo Sal (Los Roques, Venezuela). We aim at shedding light on the complex process of cultural trade contact and technological transfer between these social realities.

The study uses various techniques such as X-ray fluorescence (XRF), X-ray diffraction (XRD), optical microscopy (OM), scanning electron microscopy (SEM), and energy-dispersive X-rays (EDX) to determine the chemical and mineralogical composition of the ceramics and establish a possible provenance and production technology. After grouping the Cayo Sal samples, a comparison is made with the ceramics from the Tecnolonial project database to contextualize these ceramics within the larger picture of Spanish Atlantic trade with the Americas.

Reconstructing the trade network between the Spanish Empire and the Lesser Caribbean Antilles provides a glimpse into the cultural, economic, and political connections between the two regions. Ultimately, we can better comprehend the role of these early societies in shaping the global interconnectedness that characterizes our world today.

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## THE BELL BEAKERS OF CARDIM 6 AND PORTO TORRÃO (SOUTHERN IBERIA): PROVENANCE OF RAW MATERIALS AND CIRCULATION OF “IDEA”

RODRIGUES A. L.<sup>1,\*</sup>, MARQUES R.<sup>1-2</sup>, DIAS M.I.<sup>1-2</sup>, PRUDÊNCIO M. I.<sup>1-2</sup>, VALERA A. C.<sup>3-4</sup>, GMÉLING K.<sup>5</sup>

<sup>1</sup>Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>2</sup>Departamento de Engenharia e Ciências Nucleares (DECN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>3</sup>ERA Arqueologia S.A., Portugal

<sup>4</sup>Interdisciplinary Center for Archaeology and Evolution of Human Behavior (ICArHEB), Universidade do Algarve, Portugal

<sup>5</sup>Nuclear Analysis and Radiography Department, MTA Centre for Energy Research, Hungary

\*[alsr@ctn.tecnico.ulisboa.pt](mailto:alsr@ctn.tecnico.ulisboa.pt)

Keywords: Bell beaker productions, provenance of raw materials, circulation of “idea”

This work intends to contribute to the bell beakers phenomena discussion mainly related to provenance issues and the relationship between neighbouring archaeological sites from southern Iberia: Porto Torrão and Cardim 6 (Ferreira do Alentejo, Portugal). The existing chemical and mineralogical data from Porto Torrão bell beakers [1] will be complemented with new data, obtained by X-ray diffraction and neutron activation analyses, from the neighbour Cardim 6 site.

Using mineralogical and chemical data, a characterization of 33 ceramic pastes and 11 potential raw materials is foreseen, with a view to revealing similar or dissimilar bell beaker productions, to a better understanding of the connection between both sites. Mineralogical composition distinguishes two groups of ceramics: one more expressive mainly composed of quartz, feldspars (plagioclase), amphiboles (hornblende), and the other, representing few ceramics, mainly composed of calcite, dolomite, micas and iron hydroxides. The constant presence of plagioclase and hornblende in ceramics is an important indicator of local raw materials (materials around the sites are mostly clays derived by weathering from gabbros and diorites), supporting the idea of local production. Chemical contents of Fe, Sc, Cr, Co, Ba and rare earth elements (REE) are considered the best geochemical fingerprints to establish the bell beakers production from both sites and enabled to confirm that they were produced locally, mostly with local clays derived by weathering from gabbros and diorites, and some of them with local Tertiary clays. The different amounts of REE and the distinct Eu anomalies observed clearly distinguish these clay raw materials and two compositional groups of bell beakers.

The bell beaker productions defined support the notion of the circulation of the “idea”, and confirm the existence of relationships between both sites, reinforcing Cardim 6 as part of the clusters of funerary structures that surround the funerary complex of Porto Torrão.

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## WHAT IS ‘LA HOGUETTE’? A NEW METHODOLOGICAL APPROACH (P-XRF) TO A FAMILIAR ISSUE

SCHAUER M.

Dep. for Cultural Studies and Antiquity at Ludwig-Maximilians-Universität Munich - Near Eastern and Prehistoric  
Archaeology, Germany, [m.schauer@campus.lmu.de](mailto:m.schauer@campus.lmu.de)

Keywords: La Hoguette, p-XRF, origin

Pottery is one of the most important and numerous remnant of material culture that archaeologists can work with to understand the past. It is the main tool to define cultural groups, to identify contacts between groups and to describe identities – and the only remnants clearly to be attributed to a special pottery type called La Hoguette (LH). This pottery tradition appears in the late 6<sup>th</sup> to early 5<sup>th</sup> millennium BC in a vast area between Northern Bavaria, the Atlantic coast, the Loire delta and Netherland. By <sup>14</sup>C and by its accompanying material LH dates in the same time frame as the Linearbandkeramik (LBK), the earliest Neolithic culture of the area. Due to its typology, LH is – following literature – either attributed A) to a Mesolithic (pastoral) society or B) due to its dominant context as a special type of pottery to the LBK: The conical, stitch-decorated LH vessels are found mainly in LBK sites, but also a smaller number of camp or cave sites which are in almost all cases located in the territory of the LBK. Strikingly, in rare cases LH pottery tempered with LBK-grog is known and temper materials – even bone temper – are documented for both pottery traditions. Additionally, parallels for LH and LBK pottery can be drawn either to the transdanubian Early Neolithic (*Starčevo-Körös-Criş*) or Late Mesolithic traditions (Bug-Dnjestr). Therefore, it seems possible, that LH and LBK pottery was produced in the LBK settlements in the same pottery tradition by different cultural lineages in the LBK community.

To prove this theory, portable X-Ray Fluorescence (p-XRF) was used to identify the chemical fingerprint of pottery, daub and clay from the earliest LBK settlements of Friedberg-Bruchenbrücken in the Wetterau (Hesse). Analysis of the former two categories of finds were also performed for two settlements in the area Oberes Gäu (Baden-Württemberg). In all cases, LH and LBK pottery was locally produced either nearly exclusively from local clays (Friedberg-Bruchenbrücken) or loess (Rottenburg ‘Fröbelweg’) or a mixture of both (Rottenburg-Hailfingen). The only possibly non-local wares are thereby coarse LBK-vessels. The detailed study of Friedberg-Bruchenbrücken additionally showed that two separate technological approaches, visible in the differences in use and combination of raw materials, existed in the same settlement. Both lines produced LH as well as LBK pottery and can be traced through different settlement-phases. A production of LH-pottery by cultural lineages of the LBK hence is very likely and LH – at the current state of research – can be referred to as a subculture of LBK.

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## NEOLITHIC AND CHALCOLITHIC POTTERY FROM OGLIASTRETTO (ITALY): ASSESSING RAW MATERIALS PROCUREMENT AND PASTE PREPARATION BY PETROGRAPHIC ANALYSIS

SERINO D.<sup>1,\*</sup>, CANNAVÒ V.<sup>2</sup>, FERRARO G.<sup>3</sup>, VERBICARO G.<sup>4</sup>, LEVI S.T.<sup>5</sup>, VANZETTI A.<sup>1</sup>, MARINO S.<sup>1</sup>

<sup>1</sup>Dipartimento di Scienze dell'Antichità, Sapienza Università di Roma, Italy <sup>2</sup>Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, Italy

<sup>3</sup>Geofisica Misure s.n.c. Trebisacce, Italy

<sup>4</sup>Soprintendenza Archeologia, Belle Arti e Paesaggio per la Provincia di Cosenza, Italy

<sup>5</sup>Department of Classical and Oriental Studies, Hunter College, City University of New York, USA

\*[donatella.serino96@outlook.it](mailto:donatella.serino96@outlook.it)

Keywords: ceramic ecology, raw materials procurement, petrographic analysis

The Neolithic and Chalcolithic settlement of Ogliastretto is located in the southern part of the Plain of Sybaris (Calabria, Italy). The micro-region is characterized by a rather diverse intrusive-metamorphic lithotypes with a wide variability of raw materials suitable for the ceramic production resulting in various fabrics. In this context is therefore proper to use the holistic concept of “ceramic ecology”, situating the technological choices of potters within the frame of the alternatives offered by the local raw materials. The aim of our research is to reconstruct the patterns of exploitation of the available resources for the pottery production and to interpret them in terms of technological choices among the alternatives offered by the surrounding environment and landscape.

The present study is based on an analytical program of macroscopic characterization of pottery and thin-section petrography of 34 vessels for the compositional and the technological investigation and classification of the ceramic pastes. For the definition of the textural and compositional characteristics of the raw materials 12 samples of clays, silts, sands, and soils have been collected within a maximum distance of 7 Km from the site. The multiphase settlement of Ogliastretto also allows the diachronic investigation of change or continuity in the manufacturing processes and the raw materials procurement patterns.

The results of the first analytical step provide relevant clues to the exploitation of raw materials from different micro-basins, with an increased diversification of the local fabrics during the Chalcolithic.

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## CHALCOLITHIC AND BRONZE AGE CERAMICS FROM PEÑÓN DE LA ZORRA (ALICANTE, SPAIN). RAW MATERIALS CHOICE AND TECHNOLOGICAL CHANGE

SERNA MARTÍNEZ I.<sup>1\*</sup>, DEL PINO CURBELO M.<sup>2</sup>, GARCÍA ATIÉNZAR G.<sup>1</sup>, BUXEDA GARRIGOS J.<sup>3</sup>

<sup>1</sup>Instituto Universitario de Investigación en Arqueología y Patrimonio Histórico, Universidad de Alicante, Spain,

<sup>2</sup>Departamento de Ciencias Históricas, Universidad de Las Palmas de Gran Canaria, G.I. Tarha, Spain

<sup>3</sup>Departament d'Història i Arqueologia, Universitat de Barcelona, Spain

\*[israel.serna@ua.es](mailto:israel.serna@ua.es)

Keywords: bell-beaker, Bronze Age, Iberia

Excavations at the Peñón de la Zorra site (Villena, Alicante, Spain) have determined the existence of four archaeological phases (García Atiénzar, 2017). The first of those - Phase I - corresponds to a single trapezoidal-shaped room dated back to the Chalcolithic (ca. 2350 cal BC). Around 2100 cal BC and up to 1800 cal BC a strong architectural transformation is observed with the superimposition of construction and abandonment events of different structures generally inscribed in the Early Bronze Age (Phases II and III). The transition between the two phases is dated to around 1900 cal BC. At last, Phase IV involves the reoccupation of the site probably during the late Middle Bronze Age.

These occupations are related to a changing material culture, with the novelties introduced in the ceramic typology standing out. The first Chalcolithic phase is characterized by the presence of a richly decorated Bell Beaker assemblage (Alba & García Atiénzar, 2018). There is an important stylistic change in the later Bronze Age phases, when ceramics with simple forms predominate, generally plain but sometimes exhibiting a limited repertoire of motifs and decorative techniques. In the latter case, the incisions and impressions concentrated on the lip are characteristic.

One of the aims of the current works on the site is to define the technological traditions present across such diachronic and typological changes, including patterns of ceramic mobility and raw materials exploitation. To this end, representative pieces from each of the occupational phases were selected and 30 thin sections were prepared. The results obtained suggest an important transformation in raw materials selection and processing. The use of local pastes was common along the whole series, although the areas of procurement vary. The first phase is characterized by the use of pastes with angular crystals of spathic calcite, a technological practice that has been common since the Early Neolithic in Eastern Iberia. In contrast, in the case of the Bronze Age materials, this tradition coexists with a larger number of ceramic pastes that have no clear signs of intentional alteration. Many of them contain mainly fragments of reworked carbonaceous material together with varying amounts of rounded quartz.

To shed light on practices behind the persistence of calcite addition a multi-technique program of analysis has been put in place, this including C and O stable isotope analysis on individual spathic calcite crystals. The inclusions of two samples exhibiting crushed calcite, one from Phase I and Phase II, were analyzed. As preliminary results, the measurements clearly differentiate the inclusions from each sample. This probably indicating the use of the same paste preparation technique and, at the same time, changes in the source area exploited, in agreement with the rest of the fabrics identified by optical petrography.

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## CHARACTERIZATION OF THE GEMER WHITEWARE (S SLOVAKIA): FIRST STEPS FOR THE IMPLICATION OF A TRACEABLE FOLK POTTERY MATERIAL TYPE TO THE ARCHAEOLOGICAL DATA

SZILÁGYI V.<sup>1,\*</sup>, VIDA G.<sup>2</sup><sup>1</sup>Centre for Energy Research, Budapest, Hungary<sup>2</sup>Museum of Ethnography, Budapest, Hungary[\\*szilagyi.veronika@ek-cer.hu](mailto:szilagyi.veronika@ek-cer.hu)

Keywords: white clay, folk pottery, S Slovakia

Hungary, being situated in the Carpathian Basin, has characteristically different clay supply regions based on the geological formation and the applicability of the plastic raw material. Folk pottery research (Kresz, 1960; Kresz et al., 1991) clearly differentiates the basinal region with silty clayey alluvial sediments providing paste for earthenware of 'jar makers' and 'bowl makers'; and the mountainous regions with pure fat, so-called fire clays appropriate for earthenware of 'pot makers' and stove tiles. According to the written ethnographic data, some specific clay types were transported to far regions of the country in order to improve the properties (e.g. fire resistivity) of the clay paste and the final fired product, even if local clay sources and traditions of pottery were present. This phenomenon is declined in the light of archaeometric investigations, when clay types or clay mixes foreign from the local environment are identified as raw materials of archaeological potteries.

An example for transportation of a given clay type to other pottery districts is the white clay of Gemer (Poltar Formation, S Slovakia) which reached the western (Somogy) and southern (Mohács) regions of Hungary travelling hundreds of kms (mainly by river) (e.g. Knézy, 1972; Sarosácz, 1972). We found this raw material type appropriate for detailed archaeometric investigations in order to (1) characterize a traceable clay type from an analytical point of view and (2) determine features which can be important in identifying this raw material type in the archaeological record. For this purpose, 20 pieces of ethnographic pottery deriving from the Gemer pottery district and belonging to the collection of the Museum of Ethnography, Budapest, were studied by analytical methods (OM, PGAA).

Our results indicate that – despite the natural variability of the clayey sediment – characteristic textural features rather than a chemical signature can be identified which can make it possible to detect the utilization of the Gemer white clay in archaeological and folk pottery.

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## MEDIEVAL TO EARLY MODERN AGE (12<sup>TH</sup> – 18<sup>TH</sup> C.) WHITEWARE ON THE HUNGARIAN PLAIN (ALFÖLD, E HUNGARY): A FOREIGN MATERIAL GROUP IN THE POTTERY RECORD

SZILÁGYI V.<sup>1\*</sup>, SIMONYI E.<sup>2</sup>, TOMKA G.<sup>2</sup>, WOLF M.<sup>3</sup>, KOVÁCS Z.<sup>1</sup>, KÓNYA P.<sup>4</sup>, GMÉLING K.<sup>1</sup>,  
KREITER A.<sup>2</sup>

<sup>1</sup>Centre for Energy Research, Budapest, Hungary <sup>2</sup>Hungarian National Museum, Budapest, Hungary

<sup>3</sup>University of Szeged, Szeged, Hungary

<sup>4</sup>Supervisory Authority of Regulatory Affairs, Budapest, Hungary

\*[szilagyi.veronika@ek-cer.hu](mailto:szilagyi.veronika@ek-cer.hu)

Keywords: whiteware, medieval, raw paste types

Although, the mass produced medieval Hungarian whiteware was assumed to be manufactured in household industry parallel with other activities and from a homogeneous raw material (Holl 1956), recent studies revealed more types of white fired pottery in the medieval and early Modern Age record (Wolf 1986; Simonyi 2020; Szilágyi et al. 2010; Tomka 2018). The first step of a systematic archaeometric (petro-mineralogical and geochemical) study was carried out to characterize the composition and variability of white pottery finds from the Hungarian Plain (12 archaeological sites). The region was selected since it is potentially appropriate area for pottery manufacturing (access to alluvial clay sources, water, firing wood), but lacking refractory and white clay sources. The analytical methods involved optical microscopy, X-ray diffraction, prompt gamma and neutron activation analysis, and scanning electron microscopy with energy dispersive spectroscopy.

According to our results, the analyzed 95 potsherds outlined a clear variability with at least 5 classes of white fired clay raw materials across the c. 10000 km<sup>2</sup> territory and through a 500-550 years timespan. The classification is based primarily on the textural features of the pastes, while the mineralogical characteristics of the ceramics are very homogeneous indicating the use of similar refractory raw materials (kaolinitic). The geochemical differences are promising for the provenance analysis, which will require comparison with potential white clay sources of the Carpathian region. Based on the distribution of white vessels, it is our assumption that most of the pottery raw materials are originated from the northern mountainous area (southern part of the Northern Carpathians, SK) while there is at least one eastern clay source (probably in the Apuseni Mts., RO) which supplied raw material for the southern part of the Hungarian Plain.

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## S5. Technology and production

### INSIGHTS INTO THE CHUPICUARO CERAMIC PRODUCTION DURING THE FORMATIVE PERIOD IN MESOAMERICA

ALLOTEAU F.<sup>1,\*</sup>, BEN AMARA A.<sup>1</sup>, CANTIN N.<sup>1</sup>, CABADAS BAEZ H.<sup>2</sup>, SEDOV S.<sup>3</sup>, IBARRA G.<sup>3</sup>, CASTAÑEDA A.<sup>4</sup>, DARRAS V.<sup>4</sup>

<sup>1</sup> Archéosciences Bordeaux, Université Bordeaux Montaigne, UMR 6034, CNRS, France,

<sup>2</sup> Universidad Autónoma del Estado de México, UAEM, Faculty of Geography, Mexico

<sup>3</sup> National Autonomous University of Mexico, UNAM, Institute of Geology, Mexico

<sup>4</sup> Laboratoire Archéologie des Amériques, Université Paris 1 Panthéon-Sorbonne, ARCHAM, UMR 8096, CNRS, France

\* [fanny.alloteau@u-bordeaux-montaigne.fr](mailto:fanny.alloteau@u-bordeaux-montaigne.fr)

Keywords: Chupicuaro culture, Formative Mesoamerica, painted ceramics

Little is known about the social, cultural and economical relationships between Central Mexico and Western Regions during the Middle and the Late Formative Periods (600 BCE – 250 CE). The Chupicuaro culture is known as one of the most dynamic Formative traditions in Western Mesoamerica, notably through its well-polished ceramics combining complex shapes, shimmering colours and diversified iconographic motifs (Darras & Hamon 2020). The forcefulness of the Chupicuaro pottery tradition seems to have influenced the ceramic productions of the Basin of Mexico, or to have been the source of local imitations and reinterpretations (Darras 2006).

The CHUPICERAM project (2021-2024), financially supported by the French National Research Agency, aims to clarify the nature and intensity of these relationships, focusing on ceramic materials from Chupicuaro culture and from Cuicuilco culture – a cultural core of the Basin of Mexico. The project follows a comparative and interdisciplinary approach, bringing together teams of Mexican and French scientists. By cross-referencing the analytical results, we attempt to establish stylistic, technical, and compositional groupings that will allow us to formulate hypotheses on the manufacturing processes and sources of supply of raw materials in the diachrony and for both Chupicuaro and Cuicuilco cultures.

In the first phase, we focus on ceramic sherds from different archaeological sites and different periods of the Chupicuaro culture (Chupicuaro and Mixtlan Periods). From the corpus of about 200 sherds, archaeological groups have been established on the basis of the patterns and colours of the decorations and of the shapes of the sherds. We used non-invasive analytical methods for the characterisation of the decorations and the ceramic pastes (hyperspectral imaging,  $\mu$ -Raman, p-XRF...). In parallel, polished cross- and thin-sections were prepared from a reduced number of sherds for morphological and quantitative compositional analyses under SEM-EDX, and petrographical analyses. In addition, a comparative analysis with geological samples from nearby sites and also with ceramic replicas fired from these samples is currently undertaken for provenance studies. All the ceramic pastes of the archaeological sherds are identified as non-calcareous ( $\text{CaO} < 2.5 \text{ wt}\%$ ). Our first results show compositional differences in the diachrony (Chupicuaro sherds versus Mixtlan sherds) of these ceramic pastes, both for major elements (Na, Al) and trace elements (Rb, Zr). Regarding the decorations, regardless of the period, they consist of a mixture of clay and iron oxides for the reds, and of clay, iron oxides and manganese oxides for the black/brown ones. The clayey beige decorations are rich in calcium, while the white ones resemble the ceramic pastes in terms of composition. Together with the mineralogical data, these results are the focus of the present study.

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## UNVEILING TECHNOLOGICAL TRADITIONS OF EARLY IRON AGE POTTERS IN VILLANOVAN COMMUNITIES OF ETRURIA (CENTRAL ITALY)

AMICONE S.<sup>1-2,\*</sup>, MORANDI L.F.<sup>1-3</sup>

<sup>1</sup>Eberhard Karls University of Tübingen, Archaeometry Research Group, Germany

<sup>2</sup>Institute of Archaeology, University College London, United Kingdom

<sup>3</sup>Dipartimento di Civiltà e Forme del Sapere, Università di Pisa, Italy

\*[silvia.amicone@uni-tuebingen.de](mailto:silvia.amicone@uni-tuebingen.de)

Keywords: Ceramic technology, Etruria, proto-Etruscans

Central Italian proto-Etruscan sites associated with Villanovan material culture (late 10th – late 8th centuries BCE) have long been studied using traditional typological approaches, but little is known about the technological know-how beneath the production of pottery in these communities. In this study we applied an interdisciplinary approach (including archaeometric analysis and the study of micro- and macro traces) to a relevant selection of pottery from different Villanovan contexts, including important sites such as Tarquinia, Vulci and Vetulonia. Our approach also highlights the relevance of the geological sampling and mapping of potential clay sources on the regional scale, in order to better understand the choices made by potters during the selection of raw materials for pottery making.

Our results reveal significant differences in the selection and processing of clay sources and tempers among different sites. These are probably due to the exploitation of a range of geological sources marked by different material properties, and the existence of separate technological traditions. Furthermore, our findings allowed a clear distinction between pottery produced in settlements of northern Etruria and settlements of southern Etruria. Artisans of different sites seem to stick to established ceramic traditions, presumably consolidated through several generations of potters. Interestingly, the results also suggest that the same ceramic workshops produced urns for different graveyards.

Finally, micro- and macroscopic examinations have revealed novel information on the forming techniques, pointing to an indigenous tradition of slow-wheel throwing already at the dawn of the Iron Age in northern Etruria.

## ARCHAEOLOGICAL CHARACTERIZATION OF ITALIAN TERRA SIGILLATA FRAGMENTS FROM ROME: PRELIMINARY DATA

ARBOLINO E.<sup>1</sup>, GERMINARIO C.<sup>2</sup>, SORICELLI G.<sup>1</sup>, RICCI G.<sup>3</sup>, MORRETTA S.<sup>4</sup>, GRIFA C.<sup>2-5, \*</sup>

<sup>1</sup> Dipartimento di Scienze Umanistiche, Sociali e della Formazione, Università degli Studi del Molise, Italy

<sup>2</sup> Dipartimento di Scienze e Tecnologie, Università degli Studi del Sannio, Italy

<sup>3</sup> Cooperativa Archeologia, Italy

<sup>4</sup> Soprintendenza Speciale Archeologia Belle Arti e Paesaggio di Roma, Italy

<sup>5</sup> Center of Research on Archaeometry and Conservation Science, Università Federico II, Napoli, Italy

\* [celestino.grifa@unisannio.it](mailto:celestino.grifa@unisannio.it)

Keywords: Terra Sigillata, multi-analytical approach

Archaeological excavation at Largo Amba Aradam in Rome unearthed a complex stratigraphic sequence, characterised by several phases covering a chronological time span between the end of the I BCE and the modern age. During the first phase (period I), dated back between the end of I century BCE and the beginning of the I century CE, the site was devoted to agriculture, while in the second phase (period II), dated back ca. to the middle of I century CE, a prestigious residential building was settled here.

In the first two phases of the sequence (period I and II) a conspicuous number of Italian Terra Sigillata specimens were recovered. From the entire set of Italian Terra Sigillata vessels, sixteen representative fragments were sampled and analysed. Among them, only some specimens display a stamp typically recorded in central Italian production, whereas the others either have stamps that do not allow the determination of the production area, or do not have the stamp at all. However, all samples are covered by a homogeneous, compact red slip with a metallic luster.

The archaeometric approach adopted aimed at characterizing the vessels from the mineralogical point of view, in order to better understand the production areas of the workshops as well as provide a broader comprehension of this type of ceramic production in Rome between the end of the republican age and the beginning of imperial age.

Although on-going chemical analyses will be crucial for the determination of the provenance of vessels, specimens have been preliminarily analyzed by using Polarized Light Microscopy (PLM) and Fourier Transform Infrared Spectroscopy in Attenuated Total Reflectance mode (ATR-FTIR), aiming at defining the main mineralogical and textural features, suggesting levigation of the high CaO clays used for manufacturing the vessels.

Samples, in fact, were characterized by fine-textured pastes, pinkish in color, with scarce skeleton particles of quartz, and mica and remains of carbonates (< 0.25mm) divided into three different fabrics on the basis of the abundance of residual aplastic inclusions.

Mineralogical features suggested that they probably underwent different firing conditions. ATR-FTIR spectra allowed to detect the occurrence of calcite along with newly formed Ca-silicates (diopside and/or gehlenite) that suggested the achievement of 850°C in samples where they coexist (Grifa et al, 2019). The temperatures, instead, at least achieved (or exceeded) 950°C in those specimens in which only diopside occurs. Such firing temperatures are supported by the vitrification structures observed by Scanning Electron Microscopy (SEM), which attested an extensive vitrification stage, as proved by the well-developed network of glass. Regarding the slips, they appear weakly anisotropic or isotropic, with a thickness of ca. 20-30 µm and SEM observations confirmed their complete sintering.

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## ARCHAEOMETRIC STUDY OF TIN-GLAZED CERAMICS FROM ANABAPTIST POTTERY PRODUCTION CENTRES IN MORAVIA

BAJNÓCZI B.<sup>1</sup> \*, SZABÓ M.<sup>1</sup>, NAGY G.<sup>1</sup>, TÓTH M.<sup>1</sup>, MAY Z.<sup>2</sup>, PAJER J.<sup>3</sup> & RIDOVICS A.<sup>4</sup>

<sup>1</sup>Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungary

<sup>2</sup>Institute of Materials and Environmental Chemistry, Research Centre for Natural Sciences, Hungary

<sup>3</sup>Strážnice, Czech Republic

<sup>4</sup>Hungarian National Museum, Hungary

\*[bajnoczi.bernadett@csfk.org](mailto:bajnoczi.bernadett@csfk.org)

Keywords: faience, tin glaze, Anabaptist

Anabaptists (Hutterites) started Faience, i.e., tin-glazed earthenware production in Eastern-Central Europe in the late 16<sup>th</sup> century. The main production centres of Anabaptist Faience existed in Moravia at that time; nowadays thirteen centres are documented thanks to the archaeological research (Pajer 2021). Among them Vacenovice is regarded as the largest and most productive centre, while the oldest workshop was probably in Tavíkovice. A typical product of the workshops is the white tin-glazed ceramic with yellow, blue, green and black decorations, however, coloured-glazed faience was also produced.

Faience fragments found at these two production centres were analysed to reconstruct the production technology and the raw materials used. SEM-EDX analysis was performed to reveal the microstructure and chemistry of the tin glaze and the decorations, whereas X-ray powder diffraction and ICP-OES analyses were applied to determine the mineralogy and chemistry of the ceramic bodies.

The ceramic bodies of all the analysed tin-glazed ceramic fragments are made of Ca-rich clay pastes (typically 10-16 wt.% CaO) that contain high-temperature, newly-formed Ca-silicate phases, generally more diopside than gehlenite. The chemical and mineralogical compositions indicate the use of Ca-rich (calcareous) clay fired at c. 900-950°C. The tin glaze was applied after the first firing.

The lead-alkali type white glaze with a thickness of c. 200-400 µm contains lots of residual sand grains, as well as abundant tin oxide particles resulting in usually higher than 10 wt% SnO<sub>2</sub> content. Decorations are coloured lead-alkali glazes with variable amount of tin oxide and sand particles. They were coloured with cobalt for blue, copper together with lead-tin antimonate pigment for green, lead-tin antimonate pigment for yellow, and manganese for black. Decorations were applied to the unfired white tin glaze.

The Faience fragments from Vacenovice and Tavíkovice show a close resemblance in production technology and raw materials used to the Anabaptist tin-glazed ceramics found in the territory of the present-day Hungary (e.g., Sárospatak, Bajnóczi et al. 2014). A remarkable difference between the Moravian and the Hungarian faience finds is noticed in the type of the yellow pigment that is the more common lead antimonate in the decorations of the Hungarian finds.

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## UNDERSTANDING TECHNOLOGICAL CHOICES IN THE PRODUCTION OF EARLY MEDIEVAL MARBLE TEMPERED COARSE WARES IN PANNONIA

BAJNOK K.<sup>1,2,\*</sup>, KOVÁCS Z.<sup>3</sup>, DÖNCZ B.<sup>4</sup>, RIGO M.<sup>5</sup>, MARITAN L.<sup>5</sup>, SZAKMÁNY GY.<sup>6</sup>

<sup>1</sup>Neutron Spectroscopy Department, Centre for Energy Research, ELKH, Hungary

<sup>2</sup>Institute of Archaeological Sciences, Eötvös Loránd University, Hungary

<sup>3</sup>Institute of Technical Physics and Materials Science, Centre for Energy Research, ELKH, Hungary

<sup>4</sup>Institute for Nuclear Research (ATOMKI), ELKH, Hungary

<sup>5</sup>Department of Geosciences, University of Padova, Italy

<sup>6</sup>Department of Petrology and Geochemistry, Eötvös Loránd University, Hungary

\* [bajnok.katalin@ek-cer.hu](mailto:bajnok.katalin@ek-cer.hu)

Keywords: marble tempered coarse ware, ceramic petrography, technological choice

After the relinquishment of the Roman province of Pannonia (western Hungary) in the early 5<sup>th</sup> century AD, the following centuries represented a dynamic and politically unstable period in the territory of the former province. This period is characterised by social, cultural, economic and political interactions between the remaining Romanised population and several barbarian peoples arriving to the territory due to the increasing level of migration.

Against this backdrop of apparent disruption and change, surprising elements of longevity can be detected in certain features of the pottery repertoire, for instance, in the marble tempered coarse wares. In this study we present the archaeological science analysis of this pottery technology that became widespread in the territory in the late 4<sup>th</sup> – early 5<sup>th</sup> century and remained dominant during the 6<sup>th</sup> as well. The identification of this ware is relatively recent, as prior to the first petrographic analyses they were macroscopically grouped together with pots containing other types of carbonate temper. However, what clearly distinguishes this ware from other, similar late Roman coarse wares is the distinct technological choices concerning the temper, such as its selection and processing. As marbles are not local raw materials in this territory in a geological sense, it is especially intriguing to examine their origin; furthermore, the marble inclusions are present as crushed rock fragments, as opposed to other temper types that are more commonly derived from sediments.

Our research focuses on understanding the technological aspects as well as the roots of this pottery tradition. In particular, to better understand the provenance of the raw materials used, the scale of production, and some aspects of the production sequence. For this purpose, 71 ceramic thin sections were examined by polarised light microscopy, from which 25 samples were further analysed by SEM-EDS. In addition, 51 samples of marble inclusions were isolated from the ceramic matrix and examined by oxygen and carbon stable isotope analysis.



## THE COLOURS OF PORTUGUESE AZULEJOS. A MULTI-ANALYTICAL CHARACTERISATION OF DECORATED TILES AND THE REPLICATION OF HISTORICAL PIGMENT RECIPES

BANDIERA M.<sup>1,\*</sup>, VERONESI U.<sup>1</sup>, MANSO M.<sup>1-2</sup>, PAIS A.<sup>3</sup>, ESTEVES E.<sup>3</sup>, RUIVO A.<sup>1-4</sup>, VILARIGUES M.<sup>1-4</sup>, COENTRO S.<sup>1-4</sup>

<sup>1</sup>VICARTE, Research Unit Glass and Ceramics for the Arts, FCT-NOVA, Campus de Caparica, Portugal,

<sup>2</sup>LIBPhys - Laboratory for Instrumentation, Biomedical Engineering and Radiation Physics, FCT-NOVA, Campus de Caparica, Portugal

<sup>3</sup>Museu Nacional do Azulejo, Portugal

<sup>4</sup>Departamento de Conservação e Restauro, FCT-NOVA, Campus de Caparica, Portugal

\* [mario.bandiera86@gmail.com](mailto:mario.bandiera86@gmail.com)

Keywords: Azulejos; Archaeometry; multi analytical approach

The chromatic palette of Portuguese *azulejos* in the first half of the 17th century presented a diverse set of colours ranging from blue and white to different shades of green and yellow, through to orange, purple and brown. Despite the enormous importance of *azulejos* in the history of Portuguese art, we have no primary sources on how to prepare the colours and glaze the tiles.

The aim of the present paper is to shed light on the colouring technique of an assemblage of 17<sup>th</sup> to 18<sup>th</sup>-century Portuguese glazed tiles (*azulejos*), stored in the National Tile Museum (Lisbon, Portugal). The study includes the characterization of each colour through a suite of analytical techniques. SEM-EDS and EDXRF were employed to obtain qualitative and (in some samples) quantitative information on their chemical composition. UV-VIS FORS and  $\mu$ -Raman spectroscopy allowed us to identify the main colouring agents. Finally, to address the relationship between colour and chemical composition, colorimetric measurements were performed as well. To further understand the production of different shades of analysed colours, a number of pigments were replicated following historical recipes from Renaissance treatises.

The analytical results of historical tiles' experimental replications show that Portuguese painters followed traditional pigment recipes. The colours were obtained through a few base ingredients, namely cobalt (blue), lead antimonate (yellow/orange), manganese (purple), iron (brown) and copper (green). Moreover, by combining some of these components and by adding specific reagents, the palette could be widened to a variety of shades.

This multidisciplinary approach offers key insights on artistic practices and technological choices, filling the gap left by the absence of textual evidence. Our results reaffirm the importance of technical art history as a cross-disciplinary approach to the study and preservation of cultural heritage.

## TECHNOLOGIES AND TRADITIONS OF POTTERY AND PLASTER PRODUCTION AT NEOLITHIC MAKRI, THRACE, GREECE

BAROUDA A.<sup>1,\*</sup>, QUINN P.<sup>1</sup>, EFSTRATIOU N.<sup>2</sup><sup>1</sup>Institute of Archaeology, University College London, U.K.<sup>2</sup>Department of History and Archaeology, Aristotle University of Thessaloniki, Greece\*, [archontoula.barouda.20@ucl.ac.uk](mailto:archontoula.barouda.20@ucl.ac.uk)

Keywords: Neolithic, pottery, Greece

The aim of this doctoral research project, affiliated with the Marie Skłodowska-Curie Innovative Training Network (PlaCe), is to investigate the pottery and plaster technologies employed by the Neolithic Makri community in Northern Greece. This is a unique opportunity as the Makri site is the only systematically excavated prehistoric settlement in the Thrace region and boasts well-preserved artifacts such as black-burnished pottery, stone tools, figurines, clay architecture, and lime-plastered floors. By thoroughly examining the ceramic industries at the site, the project aims to gain insight into various aspects of raw material procurement and resource management, pyrotechnology, manufacturing traditions, and the potential for cross-craft interaction. Furthermore, the location of Makri in a key contact zone between western Anatolia and the Balkans provides a valuable opportunity to expand our understanding of the cultural development of the first Neolithic communities in southeastern Europe and the economic and socio-political processes involved in the production of their material culture. The ongoing project adopts a comprehensive interdisciplinary approach, utilizing macroscopic, microscopic, and atomic perspectives, as well as incorporating experimental data, to reconstruct the entire production process of ceramics, plaster, and earthen construction at the site. In the upcoming presentation, the research will be introduced, preliminary findings will be presented, and the expected impact of the project will be anticipated.

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## PRODUCTION CENTRES AND TECHNOLOGY OF COOKING POTS IN IRON AGE JUDAH

BEN-SHLOMO D.<sup>1, \*</sup>, BOUZAGLOU L.<sup>2-3</sup>

<sup>1</sup>Ariel University, Israel

<sup>2</sup>Tel Aviv University, Israel

<sup>3</sup>Paris 1 Panthéon-Sorbonne University, France

[\\*davben187@yahoo.com](mailto:davben187@yahoo.com)

Keywords: Cooking pots, Iron Age

The paper presents the results of a technological study of Iron Age II (ca. 1000-586 BCE) cooking ware from Judah, Israel. The background for the research is the apparent appearance of regional production centers and typological-morphological changes of cooking pots in Iron Age II Judah. Over 500 Iron Age cooking pots from various sites were studied and analyzed employing compositional analyses (petrography and NAA) and forming technique analysis.

The results indicate that cooking pots were probably produced in few central workshops (as in the Judean Hills and Shephelah) exporting their products to sites in all over Judah. This phenomenon is especially noteworthy in the Beersheba Valley where about 80% of the cooking pots were imported. Despite the appearance of the centralized workshops and the changes in typology (vessels with a smaller, thinner and more globular body become common), a new forming technique (i.e. fashioning the vessels by wheel-throwing) does not appear, and most vessels are made by wheel-coiling and/or the use of molds.

The results emphasize the potential social and economical importance of cooking pot production on the one hand and the continuity and conservative nature of pottery traditions in the ancient Levant on the other.

## **COOKING WARE AS INDICATOR FOR REGIONAL TRADE AND EXCHANGE. A VIEW FROM 4<sup>TH</sup>-1<sup>ST</sup> CENTURIES BC SOUTHERN LAZIO (ITALY)**

BORGERS B.

University of Vienna, Institute of Classical Archaeology, Austria, [Barbara.Borgers@univie.ac.at](mailto:Barbara.Borgers@univie.ac.at)

Keywords: 4<sup>th</sup>-1<sup>st</sup> centuries BC Cooking Ware, Technology, Trade

This project examines the production technology and trade of cooking ware from southern Lazio, dated to the Mid- and Late Republican eras (4<sup>th</sup>-1<sup>st</sup> centuries BC). The composition of the cooking ware was studied in detail, combining macroscopic observation with thin section petrography, wavelength dispersive X-ray fluorescence spectrometry, electron microprobe analysis and scanning electron microscopy. Towards this aim, ca. 200 samples were selected from six sites of varying type and location, including sanctuaries in Rome (e.g., Curiae Veteres, Ciampino) and Nemi (e.g., the temple of Diana), workshops in Satricum (present-day Borgo Faiti), and settlements located at Norba (present-day Norma) and Fregellae.

The results suggest that potters broadly shared the same technological tradition for producing cooking ware, in terms of raw materials, forming and firing technology. Discrete differences exist in the paste recipes, comprising individual volcanic inclusions, volcanic and sedimentary rock fragments, or a mixture of these. Some cooking ware from the Mid-Republican era seems to originate from a hitherto unknown production area in the Alban Hills, while most seem have been produced locally at the sites studied, including Satricum, Nemi and Fregellae. Statistical analyses of the ceramic assemblages further suggest that there was little trade of cooking ware between the sites. Exchange, however, seems to have occurred in the form of gifts or depositions at the sanctuaries examined.

## COMPOSITIONAL AND TECHNOLOGICAL CHARACTERISATION OF MIEVEAL POTTERY PRODUCTION AT UTRECHT, THE NEDERLANDS

BORGERS B.<sup>1,\*</sup>, TRAVÉ ALLEPUZ E.<sup>2</sup>, BAJNÓCZI B.<sup>3</sup>, GRIFFIOEN A.<sup>4</sup>

<sup>1</sup>University of Vienna, Institute of Classical Archaeology, Austria

<sup>2</sup>Universitat de Barcelona, Institut d'Arqueologia, Spain

<sup>3</sup>Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungary

<sup>4</sup>Archeologisch Bureau Griffioen, The Netherlands

\*[Barbara.Borgers@univie.ac.at](mailto:Barbara.Borgers@univie.ac.at)

Keywords: Medieval Pottery, Technology, Provenance

The Medieval town of Utrecht in the Netherlands is known to have become a large centre of pottery production between the 12<sup>th</sup> and the 15<sup>th</sup> centuries AD. Archaeological research that started in the 1970s has revealed several workshops in the suburbs, which were located north and south of the Medieval town walls along the Vecht and Vaartse Rijn Rivers. Pottery waste consists of greyware and redware. This research aims to identify the raw materials and reconstruct the technological traditions used over time, in order to reveal aspects of the organization of ceramic production in Medieval Utrecht. This permits in turn to reveal aspects of the organisation of ceramic production at Utrecht during the Medieval era.

Using a combination of polarized light optical microscopy, wavelength dispersive X-ray fluorescence spectrometry, X-ray diffraction, and scanning electron microscopy, 60 sherds of greyware and redware from four workshops, as well as clayey raw materials, were examined. Close correspondence between the mineralogical and chemical composition of the pottery waste provides several well-defined reference groups. The results indicate that Medieval potters at Utrecht used a fluvial clay deposit to manufacture greyware and redware over the time. The potters seemed to have consistently adopted technological traditions that corresponded with different production phases of the workshops, as evidenced by changes in paste recipes.

## HISTORICAL RECIPES TO PRODUCE BLUE AS-FREE PIGMENTS BY ROASTING MINERALS: USE OF ERYTHRITE AND CLINOSAFFLORITE TO YIELD COBALT BLUE

BRUZZONE L.<sup>1\*</sup>, GAGGERO L.<sup>1</sup>, ZUCCHIATTI A.<sup>1</sup>, MOLERA J.<sup>2</sup>

<sup>1</sup>Department of Earth, Environment and Life Sciences, University of Genoa, Italy

<sup>2</sup>Faculty of Sciences and Engineering, University of Vic, Spain

[\\*lisabruzzo31@gmail.com](mailto:lisabruzzo31@gmail.com)

Keywords: cobalt pigments, glaze

Cobalt blue decorations on ceramics produced between 15<sup>th</sup> and 16<sup>th</sup> centuries contain two different types of pigment: i) an As-free, used until 1520, and ii) an As-bearing type.

The raw minerals used for both pigments could be erythrite, smaltite and skutterudite (Soulier et al., 1996), all containing arsenic, which suggests that different treatments of raw materials may have played a controlling role in the removal of this element. Gratuze et al. (1996) located the origin of these minerals, between the 15<sup>th</sup> and 16<sup>th</sup> centuries, in the Erzgebirge region of Germany and the Czech Republic where, in the 16<sup>th</sup> century, the production of cobalt bearing pigments was based on the manufacture of saffron and enamel (Meltzer, 1716) that represented a revolutionary innovation.

Investigations on the thermal behavior of skutterudite (CoAs<sub>3</sub>) (Molera et al., 2021) showed the difficulty of removing arsenic from the mineral by applying roasting and smelting on mixtures.

The possibility of producing an arsenic-free pigment from erythrite or other cobalt arsenides, where the atomic ratio of arsenic to cobalt is lower than that of skutterudite, is by far debated.

The purpose of this study was to carry out roasting experiments on erythrite and clinosafflorite as described in historical treatises. The main objective was to determine if the arsenic could be removed or if the use of different fluxes could help to fractionate Co-rich, As-free phases.

Heating experiments up to 1020°C were carried out on three mineral associations (2 samples from Bou Azzer and one from Huercal Overa, Almeria). *Ex-ante* and *ex-post* characterizations by XRD, XRF, SEM-EDS, TG and DTA showed that a mixture of CaO and borax with erythrite heated up to 900°C resulted in the formation of a Co-Fe-Ni oxide and a Ca-Co-Na arsenate phase. Roasting of clinosafflorite powders at 1020°C allows the formation of Co-rich phases and As-Co-Fe-Ca phases. The reaction and blue colouring of a quartz grain and the formation of different phases of Co-Na-Ca silicates and Ca-Na arsenates were obtained by heating clinosafflorite with borax at 1020°C. With these treatments, arsenic is not fully removed and the presence of Ca, Na and Pb promotes the formation of different kinds of arsenates inside the glaze.

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## **AN INVESTIGATION ON PROVENANCE AND MANUFACTURING TECHNOLOGY OF ARCHITECTURAL TERRACOTTAS FROM THE ATHENAION IN CASTRO (APULIA, ITALY)**

CANTISANI E.<sup>1</sup>, VETTORI S.<sup>1, \*</sup>, FRANCESCHINI M.<sup>1</sup>, FANTECHI E.<sup>2</sup>, ISMAELLI T.<sup>1</sup>

<sup>1</sup>Istituto di Scienze del Patrimonio Culturale, Consiglio Nazionale delle Ricerche (ISPC-CNR), Sede di Sesto Fiorentino, Firenze, Italy,

<sup>2</sup>Centro di Servizi di Cristallografia Strutturale (CRIST), Università degli Studi di Firenze, Italy

\*[silvia.vettori@cnr.it](mailto:silvia.vettori@cnr.it)

Keywords: Terracottas, Castro, provenance

Systematic archaeological research carried out since 2000 brought to light the ancient sanctuary of Athena in the indigenous settlement of Castro (Lecce), on the Adriatic coast of the ancient Messapia region (southern Apulia). The settlement played an important cultural and religious role from the 7<sup>th</sup> to the 2<sup>nd</sup> century BC, as a place of exchange between local groups, the Greek inhabitants of Tarentum, and the Greeks from Macedonia, Epirus and the Corinthian colonies in the Adriatic Sea.

Among the many significant discoveries, various architectural terracottas are worthy of mention, since they can be assigned to temples and other sacred buildings constructed between 530-520 BC and the 4<sup>th</sup> century BC. The identified roof types can be assigned to Tarentine workshops, because of their morphological and stylistic features. The materials characterization aims to shed light on the ancient operational chain.

A multianalytical approach was adopted: microstructural, petrographic, and geochemical features were determined by performing petrographic (OM), mineralogical (XRD) and chemical analyses (XRF). Chemical and mineralogical data were elaborated statistically. Moreover, as some of the identified petrographic fabrics have revealed the presence of volcanic temper, EDS chemical analysis have been performed on clinopyroxenes, being the latter ones an effective tool for provenance attributions.

The production in Taranto or in the Athenaion at Castro itself, the origin and transport of rough materials, the technical know-how of Tarentine craftsmen represent the main topics of the research.

## CHARACTERIZATION OF ANCIENT CERAMICS AND CLAY DEOSITS FROM BATTIFRATTA CAVE, ITALY

CAPRIOTTI S.<sup>\*1</sup>, CHIARABBA E.<sup>2</sup>, MARCONI N.<sup>2</sup>, CONATI BARBARO C.<sup>2</sup> & MEDEGHINI L.<sup>1</sup>

<sup>1</sup>Department of Earth Science, Sapienza University of Rome, Italy, [sara.capriotti@uniroma1.it](mailto:sara.capriotti@uniroma1.it)

<sup>2</sup>Department of Antiquity Science, Sapienza University of Rome, Italy

Keywords: Pottery, archaeometry, provenance

The study of ancient ceramics plays a key role in defining the technological development, raw material provenance and trade, as well as the mobility of ancient societies. For this reason, the present research focused on the study of Neolithic and Bronze Age pottery from the cave of Battifratra in Sabina region (Central Italy) and of local clay deposits. The Sabina region, in fact, is an important connection point between the middle-Adriatic and the middle-Tyrrhenian areas. The aim of this work is to understand the origin of raw materials and the pottery production technology. The archeometric analyses were performed through the combined use of optical microscopy (OM) and Fourier transform infrared spectroscopy (FTIR) allowing to carry out a mineralogical-petrographic characterization of the samples and to obtain information on modelling techniques, temperature, and firing atmosphere. PCA analysis was performed on FTIR data in order to study possible relationships among ceramic samples. The results of the ceramic composition showed affinities with clays specimens, suggesting a local provenance for most of the material studied, in which the mixtures are consistent with the mineralogical-petrographic characteristics of the geological context surrounding the site.

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## EARLY CERAMIC TECHNOLOGIES AND TRADITIONS IN THE EDMOM LOWLANDS REGION OF SOUTHERN JORDAN FROM A DIACHRONIC PERSPECTIVE

CARRION ANAYA S.<sup>1</sup> \*, QUINN P.S.<sup>1</sup>, BURTON M.M.<sup>2</sup>, HOWLAND M.D.<sup>2</sup>, GIDDING A.<sup>2</sup>, NAJJAR M.<sup>2</sup>,  
LEVY T.E.<sup>2</sup>

<sup>1</sup>Institute of Archaeology, University College London, U.K.

<sup>2</sup>Department of Anthropology, University of California San Diego, U.S.A.

\* [sara.anaya.20@ucl.ac.uk](mailto:sara.anaya.20@ucl.ac.uk)

Keywords: Archaeometry Pottery Jordan

The Early Bronze Age and Early Iron Age in the Edom Lowlands Region in southern Jordan is characterised by sociocultural, economic and political changes that were part of a shifting process that was deeply linked to the changing control of copper in the Faynan district over time, which was one of the most important sources of copper ore in antiquity. During the 10<sup>th</sup>-7<sup>th</sup> BCE southern Levantine polities (Israel, Moab, Ammon, Philistia, Edom) reached the apex of ancient social complexity, which has been referred to as secondary state formation. The aim of the present project is to document and study the traditions of ceramic manufacture and usage at several previously surveyed and/or excavated settlement sites dating from the Early Bronze Age III-IV to the Early Iron Age located in the Faynan district.

The research will focus on characterising the chemical and mineralogical composition and determining the provenance and examining the technological steps and skills involved in the manufacture of the ceramics. An ‘integrated approach’ will be taken to combine the data obtained by several different scientific techniques including the macroscopic study of the ceramics, thin section petrography analysis and other compositional analytical techniques (pXRF, LA-ICP-MS, SEM-EDS, XRD). The aim is to shed light onto the organisation of pottery production at a local (site) and regional (Edom Lowlands Region) levels at every given period, which will contribute to better understand the evolution of pottery-making traditions over time by documenting any possible changes in the composition, technological skills and distribution patterns. The observations made are also expected to address the nature of any possible trade and exchange networks with other communities from an intra-regional and supra-regional (interactions with other regions such as the Beersheva Valley in Israel) perspective by comparing the published data from that of other southern Levantine sites. The role played by pottery production in the development of copper metallurgical production and in the configuration of the so-called ‘complex’ societies will also be discussed by incorporating the data obtained into the theoretical debate and interpretations of the sociopolitical structure and socioeconomic dynamics of southern Levantine communities in each period.

The scientific analysis will be carried out within the framework of the research conducted in the Edom Lowlands Region by the University of California – San Diego and the Department of Antiquities of Jordan since the 1990s. The present project will constitute one of the major archaeometric studies of the pottery from the Edom Lowlands Region and the Levant in general and will incorporate new scientific approaches and procedures for ceramic studies in the region that will aim to establish standardized protocols for archaeometric analysis (standard petrographic descriptions, terminologies and the publication of geochemical datasets).

## POTTERS AND PAINTERS. APPLICATION OF LIBS AND LA-ICP-MS ANALYSIS ON DECORATED FINE HELLENISTIC TABLEWARE

CHARLTON M.<sup>1\*</sup>, MIŠE M.<sup>1</sup>, JOVANOVIĆ J.<sup>2</sup>

<sup>1</sup>UCL Institute of Archaeology, London, U.K.

<sup>2</sup>Archaeological Museum Split, Croatia

\*[m.charlton@ucl.ac.uk](mailto:m.charlton@ucl.ac.uk)

Keywords: Hellenistic fine-ware, composition, laser ablation

Greek and Hellenistic painted vases have attracted scholars of classical archaeology for centuries, either because of the artistic value of the painted decorations or because of the depicted scenes of ancient everyday life. With the development and application of scientific methods for the analysis of ancient ceramics, scholars began to investigate the technological aspects of Greek and Hellenistic painted and slipped vases. How the layers of coloured slips and decorations were applied and at what temperature the vases were fired are some of the questions that can be investigated using analytical methods. Due to the application of thin slips on the surface, different methods are used for the chemical characterisation of the slips and the body of the same vase. The slips are commonly analysed by X-ray microanalysis, offering point-by-point analysis of mostly major elements, while different tools, such as XRF, ICP-MS, and INAA, are used for bulk body analysis. This can cause difficulties in comparing the bulk composition, and thus in determining the similarities and differences in the preparation process of the clay paste for the slips and decorations, and body of the vase. Due to the artistic value of these objects, museum curators are often reluctant to provide samples for analysis due to the invasive nature of the above-mentioned methods for chemical characterisation.

In order to address questions of slip coating technology on vases, we analysed slips and bodies of fine Hellenistic ware with LIBS and LA-ICP-MS. We will present the results of compositional analysis of the Black, Grey, and Brown Slipped Hellenistic ware from the Greek town of Issa (island of Vis) in Croatia. The methods proved useful because the results revealed differences in composition between the slips on the surface and the body of the vases. This indicates different clay preparation procedures for the slip and vessel bodies.

## HOW WAS IT MADE? STUDYING THE TECHNOLOGY OF PORTUGUESE FAIENCE FROM THE 16<sup>TH</sup> TO THE 18<sup>TH</sup> CENTURY

COENTRO S.<sup>1,2</sup>, BANDIERA M.<sup>1,\*</sup>, VERONESI U.<sup>1</sup>, PAIS A.N.<sup>3</sup>, CASTRO A.<sup>4</sup>, PIRES S.<sup>2</sup>, COUTINHO I.<sup>1,2</sup>,  
CÂNDIDO M.J.<sup>5</sup>, MIMOSO J.M.<sup>6</sup>

<sup>1</sup> VICARTE - R&D Unit “Glass and Ceramics for the Arts”, NOVA School of Science and Technology, Portugal

<sup>2</sup> Department of Conservation and Restoration, NOVA School of Science and Technology, Portugal

<sup>3</sup> Museu Nacional do Azulejo, Portugal

<sup>4</sup> UNIARQ - Centro de Arqueologia da Universidade de Lisboa, Faculdade de Letras, Universidade de Lisboa, Portugal

<sup>5</sup> Museu de Setúbal / Convento de Jesus, Portugal

<sup>6</sup> Laboratório Nacional de Engenharia Civil, Portugal

\* [mario.bandiera86@gmail.com](mailto:mario.bandiera86@gmail.com)

Keywords: faience; archaeometry; lead-tin glaze

The production of faience/majolica *azulejos* (tiles) and other decorative and utilitarian objects by Portuguese ceramists dates back to the early 16<sup>th</sup> century. Contrasting to the number of archaeological finds that attest Portuguese ceramics as an important and widespread market, there is little evidence of its production process (e.g., kilns, production markers). In this context, the discovery in Lisbon, in 2016, of kilns dated between the 16<sup>th</sup> and the 17<sup>th</sup> centuries, with faience fragments, glazed and unglazed pottery rejects, as well as stilts and saggars, offers invaluable insight into the production of historical Portuguese faience (1).

In this study, we characterised three sets of archaeological faience assemblages, comparing fragments retrieved from the above-mentioned kilns in the Largo das Olarias (Lisbon) to other faience objects, dated between the late 16<sup>th</sup> and the 18<sup>th</sup> centuries, and used in a monastic context: the Monastery of Santa Clara-a-Velha (Coimbra) and the Convent of Jesus (Setúbal). Several types of faience were considered in this study, from common wares to high-quality imitations of porcelain.

The analytical methodology included SEM-EDS (Scanning Electron Microscopy with X-Ray microanalysis),  $\mu$ -EDXRF (Micro-Energy-Dispersive X-ray Fluorescence),  $\mu$ -Raman spectroscopy, optical microscopy, and colourimetry.

Preliminary results show that all faience objects were made with calcitic clays, of which different clay mixtures could be identified. In particular, the ceramic body of the samples from the Largo das Olarias' kiln is similar to others in the monastic collections, allowing us to pinpoint their likely Lisbon provenance.

The chemical composition and morphology of the glazes also show different characteristics in thickness, homogeneity and PbO/SiO<sub>2</sub> ratios. Considering these results in the context of the better-known evolution of *azulejo* technology, part of the faience objects may be dated to the 16<sup>th</sup> century, whereas the majority is consistent with the chemical composition and morphological features of 17<sup>th</sup>-century and 18<sup>th</sup>-century glaze productions.

Most objects exhibit a blue-and-white or blue-purple-white decoration, the blue obtained from cobalt and purple from manganese oxides. The range of blue shades observed was analysed by colourimetry and compared to the chemical composition, although no connection was found between the purity of the cobalt pigment and the quality of the faience.

This study connects two research projects aiming at unveiling the connection between *azulejo* and other faience productions by researching their glaze technology and coloured decoration throughout the centuries.

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## POTTERS TECHNOLOGICAL CHOICES IN THE NEOLITHIC SITE OF LA VELA (NORTH-EASTERN ITALY)

DEIMICHEI G.<sup>1</sup>, AMICONE S.<sup>2-3</sup>, \*, PEDROTTI A.<sup>1</sup>

<sup>1</sup> LaBAAF - Laboratorio Bagolini Archeologia, Archeometria, Fotografia, Dipartimento di Lettere e Filosofia, University of Trento, Italy

<sup>2</sup> Archaeometry Research Group, University of Tübingen, Germany

<sup>3</sup> Institute of Archaeology, University College London, U.K.

[\\*silvia.amicone@uni-tuebingen.de](mailto:*silvia.amicone@uni-tuebingen.de)

Keywords: ceramic petrography, Neolithic, Alpine region

This research investigates pottery technology at the Neolithic site of La Vela-sector VII in the north-eastern Alpine region in Italy. La Vela is an open-air site on an alluvial fan in the Adige Valley. The settlement was frequented from the Mesolithic to the Early and the Middle Neolithic (V millennium BCE). The Early Neolithic layers are characterized by the presence of pottery that can be related to the Gaban group and by the first appearance of the so-called Square-mouthed pottery culture. This material culture becomes predominant in the site during the Middle Neolithic (4700-4300 BCE).

The aim of the research is to better understand the appearance and development of these cultural phenomena through the study of ceramic technology. For the analyses a representative number of samples representing different fabrics and different chronological phases were chosen. Ceramic petrography was applied to them to investigate raw materials choices and technological features.

The results highlight a great variability in the choice of raw materials that reflects a knowhow of the various natural resources present in the area. Indeed, the region is characterized by the presence of different geological outcrops. The various geological formations are well represented in the pottery analysed in this study. The data show also a continuity in the choice of tempers between different phases of the frequentation of the site. The preliminary results of this work overall give us an initial understanding of the production of the site, that will be furtherly monitored in future through a bigger number of samples and a detailed geological study.

## **COPY AND PASTE: MEDITERRANEAN IMPORTS AND LOCAL CERAMIC PRODUCTION AT THE SITE OF LA FONTETA (ALICANTE, SPAIN) DURING THE EARLY IRON AGE (8<sup>TH</sup>-6<sup>TH</sup> CENTURIES BC)**

DEL PINO CURBELO M.<sup>1,\*</sup>, VINADER ANTON I.<sup>2</sup>, LÓPEZ ROSENDO E.<sup>3</sup>, LORRIO ALVARADO A.J.<sup>2</sup>, TORRES ORTIZ M.<sup>4</sup>

<sup>1</sup>Universidad de Las Palmas de Gran Canaria, G.I. Tarha, Departamento de Ciencias Históricas <sup>2</sup>Universidad de Alicante-INAPH, Spain

<sup>3</sup>Universidad de Alicante, Spain

<sup>4</sup>Universidad Complutense de Madrid, Departamento de Prehistoria, Historia Antigua y Arqueología, Spain

\* [miguel.delpino@ulpgc.es](mailto:miguel.delpino@ulpgc.es)

Keywords: Early Iron Age, Iberia

Phoenician populations expanded across the Mediterranean, generating diverse encounters with local peoples. One of their main foci of interest was Iberia, what has been generally interpreted to be due to its richness in resources, mainly metallic ores. Something that would be proved by the concentration of their initial contacts in SW Iberia and their later expansion towards the SE arriving to the location of the current province of Alicante and some other settlements further north and on the Balearic Islands.

At the Western edge of the Mediterranean basin such encounters included early sporadic contacts during the 10<sup>th</sup>-9<sup>th</sup> centuries BC and more stable occupations during the 9<sup>th</sup>-8<sup>th</sup> centuries BC, with the foundations of colonies along the Atlantic and Mediterranean shores of Iberia. However, Phoenician - indigenous relationship was not limited to the trade of metals, as part of the colonial occupation is clearly focused on other goods, being those connected also to agriculture, fishing or even wood resources.

Cultural encounters expectably fostered changes in material culture, being one well-known phenomenon the introduction of new ceramic types and their contents into indigenous settlements, with the eventual inception of the potter's wheel and the production of the new forms taking place locally. At the same time, handmade ceramics continued being made and they appear in colonial contexts as well (mainly as cooking and storage pots), and those clearly influenced wheel thrown morphology, as some indigenous carinated shapes are replicated using the new techniques.

In this paper we deepen in this process of hybridization and mutual emulation by the archaeometric study of ceramics from La Fonteta, a Phoenician colonial settlement founded by the end of the 8<sup>th</sup> century BC with close connections to the indigenous settlement of Peña Negra, where both local handmade and wheel thrown ceramic production have been recorded. This represents early evidence of technological transfer, giving us an idea of the material conditions in which the potter's wheel inception took place in SE Iberia and coexisted with signs of technological resilience. The present study is founded on the idea that the comparison between shapes produced locally with different building methods would allow us to shed light on technological choices connected to final pottery shape and function, as well as the boundaries defined by coexisting cultural traditions.

In total 51 samples from La Fonteta were chosen for a XRF and XRD analysis, in order to obtain relevant data for both provenance and technology. Our results show great variability, with provenance clusters formed by transport jars (amphorae), tableware (grey and red-slipped tableware), and handmade pots. Compositional groups exhibiting a wide functional range agrees with results observed in other sites of similar chronology. Comparatively, typologically local wares exhibit higher compositional variability than imported vessels.

## LOCAL PRODUCTION OF IONIAN POTTERY AT CUMAE: THE CONTRIBUTION OF ARCHAEOMETRIC ANALYSES

DI VIRGILIO E.

Dipartimento di Lettere e Beni Culturali, Università della Campania Luigi Vanvitelli (Santa Maria Capua Vetere), Italy,  
[elisabetta.divirgilio@unicampania.it](mailto:elisabetta.divirgilio@unicampania.it)

Keywords: craftsmanship, fabrics, production

Since the earliest colonial times, ancient Cumae and Pithecusae, have had a strong artisanal tradition, as testified by the high quality local products. The Late-Archaic period was a time of artisanal liveliness at different levels, including religious architecture and pottery craftsmanship. This was mainly expressed by the large-scale production of unpainted fine pottery. Despite the intense circulation of imported products coming from the Eastern Mediterranean, Campanian workshops both imitated and adapted the production processes used. In this perspective, it is not always easy to attribute individual samples to the specific workshops, as the case of Ionian cups, especially in the absence of science-based data.

This poster aims to show the results of compositional analysis carried out on Ionian cups found in two main religious areas at Cumae: the so-called Temple of Jupiter on the acropolis and the suburban sanctuary of Fondo Valentino. Firstly, the macroscopic analysis observed three main macro-groups of fabrics, that differ in clay colour, inclusions, glaze, and were accordingly investigated in laboratory through scientific methods. The method combined mineralogical and chemical analyses, including X-ray fluorescence, X-ray diffraction and thin-section observation with a polarized microscope. The results permit identification of the main fabrics and technological features of Ionian cups in Campania, in particular the Vesuvius region. The results also indicate remarkable differences in terms of fabrics, slips and glaze. This suggests a provenance from different production areas and possible exchange at regional level.

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## CELADON CHARACTERIZATION BY SYNCHROTRON RADIATION-BASED XRD AND CATHODOLUMINESCENCE MICROSCOPY

EMAMI M.<sup>1,2,\*</sup>, CHAPOULIE R.<sup>2</sup>, ABDELLATIEF M.<sup>3</sup>, HANS PH.<sup>3</sup>, MONTAZERZOHOURI M.<sup>4</sup>

<sup>1</sup>Art University of Isfahan /Department of Conservation and Archaeometry, Isfahan, Iran

<sup>2</sup>Archéosciences Bordeaux /UMR 6034 CNRS, Université Bordeaux Montaigne, France

<sup>3</sup> SESAME Synchrotron /Materials Science (MS) Beamline, Jordan

\*[aminemami.ae@gmail.com](mailto:aminemami.ae@gmail.com)

Keywords: Pottery, Synchrotron, Cathodoluminescence, Mineralogy

New insights on the chemical composition of the stoneware pottery with bluish green glaze – so called celadon – from Ardeshir-Khore, 4<sup>th</sup> century AC (Iran) have been achieved by SR based X-ray diffraction analysis and cathodoluminescence microscopy. Techniques based on synchrotron radiation have been widely applied in archaeology. High-energy synchrotron radiation makes it possible to characterize the composition of the newly formed minute crystalline phases within the matrix of the pottery. At the same time, cathodoluminescence imaging provides new visions into mineralogical criteria that are not visible with the usual optical microscopy approach. However, the tiny crystals which are revealed, can be considered as real markers for the knowledge of important features such as the high firing temperatures ever reached at this time.

The exact characteristics of the geo-chemical fingerprint and phase composition of the primary clay paste is reflected by the re-crystallizations through firing as an important criterion for the “Chaîne opératoire” in ceramic technology of the past. Determining of newly formed minute crystalline phases by synchrotron XRD is essential, since identifying of the reaction products during firing of primary clay, sometimes cannot be well clarified by routine methods (Emami et al., 2021). Multidisciplinary methods are crucial for determining the primary clayey based, as well as the manufacturing processes of these prestigious objects (Cheng et al., 2002; Emami et al., 2022). Synchrotron based XRD results enable to characterize both mineralogical constituents of a pottery and its fabrication by identifying high temperature phases and defining kiln atmosphere conditions (Tite et al., 2012). The samples were studied earlier by cathodoluminescence imaging to localize the specific zones of recrystallization and the newly formed crystals. Crystal growth and its statement is revealed by means of the cathodoluminescence colour of the minerals and will be interpreted as a generation of high temperature silica and calcium phases such as mullite and anorthite.

SR-XRD and CL microscopy have clarified insights into the characterization of high temperature phases in the body and phase-interphase area between the body and the celadon glaze. Anorthite occurred mostly in interphase zones between body and glaze. Over high firing temperature of the celadons (ca. 1200°C), formation of high temperature phases such as mullite and other aluminosilicates, might be notable associated to SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> wt.% ratios.

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## COMPOSITIONAL, TEXTURAL AND MICROSTRUCTURAL FEATURES OF THE PITHOI PRODUCED FROM THE VI TO THE IV CENTURY B.C. IN THE RURAL SETTLEMENT OF JAZZO FORNASIELLO NEAR GRAVINA IN PUGLIA (APULIA)

ERAMO G.<sup>1</sup>, MUNTONI I.M.<sup>2</sup> \*, LAMBRUGO C.<sup>3</sup>, LOJACONO A.<sup>3</sup>

<sup>1</sup>Università degli Studi di Bari “Aldo Moro”, Dipartimento di Scienze della Terra e Geoambientali, Italy

<sup>2</sup>Soprintendenza Archeologia, Belle arti e Paesaggio per le province di Barletta-Andria-Trani e Foggia, Italy

<sup>3</sup>Università degli Studi di Milano, Dipartimento di Beni Culturali e Ambientali, Italy

\*[italomaria.muntoni@cultura.gov.it](mailto:italomaria.muntoni@cultura.gov.it)

Keywords: Forming, firing, Peucetia, Bradanic area

This talk will focus on the archaeometrical analysis held on the *pithoi*, the huge jars used to storage food, produced in Peucetia between the VI and the IV century B.C. The study was carried out in particular on the archaeological materials from the rural settlement of Jazzo Fornasiello near Gravina in Puglia (Bari), located in the inner Peucetia, in the Bradanic area, excavated by the University of Milan since 2009 under the supervision of the Soprintendenza Belle Arti e Paesaggio for the metropolitan city of Bari. The numerous *pithoi* fragments found in the site clearly indicate that these vessels play a key role in the economic growth and in the functioning of settlement systems in the rural economy environment.

The archaeometrical studies, conducted in collaboration between the University of Milan and the University of Bari Aldo Moro, include optical microscope (POM) and scanning electron microscopy (SEM-EDS), petrography on thin section and mineralogical bulk analysis (XRPD) of sixty samples. This analysis has allowed to know the compositional, textural and microstructural features and to identify the raw materials and the technological choices employed in the different chronological phases and in the distinct types of *pithoi* attested.

A specific study has been carried out on a *pithos*, recovered in situ by the excavators, whose profile is entirely preserved. A section of the whole profile has been cut to fully understand the production process of the vase and the method of forming and firing.

The talk will show how for the first time this analysis clarifies the hard process of making *pithoi*, which had to involve a specialized know-how, from the collecting of raw material to the firing process, bringing a new light on the interpretation of the importance of huge storage jars in the Peucetian settlements.



## ARCHITECTURAL CLAY FROM THE OENOTRIAN SETTLEMENT AT INCORONATA GRECA (PISTICCI, MATERA): A CONTEXTUAL AND TECHNOLOGICAL RE-APPRAISAL

GERMINARIO C.<sup>1</sup>, PAGANO S.<sup>1-2</sup>, MERCURIO M.<sup>1-3</sup>, IZZO F.<sup>3-4</sup>, CANTISANI E.<sup>5</sup>, SAVELLI S.<sup>6</sup>,  
TODARO S.<sup>7,\*</sup>, POPE S.<sup>8</sup>, GRIFA C.<sup>1-3</sup>

<sup>1</sup> Dipartimento di Scienze e Tecnologie, Università degli Studi del Sannio, Italy

<sup>2</sup> Dipartimento di Scienze dell'antichità, Università degli Studi di Roma La Sapienza, Italy

<sup>3</sup> Center for Research on Archaeometry and Conservation Science, Italy

<sup>4</sup> Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse, Università degli Studi di Napoli Federico II, Italy

<sup>5</sup> Istituto di Scienze del Patrimonio Culturale, Consiglio Nazionale delle Ricerche, Italy

<sup>6</sup> Department of Modern Languages and Classics, Saint Mary's University, Canada

<sup>7</sup> Dipartimento di Scienze Umanistiche, Università degli Studi di Catania, Italy

<sup>8</sup> Faculty of Humanities, McMaster University, Canada

\* [svtodaro@unict.it](mailto:svtodaro@unict.it)

Keywords: Architectural clay, tecnology, multi-analytical approach

In the Pre- and Proto- historic Mediterranean world, clay was used to produce portable containers and cooking stands but also as an exterior facing on architectural structures built with different materials. The second use leaves traces only when the structures were exposed to fire, an event that, in turn, leads to the creation of a highly heterogeneous category of artefacts such as facades, pavements, and cooking surfaces. In Italian literature the term *concotto* refers to clay fragments of this type exposed to heat. This broad definition is therefore applied to different remnants in terms of appearance and composition and could derive from sources that had very little in common.

This paper aims to re-address this category of artefacts on the basis of the material found at the Oenotrian settlement at *Incoronata Greca*; in particular, the work focuses on the material recovered during the excavation of pit-structures whose function has been the matter of some debate. It more specifically aims to re-evaluate the classification criteria of these remains and the implications for the functional interpretation of structures to which they belonged. The re-evaluation will be accomplished with a multi-stepped typo-technological approach combining the macroscopic assessment of the morphological and typological appearance with the archaeometric study of fragments.

The latter was carried out on a selection of 37 fragments following a broad typological classification as: 1) daub from superstructures of pit-dwellings; 2) daub from basal parts of pit-dwellings; 3) daub from storage pits; 4) daub from pyrotechnological structures (kilns and crucibles); 4) mudbricks.

A multi-step analytical strategy was implemented; preliminary investigations were performed via Digital Microscopy and Fourier Transform Infrared Spectroscopy in order to find similarities across the entire set of samples. Results highlighted an inhomogeneity in the data set; thus, 20 representative samples were selected for further analyses (Polarized Light Microscopy, thermal analyses, quantitative X-Ray Diffraction, X-Ray Fluorescence). Moreover, three geological materials (clays and silts) from the hillside were also collected as samples of nearby available resources.

Thin section analyses revealed that samples divide into six fabrics, identified by a base clay mixed with different proportion of sandy-grains, organic material, and grog.

Mineralogical analyses, addressed to point out more technological information for improving a classification scheme of these materials (it is crucial to determine whether the fragments underwent firing), revealed that most of the huts' structural and decorative elements contain clay minerals, indicating that they could be unfired, and the same features was observed in some pits' plasters. However, in some cases, samples show clues (colour zoning, feeble OH stretching bands, weak dehydroxylation peak) that suggest they probably experienced (very) low temperature firing.

## HUMAN MOBILITY AND TECHNOLOGICAL TRANSFER BETWEEN GREECE AND SOUTHERN ITALY: THE CASES OF PITHEKOUSAI AND CUMAE. PROJECT OUTLINE

GIOBBE M.<sup>1-2</sup> \*, KIRIATZI E.<sup>2</sup>, LEMOS I.<sup>1</sup>, MÜLLER N.<sup>2</sup>, DI VITO M.A.<sup>3</sup>, DE VITA S.<sup>3</sup>,  
CINQUANTAQUATTRO T.E.<sup>4</sup>, D'ACUNTO M.<sup>5</sup>

<sup>1</sup> Department of Archaeology, University of Oxford, U.K.

<sup>2</sup> Fitch Laboratory, British Archaeological School at Athens, Greece

<sup>3</sup> INGV National Institute of Geophysics and Volcanology, Italy

<sup>4</sup> Ministero della Cultura, Soprintendenza Archeologia, Belle arti e Paesaggio del Comune di Napoli., Italy

<sup>5</sup> Dipartimento Asia Africa e Mediterraneo, Università degli Studi di Napoli 'L'Orientale', Italy

\*[marcella.giobbe@univ.ox.ac.uk](mailto:marcella.giobbe@univ.ox.ac.uk)

Keywords: Pottery provenance; pottery technology; Greek colonization

This project aims to apply a cutting-edge approach to understand how material culture was used to promote new social and economic relations during the formative stages of the Greek colonisation in Campania, and how the process of colonisation was materialised in the ontologies of the 'colonisers' and the 'colonised'. Key pottery assemblages from selected primary deposition contexts from Pithekoussai (1) and Cumae (2) were investigated through a science-based analytical program designed to reconstruct and understand reproduction of local pottery traditions, as well as mobility of products and transfer of technologies between Campania region and Mainland Greece. The assemblages selected include fineware, coarseware and amphorae dating between the 11th century BC and the early stages of the Greek colonisation (8th-7th century BC).

This poster focuses on presenting such an integrated approach, that employs ceramic petrology alongside elemental analysis, providing both quantitative and qualitative data, compositional and textural, on a broader scale. Furthermore, a program of geological sampling and analysis has been undertaken to record and characterize through the same analytical techniques the locally available raw materials, providing a base for comparison with the ceramic samples in order to better contextualise the production of local pottery in the Campania landscape.

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## FROM JEREZ TO THE ATLANTIC: FIRST ARCHAEOMETRIC APPROACH TO SOUTHWESTERN ANDALUSIAN CERAMIC TRADE CONTAINERS PRODUCTION

GUERRERO-RIVERO S.<sup>1,\*</sup>, IÑÁÑEZ J.<sup>1</sup>, AMORES-CARREDANO F.<sup>2</sup>, ARANA G.<sup>3</sup>

<sup>1</sup>Department of Geography, Prehistory and Archaeology. Experimental space for innovation in Heritage and Cultural Landscapes (GPAC), University of the Basque Country / Euskal Herriko Unibertsitatea (UPV/EHU), Spain

<sup>2</sup>Department of Geography, Prehistory and Archaeology, University of Seville, Spain

<sup>3</sup>Faculty of Science and Technology, University of the Basque Country / Euskal Herriko Unibertsitatea (UPV/EHU). IBeA, Spain

\*[saulalberto.guerrero@ehu.eus](mailto:saulalberto.guerrero@ehu.eus)

Keywords: Jerez de la Frontera, Petrography, Spanish Colonial

Within the framework of the archeology of the Early Modern Age in the Iberian Peninsula, one of the research challenges is Castilian ceramic production and the technological changes over time. In the city of Jerez de la Frontera, Andalusia, pottery activity has been documented in the 16<sup>th</sup> century, including kitchen productions, domestic common unglazed and glazed in green and honey-coloured glazed vessels (Barrionuevo, 2008). In the year 2000, the fillings of a series of vaults were excavated in the Convent of Santo Domingo with two construction phases: the initial one from the late 15<sup>th</sup> and a later reform of around c. 1600. The registered collections are waste from production due to firing, *loza quebrada*, offering very extensive collections, 15 forms in the old phase and 25 forms in the late phase. In the late phase, a set of commercial, transport containers has been located. There are two sets, one formed by the so-called *dolias* (storage jar) or *jarras* (jars), a container with documented productions in Seville from the 14<sup>th</sup> century until the middle of the 16<sup>th</sup> century. On the other, a set of *botijas* (olive jars) with 6 formal variants of already known typology and appropriate chronology. The date assigned to the *jarras* is too late, contradicting the data known in Seville, the main productive center of these Ibero shipping containers (Amores and Chisvert, 1993). On the other hand, the existence of other olive jars production centers outside of Seville, such the Puerto Santa María, very close to Jerez, is of added interest in determining the place of production of these containers.

This poster exposes the results of petrographic and mineralogical analysis (XRD) that were carried out in 8 sherds fragments that show data on the regional productive origin, as well as textural and technological features where heterogeneous pastes are observed depending on the shape. In addition, it has been possible to differentiate productive and technological features of the *loza quebrada*, productive waste and the technical transition-evolution of the *botijas* (olive jars) in the western half of Andalusia (Goggin, 1960). The Jerez ceramic tradition was important during this period and these preliminary results contribute to the characterization of ceramic Castilian production, allowing it to be complemented with subsequent studies.

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## MANUFACTURING CHARACTERISTICS OF PLANT-TEMPERED POTTERY IN JEJU ISLAND, NEOLITHIC KOREA: INSIGHTS FROM FABRIC MICROSTRUCTURE AND MINERAL PHASE ANALYSIS

JANG S.<sup>1,\*</sup>, JIN H.<sup>1</sup> & KIM H.<sup>2</sup>

<sup>1</sup>Conservation Science Division, National Research Institute of Cultural Heritage

<sup>2</sup>Cultural Heritage Conservation Science Center, National Research Institute of Cultural Heritage, Korea

\*[fkite@korea.kr](mailto:fkite@korea.kr)

Keywords: plant-tempered pottery, X-ray CT

In the prehistoric era, pottery made by adding plants has been produced in various regions of the world. It often appears in early Neolithic pottery in Japan, China, and Russia, but in Korea, it has not been found inland on the Korean Peninsula and is only observed on Jeju Island. Plant-added pottery is known to have been excavated in 17 sites on Jeju Island, including Gosan-ri, Gangjeong-dong, and Odeung-dong. In particular, as a result of the carbon dating of accompanying charcoal, it has been produced between 7.600 and 4.500 cal BC, making it an early Neolithic pottery in Korea.

Plant opal analysis of this pottery revealed that the plants used in potteries from Gosan-ri and Samyang-dong sites mainly belonged to the Poaceae family, with Miscanthus type being the most commonly used genus. During the firing process, the added plants burned away and left behind long and thick pores. Most of the plant-tempered pottery had various traces of plants on the surface, and X-ray CT analysis showed pores created by the burning of plants in the internal structures. However, some pottery showed no visible traces of plants on the surface, although CT scanning images revealed a large number of pores made by plants in the microstructure. Jeju Island has a long history of volcanic activity, dating back to 20.000 years ago, resulting in the presence of volcanic ash, basalt, and amorphous materials in some areas. As a result of X-ray diffraction and microscopic analysis, Gosan-ri, where the many plant-tempered potteries were excavated, had a high concentration of volcanic amorphous materials and almost no clay. On the other hand, clay minerals such as chlorite and mica were identified in Gangjeong-dong and Odeung-dong, along with olivine and pyroxene, and the firing temperature was estimated to be between 550 to 700°C based on the mineral phase. Despite the differences in the mineralogical characteristics of the raw materials used in each pottery on Jeju Island, the same plant addition in the manufacturing process was found, indicating that it may be considered a type of tradition.

Plant-tempered pottery in Neolithic Japan is also found in the Kanto region and is estimated to be a long-standing tradition in a specific area, and microscopic observation revealed that a large number of plants were added to make pottery and many pores were distributed inside. In Jeju Island, the tradition of plant tempering was maintained for a period before disappearing after the introduction of appliqué pottery. However, X-ray CT results of early appliqué pottery revealed traces of plants inside, suggesting that the tradition of adding plants was still present to some extent.

## **COPY AND PASTE. TECHNOLOGICAL CHOICES AND SKILLS ADAPTATION IN PHENEOS, ARCADIA**

KLÖCKL R.<sup>1</sup> \*, TESTOLINI V.<sup>1</sup>

Institute of Classics, Department of Archaeology, University of Graz

\*[Austria.regina.kloeckl@uni-graz.at](mailto:Austria.regina.kloeckl@uni-graz.at)

Keywords: pottery, production, Peloponnese

In recent years, the historical “ceramic landscape” of the northern Peloponnese has become the focus of various research projects. Pottery production in the coastal areas of Corinth and Sikyon is well understood, while the inner Peloponnese has received little attention. This is changed by the project “6.500 Years of Solitude?”, which aims at a detailed analysis of ceramic production and technology from the hill of Pheneos, Arcadia.

This paper focuses on the ceramic finds from the Archaic, Classical and Hellenistic periods. Macroscopic and petrographic analyses identified pottery produced in the valley as well as ceramics that have come from other areas of Greece. The presence of similar shapes and finishing in local and non-local fabrics shows that potters in Pheneos employed techniques related to those of potters in more prominent locations. The transmission of aspects of production know-how indicates a connection between artisan communities even in less affluent areas of Greece. For instance, echinus bowls were made from a fine fabric, with black slip as in other Greek regions. Also, such bowls appear in a less refined version with a coarser fabric similar to cooking ware, suggesting that the local workshop tradition was adapted to produce the new fashionable table sets. The quality of the vessels is not as high as in the main production centres, but some of the techniques employed (e.g., control of the firing atmosphere) made it to more peripheral sites.

This study of ceramic raw material choices and manipulation fills gaps in the mapping of pottery production in mainland Greece. The interpretation of the results contributes to an interdisciplinary approach in reconstructing ceramic technology and production in Pheneos. This will lead to a better understanding of the impact and technological influence of powerful cities such as Sparta, Argos or Corinth on interjacent cultural landscapes.

## FROM MACRO TO MICRO: ADVANCED AND EXPERIMENTAL METHODS FOR THE ANALYSIS OF FINISHING TECHNIQUES AND POST-FIRING TREATMENTS ON ANCIENT CERAMICS

KOUTOUVAKI E.<sup>1, \*</sup>, VIDALE M.<sup>1</sup>, AMICONE S.<sup>2-3</sup>, ALOUPI E.<sup>4</sup>, MARITAN L.<sup>5</sup>

<sup>1</sup>Department of Cultural Heritage: Archaeology and History of Art, Cinema and Music, University of Padova, Italy

<sup>2</sup>Eberhard Karls Universität Tübingen Archaeometry Research Group, Germany

<sup>3</sup>Institute of Archaeology, University College London, U.K.

<sup>4</sup>Thetis Authentics Ltd, 4 Diagoras str., 11636, Athens, Greece

<sup>5</sup>Department of Geosciences, University of Padova, Italy

[\\*eirini.koutouvaki@studenti.unipd.it](mailto:*eirini.koutouvaki@studenti.unipd.it)

Keywords: ceramics, EMAC2023, Mahtoutabad, Polychrome pottery, Technology

The study of the decoration on a pot's surface is essential in gaining insight into the pot's function and aesthetic quality. At the same time, the coatings, the finishing techniques, and the decorative patterns, all allow a deep understanding into the potter's technological know-how.

This presentation focuses on polychrome decorated pottery from the site of Mahtoutabad in south-eastern Iran (Madjidzadeh, 2002; Madjidzadeh & Pittman, 2008; Desset et al., 2013; Vidale & Desset, 2013). This ceramic class is characterized by brown linear motives on buff surface, but often two or three colours decorate the same pot (red/brown, black, white). Its production is dated from the late 5<sup>th</sup>/early 4<sup>th</sup> mil. BCE until the 3<sup>rd</sup> mil. BCE and is attested in contemporary sites in Iran and possibly in Pakistan (Vidale & Desset, 2013). The early dating, the large-scale, specialized, and long-lasting production of this pottery, as well as its changes into the mid-4<sup>th</sup> mil. BCE - so-called Aliabad ware-, raise important questions about the potters' ability of producing this exceptional style.

The ongoing macroscopic investigation of Mahtoutabad's pottery provides valuable information. However, this project takes a step beyond the typological documentation and explores the technological characteristics of this assemblage. The aims of this study are multiple: i) to clarify the conditions under which the polychromy is achieved (firing atmosphere, raw materials, specific techniques); ii) to detect possible technological changes in the production throughout the site's lifespan; and iii) to address questions regarding the production organization, the potters' skills, the degree of specialization, and the technological choices, as well as to validate them through an experimental approach. To achieve these, a multi-disciplinary, three-staged approach will be followed integrating: a) macroscopic examination of the material, b) application of analytical techniques (ceramic petrography, XRPD,  $\mu$ -XRD,  $\mu$ -XRF, SEM-EDX, XRF), and c) experimental reproduction of pots and their coatings.

This work presents the preliminary results of an ongoing MSCA PhD project and offers an opportunity to discuss the operational sequence of the polychrome decorated pottery from Mahtoutabad, throughout its lifespan. The results provide also a first glance at the role of this production within the social context of south-eastern Iran in the 4<sup>th</sup>-3<sup>rd</sup> mil. BCE.

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## RECONSTRUCTION OF FIRING CONDITIONS OF ARCHAEOLOGICAL CERAMICS BASED ON THE IDENTIFICATION OF CLAY AND INDEX MINERALS

KRÁLOVÁ K.<sup>1,\*</sup>, THÉR R.<sup>1</sup>, KLOUŽKOVÁ A.<sup>2</sup>, KOLÁŘOVÁ M.<sup>2</sup>

<sup>1</sup>Department of Archaeology, University of Hradec Králové, Philosophical Faculty, Hradec Králové, Czech Republic

<sup>2</sup>Faculty of chemical technology, Department of Glass and Ceramics, University of Chemistry and Technology Prague, Czech Republic

[\\*karolina.kralova@uhk.cz](mailto:*karolina.kralova@uhk.cz)

Keywords: archaeological ceramics, experimental archaeology, clay minerals

The analysis presented employed various analytical methods for the identification of the pottery firing conditions with a particular emphasis on estimation of firing temperatures. The focus was on the identification of the raw materials of the fired ceramic materials and on the reconstruction of the firing process by index minerals. Moreover, the influence of the flue gas composition on the mineralogical composition of the final product was evaluated.

The chemical and mineralogical composition was studied on experimental samples of selected ceramic clays fired at different temperatures and different oxidation-reduction conditions. The thermally treated samples were subjected to a hydrothermal treatment to recover hydroxyl groups. This new methodology aims at the identification of raw clay minerals from the original mass before firing. The procedure of this innovative method is based on the fact that the clay minerals are dehydroxylated by firing, and therefore the bonds can be partially restored by rehydroxylation. The changes were observed by infrared spectroscopy. Two- (kaolinite) and three-layer clay minerals were identified in the experimental samples. Together with the changes in mineralogical composition, which were measured by X-ray diffraction. Thermal analysis observed chemical and physical transformations during the technological process of firing and subsequent rehydroxylation.



## TECHNICAL AND STYLISTIC SPECIFICITIES OF INCISED GLAZED CERAMICS FROM TAKHT-E SOLEYMAN USING DARK-COLOURED CLAY LAYERS (IRAN, 12<sup>TH</sup>/13<sup>TH</sup> CENTURY CE)

KUNST K.<sup>1</sup>, ALLOTEAU F.<sup>2,\*</sup>

<sup>1</sup> Institute for Ancient Near Eastern Archaeology, Free University of Berlin, Germany

<sup>2</sup> Rathgen-Forschungslabor, Staatliche Museen zu Berlin, Stiftung Preußischer Kulturbesitz, Germany

\* [fanny.alloteau@u-bordeaux-montaigne.fr](mailto:fanny.alloteau@u-bordeaux-montaigne.fr)

Keywords: Takht-e Soleyman ceramics; incised glazed pattern; dark-coloured clay layer

The Museum of Islamic Art in Berlin houses a diverse range of glazed Islamic vessel pottery excavated at Takht-e Soleyman. Sherds and semi-complete objects with incised decorations along with mono- or bichrome glazes represent with approximately 900 pieces a major group of the archaeological material. The wares date into the 12th and 13th century CE and are historically known as Sgraffito, Champlevé, Gabri or Garrus Ware. In terms of the decoration technique, the linear and planar incisions are executed through a white slip layer into a red earthenware body. The glazes are transparent and either green- or yellow-coloured or colourless; the latter resulting in a white colour impression. “Colours” are applied alone or in combination. The intended purpose of the general decoration concept - the contrasting effect of a white slip against an exposed red clay body enhanced by a glaze (Watson 2004) - is not as apparent when using a transparent colourless glaze. For this reason, a significant amount of the mainly transparent colourless glazed sherds shows a modification, that would enable the incised patterns to appear dark. Remarkably, for about 40% of those sherds, our observation on edges with the naked eye and under optical microscopy indeed reveals the presence of a dark-coloured clay layer of variable thickness, going up to several hundreds of micrometers, right below the decoration (white slip / glaze).

Our multi-spectroscopic investigation (XRF, ESEM-EDX,  $\mu$ -Raman) of a reduced number of sherds highlight the chemical and mineralogical specificities of these sharply articulated dark-coloured layer in comparison with the underlying red clay bodies.

These results will be the focus of the present communication in order to discuss the manufacturing technique. In particular, it is assumed that modified dark-coloured clay layers were intentionally applied at specific areas of greenwares, partially in combination with iron- and/or manganese-rich particles within the glazes, to darken the appearance of incised decorations.

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## MICROSTRUCTURE ANALYSIS AND COLORING MECHANISM OF THE BLACK-GLAZED TEA BOWLS FROM THE JIAN KILN OF CHINA

LI W.

Ancient Ceramics Research Center, Shanghai Institute of Ceramics, Chinese Academy of Sciences, Shanghai, China

[liwd@mail.sic.ac.cn](mailto:liwd@mail.sic.ac.cn)

Keywords: black-glazed tea bowl, microstructure, coloring mechanism

The Jian kiln is located in present-day Jianyang county of Fujian Province, China. The Tenmoku tea bowl from the Jian Kiln was greatly appreciated by Zhao Ji, Emperor Huizong of the Northern Song Dynasty. Since the manufacturing techniques were lost, the Tenmoku bowl has been appraised as mysterious and costly treasure through the generations past.

This study focuses on the excavated Tenmoku bowl shards with different visual appearances, using various characterization techniques, such as OM, EDXRF, angle-resolved reflectance spectra, XRD, micro-Raman, SEM-EDS-EBSD, and AFM. Optical properties of the feature areas were characterized, and the relationship between chemical composition, microstructure, corrosion characteristics, firing process, burial environment, and coloring mechanism was investigated.

The thick and lustrous black glaze of Tenmoku bowl usually features streaked or mottled patterns, called “hare”s fur (HF)” or “oil spot (OS)”. Observing the excavated Tenmoku bowl shards, most of them are brown HF. Samples with silvery HF or OS patterns are rare. In some areas of the surfaces of a very small number of excavated Tenmoku bowls, there is a phenomenon of color variation with the observation angle.

The study shows that the HF and OS patterns on the surface were formed due to the supersaturated crystallization of iron oxides, usually a mixture of  $\epsilon$ -Fe<sub>2</sub>O<sub>3</sub> and hematite. The color and luster of the HFs and OSs are closely related to the orientation and order of crystallization, but not associated with a particular phase of iron oxide. The blue HFs on the glaze surface are assumed to be coherent light scattering by an amorphous photonic structure, which is formed by the oriented arrangement of crystals of iron oxides. The silvery HFs on the glaze surface is due to the total light reflection by the dendritic crystal directionally tiled on the glaze surface, which inhibits the chemical coloration of iron oxides. However, due to the crystal arrangement order is not uniform, from a certain angle, the silvery hare’s fur may still show a little brown chemical color.

## THE EARLY DAYS OF CERAMIC LEAD-GLAZING IN THE ANCIENT MEDITERRANEAN: UNRAVELLING TECHNOLOGICAL PRACTICES AT LESBOS, CENTRAL GREECE, AND CENTRAL ITALY

LIARD F.<sup>1</sup>\*, BEN AMARA A.<sup>2</sup>

<sup>1</sup> Faculté de Philosophie, Lettres et sciences humaines, Université Saint-Louis, Belgium

<sup>2</sup> Archéosciences, Université Bordeaux Montaigne, France

\*[florence.liard@usaintlouis.be](mailto:florence.liard@usaintlouis.be)

Keywords: Glaze analysis, Roman pottery, SEM-EDS

The acme of the production of lead-glazed pottery in the Ancient Mediterranean is commonly seen as a result of the Roman conquest of Cilicia in the mid-1st century B.C. In this regard, this type of glaze is often regarded as one of the many technological innovations that took place in a context of increased interactions between the Hellenistic and the Roman worlds. Nevertheless, the exact conditions that fostered this technological development – that is, the use of lead oxide to produce a pottery glaze – remain unclear. Based on the SEM-EDS analysis of the microstructure and bulk chemical composition of the fabrics and glazes, this research aims at reconstructing the successive steps of the experimentation and diffusion of pottery lead-glazing between the 1st century BC and the 1<sup>st</sup> century AD.

We present the results obtained from 48 vessels attributed to the late Hellenistic and early Roman periods. The vessels were sampled at Athens, Mytilene and Ostia, and we identified them petrographically as originating from industries in Asia Minor, Mainland Greece, and the area of Rome. This research builds on previous archaeological and archaeometric research on this type of ware.

Our SEM-EDS analysis indicates that the earliest, and also easternmost, lead glazes among our sample set are from Lesbos; they display technological differences with the (essentially later, and westerner) glazes from Attica, Corinthia and Rome. Indeed, Lesbian glazes were applied onto a non-calcareous fabric; they were produced by mixing lead oxide with clay, instead of using a quartz-rich sand (as identified elsewhere); they were coloured using iron oxide. In relation with a strong continuity of technological practice in the selection and use of clays identified among Lesbian mouldmade pottery since at least the 3rd century BC, it appears that lead-glaze pottery production in Lesbos may have started in a Hellenistic context rather than under a Roman impulse. Other compositional resemblances were highlighted with Seleucid, and even far-eastern Asian productions. The situation is different for mainland Greek workshops: the selection and treatment of the clays differ from the practices recorded for the local black-glazed Megarian bowls; the lead glaze production and colouring techniques (using copper oxide) seem to reproduce a potentially Roman standard that we also identified in the area of Rome. Therefore, these industries may have started after the Roman conquest, in a different sociocultural and economical context.

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## NEW RESEARCH ON SHANG PERIOD BRONZE CASTING CERAMIC TECHNOLOGY FROM ANYANG, HENAN PROVINCE, CHINA

LIN S. R.<sup>1-2,\*</sup>, CHEN J. L.<sup>1</sup>, QUINN P. S.<sup>2</sup>, KONG D.M.<sup>3</sup>

<sup>1</sup>School of Archaeology and Museology, Peking University, China

<sup>2</sup>Institute of Archaeology, University College London, U.K.

<sup>3</sup>Anyang Institute of Archaeology and Cultural Relics, China

\*[shirui.lin.22@ucl.ac.uk](mailto:shirui.lin.22@ucl.ac.uk)

Keywords: Ceramic mould, Bronze casting, Ceramic technology

Piece mould casting technology served as the foundation for elaborate bronze vessel production in China during the Shang dynasty (1600-1046 B.C.). Sophisticated ceramic technology was used to obtain high-performance mould materials that were an essential part of the bronze casting production. Building on several scientific studies on the well-known moulds of Anyang city, Henan province, China, the present project is conducting research on recently excavated material from the large foundry site of Xindian. Samples of outer-moulds, cores and models have been analysed, as well as furnace fragments, domestic pottery fragments and local clay samples, for comparison.

In order to characterise the raw materials, paste preparation recipes and firing technology, the samples are being analysed via thin section petrography, ED-XRF, SEM-EDS, LA-ICP-MS, FTIR and thermo-mechanical testing. This has revealed a high degree of standardisation and the use of specific recipes for the different mould types. Most of the outer-moulds are composed of two layers; a sand-tempered coarse outer layer and a fine silty inner layer into which the details of the outer-moulds were impressed. The fine homogeneous inner layer is composed mainly of quartz silt and has a surprisingly low clay content, giving it low shrinkage and high refractoriness. It is also fairly porous, permitting the escape of gasses and vapour during casting. Previous studies have suggested that the paste used to make the crucial inner layers were prepared by refining loess clay, however, samples of loess reveal this to have a higher CaO content. Experiments on local clay are in progress to test this theory analytically. The fine, quartz-rich nature of the inner layers means that they are challenging to group petrographically. Quantitative mineralogical data from point-counting and QEM-Scan is therefore being used to explore the variability between and within samples more effectively, as well as to compare this to the local clay samples.

The clay models used to impress specific shapes of different accessories into the outer-moulds were made from a similar silty paste. In comparison, the large body cores located within the bronze objects are clay-rich and have a blocky microstructure, perhaps satisfying the mechanical strength requirements to withstand serious stress as the metal shrunk during cooling.

These three types of moulds were all fired to a relatively low temperature of < 800°C before use. Additional materials were also used for specific reasons. A black sooty layer applied on the interior/exterior surface of outer-moulds/cores served as a parting agent. A red clay slip applied on the parting surface of outer-moulds served as an adhesion agent to make different pieces more tightly assembled. The red layer is distinct from the grey or brown mould body, indicating multiple heating possibly related to a preheating process after firing.

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## FINGERPRINTING CERAMICS FROM THE CHALCOLITHIC SANTA VITÓRIA ENCLOSURE (SW IBERIA)

MARQUES R.<sup>1-2,\*</sup>, RODRIGUES A.L.<sup>1</sup>, PRUDÊNCIO M.I.<sup>1</sup>, DIAS M.I.<sup>1-2</sup>, VALERA A.C.<sup>3-4</sup>, BASÍLIO A.C.<sup>3-4</sup>, GMÉLING K.<sup>5</sup>

<sup>1</sup>Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>2</sup>Departamento de Engenharia e Ciências Nucleares (DECN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>3</sup>ERA Arqueologia S.A., Portugal

<sup>4</sup>Interdisciplinary Center for Archaeology and Evolution of Human Behavior (ICArHEB), Universidade do Algarve, Portugal

<sup>5</sup>Nuclear Analysis and Radiography Department, MTA Centre for Energy Research, Hungary

\*[rmarques@ctn.tecnico.ulisboa.pt](mailto:rmarques@ctn.tecnico.ulisboa.pt)

Keywords: Chalcolithic, Geochemistry, Provenance and mobility

The archaeological site of Santa Vitoria is located near Campo Maior (Alentejo, Southern Portugal). This chalcolithic site can be described as a ceremonial enclosure of circular tendency forming sequences of contiguous semi-circular lobules defined by two concentric ditches. The inner enclosure of Santa Vitória has an entrance facing the summer solstice. The ditches reveal fillings where natural processes, but mainly anthropic ones, were registered. In other words, they were filled with intentional depositions.

In this work, the characterization of a set of 25 ceramic artefacts from the archaeological site of Santa Vitória is carried out for the first time by means of Neutron Activation Analysis and X-Ray diffraction. The studied samples are all from ditch 1, but collected in different sections (1 and 2): section 1 had two distinct filling phases and the ceramics analyzed (10 sherds) are from the upper part of the ditch, while in the section 2 only the lower part of the filling was excavated and the ceramics (15 sherds) correspond to the first filling phase. The main goal of this study is to establish the chemical and mineralogical patterns of the ceramics, contributing for the discussion of provenance, mobility and technology of production in the Chalcolithic.

The results obtained show that the majority of the samples include quartz and plagioclase as main minerals, associated to phyllosilicates and small proportion of amphibole, K-feldspars and hematite.

The chemical results, namely the cluster analysis using chemical contents as variables, evidence that two ceramics have distinct behavior mainly due to different contents of Na, Fe and rare earth elements (REE), and were classified as outliers. The remaining ceramics studied (23) form two main groups: one comprising the ceramics from section 1, and the other with the ceramics from section 2. The main differences found between these groups, besides the macroscopic observation of the ceramic pastes (coarser pastes in ceramics from section 1), are the general tendency for higher contents of Na, K, Fe, Rb and Cs in ceramics from section 2, probably due to a higher content of feldspars and phyllosilicates, as well as iron oxides. It should be noted that these last ceramics also show Ca in their composition, which was not found in ceramics from section 1. In general, a tendency for higher contents of REE is observed in ceramics from section 1.

This preliminary study in Santa Vitória site revealed a clear distinction of the two sections, particularly the different filling phases, and confirms the need to perform deeper and wider ones in order to better understand the compositional patterns of the ceramics, enabling the evaluation of the impact of this type of sites, ditched enclosures and related artefacts for a more holistic understanding of the Chalcolithic in SW Iberia.

## COMPOSITIONAL STUDY, PROVENANCE AND CIRCULATION OF CHALCOLITHIC BELL BEAKERS AND PENHA-TYPE CERAMICS (NW PORTUGAL)

MARQUES R.<sup>1-2,\*</sup>, RODRIGUES A.L.<sup>1</sup>, RUSSO D.<sup>1-2</sup>, PRUDÊNCIO M.I.<sup>1</sup>, VALERA A.C.<sup>3-4</sup>, BASÍLIO A.C.<sup>4</sup>,  
RAMOS R.<sup>3</sup>, DIAS, M.I.<sup>1-2</sup>, HARSÁNYI I.<sup>5</sup>, KASZTOVSZKY Z.<sup>5</sup>, SZILÁGYI V.<sup>5</sup>, GMÉLING K.<sup>6</sup>,  
KOVÁCS I.<sup>7</sup>, SZŐKEFALVI-NAGY Z.<sup>7</sup>

<sup>1</sup>Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, Portugal,

<sup>2</sup>Departamento de Engenharia e Ciências Nucleares (DECN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>3</sup>ERA Arqueologia S.A., Dafundo, Portugal

<sup>4</sup>Interdisciplinary Center for Archaeology and Evolution of Human Behavior (ICArHEB), Universidade do Algarve, Portugal

<sup>5</sup>Nuclear Analysis and Radiography Department, Centre for Energy Research, Hungary

<sup>6</sup>Centre for Energy Research, Nuclear Analysis and Radiography Department, Hungary

<sup>7</sup>Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, Hungary

\*[rmarques@ctn.tecnico.ulisboa.pt](mailto:rmarques@ctn.tecnico.ulisboa.pt)

Keywords: Provenance, Bell Beakers and Penha-type, rare earth elements

The study of the “Bell Beaker” phenomenon is well documented across Europe, and in Portugal a few studies were done comprised of a compositional approach in order to infer the provenance and circulation of these materials, particularly in the central and southern regions. Regarding the Penha type ceramics, they have been documented in the northwest of the Iberian Peninsula, in Chalcolithic contexts and associated with bell beaker, but without an analytical approach so far. The present work is the first compositional study of Bell Beaker and Penha-type ceramic artefacts from the Chalcolithic of NW Portugal, collected in the Megalithic Necropolis of Motas (Monção). Additionally, one ceramic from the Neolithic context is also studied. The main objectives of this work are the: i) compositional characterization of ceramics from Mamoá das Motas 1, Motas 5, and Soalhosa 1; and ii) evaluation of the similarity/dissimilarity of these typologies and chronologies (Bell Beaker vs. Penha-type; Chalcolithic vs Neolithic). For the compositional study, nuclear methods of chemical analysis were used (PGAA, NAA and PIXE).

The results indicate that among the studied elements, the rare earths elements (REE) and antimony are the best indicators for differentiating the studied typologies/chronologies. The composition of the ceramic pastes from Penha-type with incised decoration found in Motas 5 clearly differs from those found in Motas 1, pointing to local/regional production with different raw materials, or different provenance. The Penha-type ceramics found in Motas 1 differ from the Bell Beaker ceramics, showing higher Sb contents, lower REE contents and lower negative Eu anomaly. The Neolithic sample (boquique) differs from all studied Chalcolithic samples essentially by the REE pattern (lower LREE contents).

This first study shows compositional differences between the different typologies, in particular those of the Penha-type. Therefore, a more comprehensive study of these materials is justified, including local/regional raw materials and a greater number of ceramics, in order to achieve a better differentiation between provenance/mobility of artifacts, people and ideas in the NW of the Iberian Peninsula during the Chalcolithic.

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## TECHNOLOGICAL CHARACTERIZATION OF PRODUCTION OF INKA-STYLE POTTERY IN THE SOUTHERN BORDER OF TAWANTINSUYU (INKA EMPIRE)

MARTÍNEZ A.<sup>1, \*</sup>, QUINN P.<sup>1</sup>, SILLAR B.<sup>1</sup>, AMICONE S.<sup>1-2</sup>

<sup>1</sup>Institute of Archaeology, University College London, U.K.

<sup>2</sup>Archaeometry Research Group, Eberhard Karls University of Tübingen, (Tübingen), Germany

\* [andrea.carrasco.19@ucl.ac.uk](mailto:andrea.carrasco.19@ucl.ac.uk)

Keywords: Inka style pottery, ceramic production, state control

This paper presents preliminary findings of an ongoing doctoral project which seeks to investigate the degree and nature of state control on Inka-style pottery production in Central Chile, the southern extent of the empire (South America). This work is mainly centred on the technological characterisation of Inka-style pottery production in the Aconcagua Valley during the Late Period (c. 1.400-1.536 AD). The analysis focuses on aríbalos and shallow plates. These Inka pottery forms have been recognised in different provinces of the empire but have no local antecedents in the study area. The Inka-style vessels are compared with ceramics of previous local styles (Late Intermediate Period c. 1.000-1.400), foreign styles (Diaguitas) and new local pottery appearing in the Inka presence period.

The ceramic fragments have been characterised technologically with a *chaîne opératoire* approach, considering their raw material sources, forming process, pigments elaboration, and changes in the firing stage. For this purpose, analyses are carried out at different scales, considering macro-traces, ceramic petrography of thin sections, and compositional analyses (pXRF,  $\mu$ XRD2, SEM-EDS and LA-ICP-MS).

Preliminary results seem to indicate local sourcing of raw materials, with a continuity of the local pottery tradition in the early stages of Inka-style pottery production, but with changes in finishing, decoration, and firing. At the decorative level, the black paints show a differential mineralogical pattern in their composition, distinguishing the local pottery tradition from the Inka style, the latter having more similarity with contemporary foreign styles (Diaguita). The results are analysed to assess how continuities in local practice relate to the influence of Inka imperial institutions and Diaguita foreign pottery specialists to consider potential mechanisms for knowledge transmission and the adoption of new technological practices.

## LYING ON THE SEABED: MODELLING POST-DEPOSITIONAL ALTERATION OF POTTERY IN MARINE ENVIRONMENTS

MASCARO M.E.<sup>1</sup> \*, AURIEMMA R.<sup>2</sup>, CHAPOULIE R.<sup>3</sup>, MAZZOLI C.<sup>1</sup>, PEZESHKANJALILI H.<sup>1</sup>,  
MARITAN L.<sup>1</sup>

<sup>1</sup>Department of Geosciences, University of Padova, Italy

<sup>2</sup> Department of Cultural Heritage, University of Salento, Italy

<sup>3</sup> Archéosciences Bordeaux UMR 6034, CNRS, University Bordeaux Montaigne, France

\*[mariaemanuela.mascaro@phd.unipd.it](mailto:mariaemanuela.mascaro@phd.unipd.it)

Keywords: ceramics, EMAC2023

The project on the archaeometric study of ceramic amphorae belonging to some ship cargoes found in the underwater archaeological site of Torre Santa Sabina (TSS) (Apulia, Southern Italy) (Auriemma et al., 2022) is presented here. The main aim of this research is to identify the systematic physical, chemical and mineralogical alterations occurring in ceramic samples buried in seawater for centuries, in order to propose methodological and sampling criteria that could be extended to all fired clay finds from underwater sites. For these purposes, geochemical, mineralogical and micro-stratigraphic features of the ceramic samples will be investigated by a multi-analytical approach. The precipitation of secondary phases in pores, the enrichment and depletion of chemical elements, the transformation of pristine mineral phases into new phases, and devitrification processes (Maritan, 2020) are the main considered aspects. A comparison between sherds of similar productions but recovered from both marine and terrestrial sites, is also provided in order to verify the systematic nature of the main alteration processes in objects exposed to different burial environments. Preliminary petrographic, mineralogical and microchemical analyses were carried out on 30 samples by optical microscopy, XRPD, XRF and SEM-EDS. The polarising light microscope analysis allowed to define the complex nature of the ceramic bodies from the underwater site of TSS, showing a 'chromatic' stratigraphy linked to post-depositional processes and the precipitation of secondary phases. Such characteristics were not found in the comparison samples from the terrestrial site of Giancola (GC), indicated as a possible production centre for some of the ceramic types found in the submerged site. XRPD analysis was employed to define which mineralogical phases were initially present in the ceramic bodies and which precipitated during burial. Quartz, K-feldspar, plagioclase, muscovite/illite, haematite, diopside and calcite are the primary mineralogical phases detected in the marine samples, which are quite different from those present in the GC ones and the statistical treatment of diffraction patterns by cluster analysis clearly separates the two ceramic types. Chemical analysis by XRF confirms these differences, suggesting that the GC site cannot be considered the production centre of the ceramic amphorae found on the TSS seabed. SEM images of secondary phases confirm the presence of pyrite, gypsum and magnesian calcite in the underwater samples, also detected by XRD.

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## THE PRODUCTION OF TERRA SIGILLATA IN AREZZO, CENTRAL ITALY: AN ARCHAEOOMETRIC INVESTIGATION

MASCARO M.E.<sup>1</sup>, CANTISANI E.<sup>2</sup>, RICCI M.<sup>3</sup>, PALLECCHI P.<sup>4</sup>, VILUCCHI S.<sup>4</sup>, PASQUAL D.<sup>1</sup>,  
MARITAN L.<sup>1</sup>

<sup>1</sup> Department of Geosciences, University of Padova, Italy

<sup>2</sup> CNR-ISPC, Institute of Heritage Science (Florence Unit), Italy

<sup>3</sup> Department of Chemistry "Ugo Schiff", University of Florence, Italy

<sup>4</sup> Superintendence Archaeology, Fine Arts and Landscape for the Metropolitan City of Florence and the Provinces of Pistoia and Prato, Italy

\*[mariaemaneula.mascaro@phd.unipd.it](mailto:mariaemaneula.mascaro@phd.unipd.it)

Keywords: ceramics, EMAC2023

This paper reports the results of an archaeometric investigation conducted on a set of twenty-five fragments of terra sigillata representing both ceramic ware and the moulds used to form them, dating from around 30 BCE to 30 CE. They were all found during an excavation carried out in the second half of the 19<sup>th</sup> century in possible production centres within the city of Arezzo, Tuscany (central Italy). The main aim of the research was to characterise both ceramic bodies and coatings and to obtain information on production technology and provenance, as well as possible differences between the two classes of materials. For this reason, a multidisciplinary approach, consisting in the mineralogical and chemical analysis were performed on all the samples (Sciau et al., 2020). Microscopically, the potsherds showed a well-purified body, sharing very similar mineralogical compositions, mainly consisting in quartz, anorthite, pyroxene, hematite, and K-feldspars; illite/muscovite was also frequently encountered. The mineralogical phases detected suggest firing temperature between 850°C and 1000°C under oxidising conditions of a calcareous-illitic clay. The slips resulted to be produced with a Fe-rich illitic clay (Fe content of around 10-15 wt.%) (Leon et al., 2015). The comparison of the chemical data (Maritan et al., 2013) also with terra sigillata wares from important production areas (Italy, Spain, France, northern Africa and Turkey), indicated systematic differences which allowed to define that the studied samples were locally produced in Arezzo. Moreover, both the ware and the matrixes resulted to be produced using the same type of clay, indicating that also the selection of the raw material and the production of moulds were of great importance in the terra sigillata *chaîne opératoire*.

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## TECHNOLOGICAL FEATURES OF THE LATE BRONZE AGE POTTERY IDENTIFIED AT TOPOLIȚA (NEAMȚ COUNTY), EASTERN ROMANIA

MATAU F.<sup>1, \*</sup>, BREABAN I.-G.<sup>2-3</sup>, PINTILEI, M.<sup>4</sup>, CHISCAN O.<sup>5</sup>, DIACONU V.<sup>6</sup>, STANCU A.<sup>5</sup>

<sup>1</sup>ARHEOINVEST Center, Interdisciplinary Research Center, Department of Exact and Natural Sciences, Alexandru Ioan Cuza University of Iași, Romania

<sup>2</sup>CERNESIM Center, Interdisciplinary Research Center, Department of Exact and Natural Sciences, Alexandru Ioan Cuza University of Iași, Romania

<sup>3</sup>Department of Geography, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iași, Romania

<sup>4</sup>Department of Geology, Faculty of Geography and Geology, Alexandru Ioan Cuza University of Iași, Romania

<sup>5</sup> Faculty of Physics, Alexandru Ioan Cuza University of Iași, Romania, 6. Museum of History and Ethnography, Târgu Neamț, Romania

\*[florica.matau@uaic.ro](mailto:florica.matau@uaic.ro)

Keywords: pottery, *chaîne opératoire*, *communities of practice*

This paper aims to examine the technological features of the Late Bronze Age ceramic assemblage discovered at Topolița (Neamț County) using a *chaîne opératoire* approach. The archaeological site is in the Subcarpathian area of eastern Romania and was assigned based on the typological features of the ceramic artefacts to the *Noua* culture (second half of the 16<sup>th</sup> century to the 12<sup>th</sup> century BC). The dataset investigated in this study consists of thirty potsherds selected to represent the stylistic and functional variability detected at the site. For assessing the various stages of the *chaîne opératoire* (raw materials selection, paste preparation, manufacturing procedures, surface finishing and firing conditions), the pottery samples were studied using an integrated analytical approach combining macroscopic observation with petrographical, spot chemical analysis determined by laser-ablation induced coupled plasma mass spectrometry (LA-ICP-MS) and mineralogical investigations performed by X-ray powder diffraction (XRPD).

This *chaîne opératoire* approach to pottery production revealed a rather conservative behavior starting with the raw materials selection combined with a significant degree of variability in the processing and finishing sequences. Besides, the analysis of the ceramic assemblage discovered at Topolița provided qualitative data to assess the co-existence of various *communities of practice* involved in pottery production during the investigated timespan in the eastern part of nowadays Romania.

## MODELLING ALTERATION PROCESSES EXPERIENCED BY ROMAN AMPHORAE FROM CROATIAN UNDERWATER SITES

MISE M.<sup>1</sup>, QUINN P.<sup>1</sup>, MASCARO M.E.<sup>2</sup>, MARITAN L.<sup>2,\*</sup>

<sup>1</sup>University College of London, U.K.

<sup>2</sup>Department of Geosciences, University of Padova, Italy

[\\*lara.maritan@unipd.it](mailto:lara.maritan@unipd.it)

Keywords: ceramics, EMAC2023

Amphorae, a common type of container for packing and transporting goods in the Mediterranean from the Bronze Age to the Late Roman period, represent a valuable record of trade and other economic activities that took place in ancient times. Because of their use, transport amphorae are found in different archaeological contexts, from terrestrial sites linked to production centres or sites where amphorae were discarded after their contents were used, so called consumption sites. The shape of the amphorae made them suitable for shipping, so they are often found as cargoes in wrecked ships in the sea and rivers.

In recent years, the study of amphorae by scientific methods has become common throughout the Mediterranean, not only for the study of provenance but also for the study of ancient trade routes. Since the latter study compares amphorae recovered in shipwrecks and terrestrial sites, a direct comparison of these amphorae could be hampered by different post-depositional alterations in amphorae microstructure and composition.

In the presentation, the authors will present the results of mineralogical and chemical analysis of amphorae from shipwrecks from Dalmatia (Croatia) by XRD and microstructural investigation by SEM. The aim of the research was to determine which how the alteration processes affected the original composition of the ceramics, also in relation to the type of raw material used and the amphorae production technology (especially firing temperature), as well as environmental conditions at the microscale.

## IRON AND IRON-MANGANESE CRYSTALLINE PHASES AS TRACERS OF ANCIENT LEAD GLAZE PRODUCTION TECHNIQUES

MOLERA J.<sup>1,\*</sup>, SALINAS E.<sup>2</sup>, COLOMER M.<sup>3</sup>, VALLCORBA O.<sup>4</sup> & PRADELL T.<sup>5</sup>

<sup>1</sup>MECAMAT, Facultat de Ciències i Enginyeries. Universitat de Vic - Universitat Central de Catalunya, Spain

<sup>2</sup>Departamento de Geografía, Historia y Humanidades, Universidad de Almería, Spain

<sup>3</sup>Campus Mundet, Universitat de Barcelona, Spain

<sup>4</sup>ALBA Synchrotron Light Source, Spain

<sup>5</sup>Dept. Física, Barcelona, Universitat Politècnica de Catalunya BarcelonaTech, Spain

\*[judit.molera@uvic.cat](mailto:judit.molera@uvic.cat)

Keywords: Glaze, iron, manganese

Since medieval times, lead glazes have been coloured and decorated using Iron oxides. During firing, the original raw pigments react, dissolve, and recrystallize into new crystalline compounds. The composition of the raw pigment, glaze and ceramic body, method of application, and thermal paths affect the nature, size, and distribution of these crystals. Analysing the crystalline phases in ancient glasses is useful for determining ancient production techniques and can provide information on the final colour and appearance of the glaze.

Neoformed crystals of andradite, melanotekite, and magnetoplumbite have been found in glazed ceramics from the 11<sup>th</sup> to 17<sup>th</sup> centuries (1,2,3) that feature black decorations rich in iron. In order to determine the temperature range at which these pigments were formed, an X-ray powder diffraction experiment was conducted at the ALBA synchrotron using various mixtures of PbO-SiO<sub>2</sub> glazes with the addition of Fe<sub>2</sub>O<sub>3</sub>. The influence of Al<sub>2</sub>O<sub>3</sub>, CaO, and MgO was studied by adding kaolinite, calcite, or dolomite to the aforementioned mixtures. The sequence of formation of the various crystalline phases during heating and cooling was established. In addition, recreations of the glazed ceramics were made in the laboratory at different temperatures ranging from 690°C to 1020°C to identify the phases formed using optical and electronic microscopy.

Furthermore, while our previous research (4) has focused on studying the compounds formed by Mn oxide in glazes, the current study expands on this by examining the compounds resulting from the combination of Fe and Mn in glazes. The kinetic profile of the experiment was designed to provide information on the sequence of iron and iron-manganese phases formed during heating and cooling.

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## **A MULTI-ANALYTICAL APPROACH TO INVESTIGATE POTTERY MANUFACTURE AND PRODUCTION AT HELAWA (KURDISTAN REGION OF IRAQ) DURING THE CHALCOLITHIC PERIOD (C. 5300-3800 BCE)**

MORABITO G.<sup>1, \*</sup>, VACCA A.<sup>2</sup>, PEYRONEL L.<sup>2</sup>, GATTA G.D.<sup>1</sup>

<sup>1</sup>Dipartimento di Scienze della Terra, Università degli Studi di Milano, Italy

<sup>2</sup>Dipartimento di Studi Letterari, Filologici e Linguistici, Università degli Studi di Milano, Italy

\*[giulia.morabito@unimi.it](mailto:giulia.morabito@unimi.it)

Keywords: Kurdistan pottery

The archaeological excavations carried out by the Italian Archaeological Expedition of the University of Milan in the Erbil Plain (Kurdistan Region of Iraq) are providing new information for the exploration of the societal transformation that occurred from the prehistoric phases up to the medieval period. Tell/Girdi Helawa is a pre- and proto-historic site with a substantial occupation spanning from the Halaf to Late Chalcolithic periods (VII-IV millennium BCE). The excavation along the southern slope of the mound brought to light a thick stratigraphic sequence of in-situ structures and deposits with associated pottery, that allowed an assessment of the ceramic pottery typology, and the investigation of the changes in production and manufacture through times.

The aim of this study is an archaeometric characterization of a set of 67 ceramic fragments coming from the Helawa site. A multi-analytical approach was adopted, in order to provide a complete picture of the raw materials used, manufacturing processes, and firing technologies of these ceramic materials. Mineralogical and texture analyses were performed by means of petrographic thin-section observations under the polarised light microscope, X-Ray powder diffraction with Rietveld full-profile fit to the diffraction patterns (providing quantitative phase analysis, along with the amorphous fraction estimation) and scanning electron microscopy investigations with chemical microanalysis (by SEM-EDS, EPMA-WDS). The preliminary crystallochemical and textural data are providing unambiguous markers for the reconstruction of the raw materials assemblages and the firing conditions, which appear to be different in diverse periods.

## **REVEALING THE KNOW-HOW – INTEGRATED STUDIES ON COOKING POTTERY MANUFACTURING TRADITIONS FROM THE 3<sup>RD</sup> -7<sup>TH</sup> CENTURIES CE. A CASE STUDY FROM NEA PAPHOS, CYPRUS**

NOCOŃ K.<sup>1, \*</sup>, MARZEC E.<sup>2-3</sup>, KIRIATZI E.<sup>3</sup>

<sup>1</sup>Polish Centre of Mediterranean Archaeology, University of Warsaw, Poland

<sup>2</sup>Institute of Mediterranean and Oriental Cultures of the Polish Academy of Sciences, Poland

<sup>3</sup>Fitch Laboratory, British School at Athens, Greece

[\\*k.nocon@uw.edu.pl](mailto:k.nocon@uw.edu.pl)

Keywords: Cooking pottery, Middle and Late Roman periods, Nea Paphos

The micro economic history of the Hellenistic and Early Roman (3rd c. BCE-2nd c. CE) Nea Paphos has been recently widened with integrated macroscopic and scientific studies on cooking pottery, tableware and lamps, which indicated that the city was a significant centre of ceramic production in those times. However, our knowledge about the pottery production in the Middle and Late Roman periods (3rd-7th c. CE) is still insufficient due to the lack of actual workshops as well as scientific analysis of relevant pottery. To fill this gap, the ongoing project aims to focus on the provenance and technology of Middle and Late Roman cooking pottery in order to investigate transformation their production and consumption patterns over time. The large corpus of Middle and Late Roman cooking pottery (880 diagnostic fragments of rims, handles, and bottoms) from the excavations on the Agora and several Trial Trenches located in the Archaeological Park in Nea Paphos was examined with emphasis on macroscopic fabric and morphological features. Additionally, selected samples representing visual and stylistic variability of this assemblage were subjected to scientific analysis, including thin section petrography, wavelength dispersive X-ray fluorescence spectrometry and refiring tests.

The results of these integrated research indicated the presence of cooking pottery produced locally and imported (both from Cyprus and beyond). This poster presents the compositional and morphological characterisations of Middle and Late Roman cooking pottery identified as local for Nea Paphos. Furthermore, it discusses developments in the local traditions of cooking pottery manufacture and changes in the ceramic know-how over the Middle and Late Roman periods.

## COOKING WARE AT PREHISTORIC TOUMBA THESSALONIKI: AN INDICATOR OF CONTINUITY IN POTTING TRADITION AND CULINARY PRACTICE

OGAWA T.<sup>1-2,\*</sup>, MÜLLER S.N.<sup>1</sup>, PROCOPIOU H.<sup>2</sup>, TRIANTAFYLLOU S.<sup>3</sup>, ANDREOU S.<sup>3</sup>, KIRIATZI E.<sup>1</sup>

<sup>1</sup>Fitch Laboratory, British School at Athens, Greece

<sup>2</sup>Department of History of Art and Archaeology, University Paris 1 Panthéon-Sorbonne, France

<sup>3</sup>Department of History and Archaeology, Aristotle University of Thessaloniki, Greece

\*[timothee.ogawa@bsa.ac.uk](mailto:timothee.ogawa@bsa.ac.uk)

Keywords: Cooking ware - *Chaîne opératoire* - Toumba Thessaloniki

Recent archaeological research undertaken in Central Macedonia during the last decades has provided significant new data on the daily life of prehistoric communities in the Middle Bronze Age until the end of the Late Bronze age. In this context of intense socio-cultural interactions between Northern Greece, the Balkans and the Mycenaean world, the current project aims to focus on cooking ware. The latter comprises a ceramic category that has been for long overshadowed by finer decorated wares, despite the inherent challenges both in its manufacture and use and consequently the rich information it can provide on various aspects of past societies.

In this presentation, the emphasis will be on the technological aspect of such vessels. Through an integrated study of the *chaîne opératoire*, combining macro- and microscopic analysis as well as elemental analysis, the fabric and the fashioning techniques of the cooking pots will be investigated. The ultimate objective is to identify communities of practice and reconstruct the organisation of the local cooking ware production, but also investigate networks of circulation of such vessels and/or their technologies. hence established if the production was locally produced or imported for instance.

The research focuses on the settlement of Toumba Thessaloniki, a coastal site located in the centre of the study area with habitation spanning at least from the mid-2<sup>nd</sup> mil. to the early 1<sup>st</sup> mil. BC. The site offers the opportunity for a diachronic study of the cooking ware as well as an intra-site comparison of the repertoire of the cooking equipment between households. The preliminary results of this research suggest that the Toumba Thessaloniki communities continued sharing common potting traditions and thus culinary practices with sites mainly in the region and the Balkans with only minor influences from southern central and southern Aegean. Methods, tools and materials involved in the manufacture of cooking pots show minor (if at all) change over time and across space and the same seems to apply to the relevant cooking practices.

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## THE ORIGIN OF THE LEAD USED IN THE PRODUCTION OF GLAZES: THE CASE OF MAIOLICA MADE IN THE FLORENTINE AREA BETWEEN THE 15<sup>TH</sup> AND 19<sup>TH</sup> CENTURY

PAGHI D.<sup>1,\*</sup>, MANCA R.<sup>1</sup>, CASALINI M.<sup>1</sup>, CHIARANTINI L.<sup>2</sup>, BRAGAGNI A.<sup>1</sup>, TOMMASINI S.<sup>1</sup>,  
BENVENUTI M.<sup>1-3</sup>

<sup>1</sup>Dipartimento di Scienze della Terra (DST), Università degli Studi di Firenze, Italy

<sup>2</sup>Centro Interdipartimentale di Microscopia Elettronica e Microanalisi (MEMA), Università degli Studi di Firenze, Italy

<sup>3</sup>Istituto di Geoscienze e Georisorse (IGG), CNR, Italy

\*[dilettapaghi@gmail.com](mailto:dilettapaghi@gmail.com)

Keywords: archaeometry, lead isotope, maiolica

The production techniques and materials used for the manufacture of Italian maiolica during the Middle Ages and the Renaissance have been broadly studied in the past. However, very little is known about the provenance of the raw materials used to produce the tin-opacified glaze typical of maiolica. This study aims at obtaining a first set of data on the provenance of lead used as flux in the production of maiolica glazes in the Florentine area.

Maiolica wares made between the 15<sup>th</sup> and 19<sup>th</sup> centuries were analysed to trace the lead's origin and its possible variation over the centuries. Two of the main productions of Tuscany were investigated: the one of Montelupo Fiorentino and the Ginori manufactory in Doccia (Florence, Italy). The analysis of lead isotopes was performed by thermal ionization mass spectrometry (TIMS). Moreover, the samples were analysed by scanning electron microscopy (SEM-EDS) to characterize their layered structure and chemical composition.

Isotope analysis showed that the samples tend to be distributed into distinct groups according to their historical period of production. This indicates the potentiality of discriminating between maiolica produced at different times by lead isotope analysis, although a larger dataset would be needed to confirm this. The comparison with the lead isotope composition of the deposits of the European and Circum-Mediterranean area, from which lead was historically extracted, showed that the isotopic composition of samples differs from that of the Italian deposits, suggesting that lead was imported from abroad. All the samples are compatible with German ore deposits, in agreement with historical sources: Cipriano Piccolpasso mentions the proverb 'piombo tedesco, stagno fiandresco' ('German lead, Flanders tin') in his famous treatise about maiolica written in c. 1557. At the same time, also the lead deposits of Great Britain, Bulgaria, France, and south-western Switzerland are isotopically compatible with the investigated maiolica glazes and cannot be excluded as possible centres of supply.

Lead isotope analysis on Tuscan manufactories investigated provided promising results for the reconstruction of Italian maiolica technology and the commercial relations in the European and Mediterranean area over time.

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## YCHSMA POTTERY PRODUCTION: EXPERIMENTAL ARCHAEOLOGY TO RECREATE THE FIRING CONDITIONS

PAREJA D.<sup>1,2,3,\*</sup>, IÑÁÑEZ J.<sup>2</sup>, CHAPOULIE R.<sup>1</sup>, BEN AMARA A.<sup>1</sup>, DÍAS L.<sup>3</sup>

<sup>1</sup>Archéosciences Bordeaux, UMR 6034 CNRS - Université Bordeaux Montaigne, Maison de l'Archéologie, , France,

<sup>2</sup>GPAC, C. I. Micaela Portilla, Universidad del País Vasco (UPV/EHU), Spain

<sup>3</sup>Grupo de Investigación Sociedades Prehispánicas del Litoral-Yungas, Departamento Académico de Arqueología, Universidad Nacional Mayor de San Marcos, Facultad de Ciencias Sociales, , Peru

\*[reynaldo.pareja-anyosa@etu.u-bordeaux-montaigne.fr](mailto:reynaldo.pareja-anyosa@etu.u-bordeaux-montaigne.fr)

Keywords: Ychsma pottery, experimental archaeology, ceramic firing, XRD, Peru

The Ychsma society was one of the most important pre-Hispanic cultures in South America, which developed between 900 and 1532 AD on the central coast of present-day Peru, including the lower basins of the Rímac and Lurín valleys. Between 1470 and 1532 AD, the land was conquered and placed under the authority of the Inca Empire, which ruled the region until the conquest by Spaniards. Despite this, under Inca governing the local elites maintained their social position and control over the population.

For a better understanding of the Ychsma pottery production, we followed a multidisciplinary approach to achieve a holistic vision of ceramic production during this period. On the one hand, through experimental archaeology and ethnographic information, we identified the manufacturing technique and features related to the “chaîne opératoire” and firing procedures employed by Ychsma potters. Subsequently, we performed a firing experiment to reproduce the ancient open-fire firing system used by Ychsma artisans. Thus, several thermocouples were placed in the firing pit. The results show that with this system, it is possible to reach high temperatures (1056°C). On the other hand, a mineralogical study by powder XRD and controlled temperature XRD was also carried out to measure the firing temperatures on archaeological and experimental samples, which helps to identify the changes in the phases of the minerals, and have a better understanding of the Equivalent Firing Temperatures.

All these data constitute a reference to grasp the aspects related to the elaboration and firing of Late Intermediate Horizon Ychsma ceramics.

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## THE NEOLITHIC POTTERY OF RIO TANA (CENTRAL ITALY, ABRUZZO): NEW DATA FROM THE ARCHAEOMETRIC INVESTIGATIONS

RUSSO G.<sup>1,\*</sup>, PETRINELLI PANNOCCHIA C.<sup>2</sup>, VASSANELLI A.<sup>2</sup>, MEDEGHINI L.<sup>3-4</sup>, CAPRIOTTI S.<sup>3</sup>, MIGNARDI S.<sup>3-4</sup>

<sup>1</sup>CNR-ISPC, Rome, Italy

<sup>2</sup>Department of Civilizations and Forms of Knowledge, University of Pisa, Italy

<sup>3</sup>Department of Earth Sciences, Sapienza University of Rome, Italy

<sup>4</sup>Cnr-IGAG, Rome, Italy

\*[gilda.russo@ispc.cnr.it](mailto:gilda.russo@ispc.cnr.it)

Keywords: Early Neolithic, archaeometric analyses, pottery production

This work aims to present the preliminary results obtained from the analysis of the pottery complex collected at Rio Tana, a neolithic settlement located on the southeast terrace of the Fucino Basin (central Italy).

The characteristics of this production reveal a strict connection with the middle-Adriatic impressed ware. The complex is characterized by an abundance of coarse pottery products and simple shapes, among which the open types prevail. The incidence of decoration is scarce and obtained almost exclusively with engraved lines and plastic elements.

To better define the technical aspects of this production, samples of sherds, chosen from various levels and areas of the site, were analyzed with a multi-analytical approach, including optical microscopy in thin section, X-ray powder diffraction, and Scanning Electron microscopy with microanalyses (Russo et al., 2022).

The results reveal the existence of several pottery productions because of various manufacturing techniques, functional objectives, and cultural traditions.

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## COILING YOUR WAY UP: NEW VISUAL EVIDENCE OF EARLY MESOAMERICAN (CAPACHA) POTTERY FORMING TECHNIQUES

SALGADO-CEBALLOS C.<sup>1,\*</sup>, DE LUCIO MORALES Ó.<sup>2</sup>, MITRANI A.<sup>2</sup>

<sup>1</sup> Departamento de Estudios Mesoamericanos y Mexicanos, CUCSH, Universidad de Guadalajara,

<sup>2</sup> LANCIC, Instituto de Física, Universidad Nacional Autónoma de México

\*[carlos.salgado@academicos.udg.mx](mailto:carlos.salgado@academicos.udg.mx)

Keywords: Forming, technology, coiling

Capacha (ca. 1200-900 BCE) is one of the two oldest ceramic complexes known from western Mesoamerica (Salgado-Ceballos et al., 2021). While overall formal similarities to other early pottery complexes found elsewhere in the Americas are well discussed and documented (Kelly, 1980), there is little about the sequence of forming steps employed in the production of Capacha pottery. A reconstruction of these steps would allow a technological (and more socially meaningful) comparison of Capacha pottery with the pottery complexes to which is supposedly related.

In this study, the techniques used in forming Capacha pottery are being reconstructed using a variety of analytical approaches that aim to highlight diagnostic attributes of such practices, including surface morphology and topography, joints between segments, specific fractures, and alignments and orientations of voids and inclusions (Thér, 2020). The set of samples analyzed here consists of several pottery fragments or sherds of variable size selected from the archaeological material recovered at Las Fuentes, the largest Capacha site known to date (Colima, western Mexico). Selected either because they seemed to macroscopically show different marks (macrotraces) of forming practices, or at least the potential to observe them once analyzed at a different level or scale, the surfaces, profiles, and internal structures of these potsherds were then qualitatively analyzed by a variety of 2D and 3D imaging methods and techniques, including X-radiography (Berg & Ambers, 2016). Finally, this work also discusses what this new evidence of pottery-forming techniques tells us about the organization of Capacha pottery production and the extent of pottery technological knowledge transfer within Capacha society.

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## PRELIMINARY STUDY ON LATE ROMAN POTTERY FROM KYPARISSIA, PELOPONNESE, GREECE

VALANTOU V.<sup>1,\*</sup>, PALAMARA E.<sup>1</sup>, ZACHARIAS N.<sup>1</sup>

<sup>1</sup>Laboratory of Archaeometry, Department of History, Archaeology and Cultural Resources Management, University of the Peloponnese, Greece

\*[celiasitia@gmail.com](mailto:celiasitia@gmail.com)

Keywords: Late Roman pottery, Kyparissia, analytical techniques

Pottery is one of the most important indicators of economic activity for antiquity. Due to the good preservation of ceramic products in burial conditions, the continuous transformation of the typology of clay vessels and the abundance of material in the excavation assemblages, ceramics constitute a major cultural indicator, revealing trade transactions and cultural contacts between regions, projecting the daily habits, the social status and well-being of the inhabitants, highlights the technological developments in the production of goods. Therefore, the study and understanding of ceramic assemblages becomes essential in archaeological research.

This study focuses on the archaeological and archaeometric preliminary study of Late Roman pottery from Kyparissia, Messenia, in the Peloponnese prefecture, Greece. Kyparissia, built on the coast of Western Messenia, in the bay of the same name, was from ancient times an important port and hub between the West and the East, with increased activity during the Hellenistic, Roman and Late Roman periods, when trade routes oriented towards West. The rescue excavations in plots and streets of Kyparissia from the beginning of the 20th century until today brought to light construction remains of private and public buildings, parts of the Hellenistic and Roman cemetery of the city, with rich finds (ceramics, coins, statues, marble architectural remains, mosaic floors, etc.) that demonstrate the importance and prosperity of the city, which extends from the coastal front to the lower part of the medieval castle. Late Roman pottery has been the subject of intensive study in recent decades with the shift of archaeological research to the study of everyday life and the utilitarian objects that surround it. However, in many areas of Greece it has not yet undergone a thorough archaeological and archaeometric study, therefore the need for investigation and documentation of local producers and the imported products of important centers is considered essential. From the area of Kyparissia no ceramic assemblage of the period has been studied and published, so this gap will be partially filled by this ongoing project. The material under study comes from rescue excavations carried out by the Ephorate of Antiquities of Messenia in 2006 and 2007, in the city of Kyparissia, specifically in a plot in Mousga, an area with abundant residential remains, and a second plot in the southeast of the railway station. In both cases, the residential remains date from Hellenistic times to the Late Roman period (Archaologikon Deltion 2006; 2007; 2010). Here we present the preliminary results of the technological analysis of an assemblage of fine and coarse ware vessels, selected as typologically representative of the later residential phases, in order to investigate technological choices and address provenance issues, as no pottery material has ever been studied in the area. A combination of optical microscopy (OM), petrography analyses (PA) and Scanning Electron Microscopy coupled with Energy Dispersion X-ray Analysis (SEM/EDS) techniques has been used for their mineralogical and chemical characterization. Different fabrics were identified, and an effort was made to find correlations between them and the different types of pottery. Various technological parameters (such as the presence of slip, mixing of clays, addition of temper, firing conditions, etc.) were examined. Finally, a preliminary evaluation of their origin was undertaken with particular emphasis in the identification of imports from significant nearby centers, such as Western Peloponnese and the Southern Italy (Berlin & Heath, 2005).

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## EXPLORING EARLY MEDIAEVAL CYPRUS THROUGH ITS COOKING POTS. SOME PRELIMINARY REMARKS.

VASILEIOU T.K.<sup>1,\*</sup>, VIONIS A.K.<sup>1</sup>

<sup>1</sup>Department of History and Archaeology, Archaeological Research Unit, University of Cyprus, Cyprus,

[\\*vasileiou.theodoros@ucy.ac.cy](mailto:vasileiou.theodoros@ucy.ac.cy)

Keywords: cooking vessels, petrography, early-mediaeval Cyprus

The early mediaeval times in Cyprus are signified, conventionally, by the Arab invasions of the mid-7<sup>th</sup> century (649/650) (Metcalf, 2009). Past research saw those events as the catalyst which led to a “transformation” from a prosperous province to a marginal territory struggling to balance between two antagonising empires (Stewart et al., 2014). In the last decades, studies have shifted their focus on the reassessment of the scant, yet present, material culture of this period (Gabrieli, 2020; Vionis, 2020, 2023). In pottery studies, despite the advance in typological and distribution aspects, few studies have explored technological issues of early-mediaeval ceramic production such as fabric variability, continuity or technological transitions through instrumental analysis (Manning et al., 2002; Rautman et al., 2003; Gabrieli, 2006; Vionis, 2020).

This study focuses on the compositional and technological characterisation of cooking vessels typically found in relevant contexts in Cyprus, representing both wheel-thrown (mainly the Dhiorios type cooking pot) and handmade traditions (hand-built or on the turntable). Petrographic analysis on samples coming from four major early-mediaeval sites of the island, showed a variety of local clays for the production of handmade vessels and vessels built on the turntable, and both local and alien -to Cyprus- fabrics for the production of “shared” cooking wheel-thrown vessel types found across the island and beyond, supporting the already proposed idea of a ceramic koine persisting through the beginning of the Byzantine Early Middle Ages on an intra and inter-regional level (Vionis, 2020). As part of a wider project focusing on early-mediaeval ceramics in the Eastern Mediterranean (PlaCe-ITN MSCA), this study aims to contribute to the ongoing research effort of re-evaluating Byzantine Early Middle Ages in Cyprus.

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## S6. Theory and Methods

### REPRESENTATIVENESS OF A CERAMIC ASSEMBLAGE - SIGNIFICANCE AND CONFIDENCE IN RELATION TO SAMPLE SIZE

HEIN A. <sup>1,\*</sup>, BUXEDA I GARRIGÓS J. <sup>2</sup>, KILIKOGLU V. <sup>1</sup>

<sup>1</sup>Institute of Nanoscience and Nanotechnology, N.C.S.R. "Demokritos", Attica, Greece

<sup>2</sup>Material Culture and Archaeometry UB (ARQUB), Dept. of Histor and Archaeology, University of Barcelona, Spain

[\\*a.hein@inn.demokritos.gr](mailto:a.hein@inn.demokritos.gr)

Keywords: compositional variation, representativeness, sampling strategy

Ceramic objects, such as pottery vessels, ceramic tools or construction parts, are typically among the most common finds in an archaeological excavation. Their analytical examination provides manifold information about the character of a specific site, about cultural, economic or political relations among sites and about technological issues taking into account manufacturing technology, function and use of the ceramics.

A large part of the research is based on the assumption that for ceramic manufacture at a specific production place, and an individual clay paste was used, which was prepared and processed from raw materials collected from the vicinity of the workshop. The hypothesis that raw materials from different natural sources can be distinguished in terms of their composition implicates the potential for determining a compositional reference pattern/group which defines the origin of production of a particular group of ceramics. The origin of production can refer to an individual pottery workshop operated during a limited time period, it can refer to a pottery production site active during different periods using the same raw material source, or it can refer to an entire area or region with access to raw material sources within a specific geological context. The spatial and chronological extension of the presumed origin of production affects the compositional variation, which can be expected for ceramics.

The potential scope of an analytical ceramic case study is the categorization of an assemblage according to different compositional groups. The compositional patterns of the groups can be further investigated in terms of similarity or dissimilarity to reference patterns of production places in question in order to verify their origin. A reference pattern, however, is not a distinct 'fingerprint' but essentially an estimation of the average composition of ceramics manufactured at a particular place from a specific clay paste prepared in a more or less consistent process. In order to estimate the average composition of an individual category of ceramics and to assess its variation, it is, thus, necessary to analyze a sufficient number of samples. These are selected commonly from individual ceramic assemblages discovered at archaeological sites keeping in mind the character of the site, the state of preservation and pre-selection based on particular interest and preferences.

The present paper will discuss the representativeness of ceramic analyses with regard to the number of samples and the sampling strategy taking into account the expected variation due to natural variation of raw materials as well as variation in clay paste processing and preservation.

## NEUTRON ACTIVATION ANALYSIS OF ARCHEOLOGICAL CERAMICS: AN APPROACH TO CREATION OF REFERENCE GROUPS

BADAWY W.<sup>1-2,\*</sup>, DMITRIEV A. YU<sup>1</sup>, KOVAL V. YU.<sup>3</sup>

<sup>1</sup>Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, Dubna, Russian Federation,  
<sup>2</sup>Radiation Protection and Civil Defense Department, Nuclear Research Center, Egyptian Atomic Energy Authority, (EAEA),  
Abu Zaabal, Egypt <sup>3</sup>Institute of Archeology of the Russian Academy of Sciences, Russia

\*[wael@jinr.ru](mailto:wael@jinr.ru)

Keywords: Neutron activation, archaeological ceramics, multivariate statistics

The present work was carried out to apply instrumental neutron activation analysis (INAA) and multivariate statistical methods in determining the distribution patterns of elemental composition in archeological ceramics with respect to their classification and provenance.

A total of 48 archeological samples of selected types were studied, originating from different sites in Russia. The distribution of trace and major elements was analyzed to evaluate the origin of the samples and to compare the results of this study with those of previous investigations conducted by other groups using different methods. The results of study revealed that the use of INAA and other related analytical methods can be a valuable complementary tool for the analysis of archeological artifacts to understand their historical background and to obtain reliable information about their origin. The concentrations of 37 elements (mg/kg) were determined. Multivariate statistical analysis was performed to classify the archeological ceramics according to their origin. The relevant statistics show that the chemical composition of the analyzed ceramics is significantly different according to the origin of the samples. Based on these results, three main reference groups of archeological pottery can be distinguished. To identify the importance of the elements, a machine learning method was applied.

The results show that Cr was the most important element associated as a fingerprint with the origin of the ceramic products. These reference groups serve as baseline data for determining the fragments' place of manufacture and are considered reasonable judgments based on experimental data.

## ARCHITECTURAL AND HYDROGRAPHIC REUSE OF CERAMICS IN LATE ANTIQUITY ASCALON

EHRlich S.

Fulbright U.S. Scholar Program & The Leon Levy Expedition to Ashkelon & The Hebrew University of Jerusalem, Institute of Archaeology & The W.F. Albright Institute for Archaeological Research, [simeon.ehrllich@gmail.com](mailto:simeon.ehrllich@gmail.com)

Keywords: Late antiquity, reuse, architectural ceramics

This paper investigates the secondary usages of ceramic vessels as building materials at the Levantine port of Ascalon (modern Ashkelon, Israel) during the Roman and Byzantine periods (c. 63 BCE-640 CE). It argues that particular kinds of vessels underwent certain kinds of transformations and were used for specific architectural purposes. Nevertheless, such finds were noted as transition style during the field campaigns of the Leon Levy Expedition to Ashkelon (1985-2016), the material still remains poorly understood. Each find received little study after initial discovery and no full synthesis of this material has yet been attempted.

All vessels discussed herein have undergone “Type C” reuse as per the categorization of Peña 2007; that is to say, they have undergone physical modifications and have been put to uses qualitatively different from their original functions. At issue are questions of type, context, function, and chronology: What kinds of reuses and modifications do we see? In what kinds of buildings and which parts thereof are ceramic vessels being employed as construction materials? Why are these repurposed ceramics being chosen instead of more traditional building materials? Are there discernible trends over time that can be seen for modifying the ceramics in this way?

The present study presents a typology of ceramic containers in secondary usage at Ascalon sawed-off LR4 amphorae which were used in hydrological/agricultural installations; Phocaeen red slip ware rim sherds set in plaster subflooring; and storage jars sherds, cut to standard size and arranged in herringbone tessellations as flooring and attempts to identify the chronological and contextual parameters under which each type would appear.

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## INVESTIGATING POTTERY FORMING TECHNIQUES THROUGH THE APPLICATION OF NON-DESTRUCTIVE SMALL-ANGLE NEUTRON SCATTERING (SANS)

GAIT J.<sup>1,\*</sup>, BAJNOK K.<sup>1</sup>, HUGOT N.<sup>2</sup>, PÉPY G.<sup>3</sup>, LEN A.<sup>1</sup>  
<sup>1</sup>Neutron Spectroscopy Department, Centre for Energy Research, ELKH, Hungary  
<sup>2</sup>ENSTA Paris- Institut Polytechnique de Paris 3 Independent researcher, France

\* [john.gait@ek-cer.hu](mailto:john.gait@ek-cer.hu)

Keywords: Small-angle neutron scattering, pottery forming techniques, non-destructive analysis

This study introduces small-angle neutron scattering (SANS) as a method for the non-destructive analysis of primary forming techniques in archaeological pottery. By measuring the magnitude and direction of anisotropy in 2D neutron scattering within a specified volume of a sample, the aggregated (or “preferential”) orientation of nano-scale objects (*i.e.* particles/voids) can be measured, which in turn can be correlated with categories of forming techniques.

Previously, some studies of forming techniques utilizing the orientation of objects (e.g. by X-ray microtomography or optical microscopy), have tended to rely on observing comparatively large objects (*i.e.* mm scale), and therefore have often been restricted to coarse-textured wares. However, the small size of the objects that cause small-angle scattering, c. 1-100 nm, suggests that SANS may be able to detect preferred orientations within the clay-sized fractions, and therefore may be suitable for examining both coarse and fine-textured wares.

To demonstrate the application of SANS, results are presented from extensive studies of experimental pottery, utilising a range of fabrics, forming techniques and firing temperatures, together with 2D and 3D modelling. In these experimental studies, fine-textured wheel-thrown vessels can be differentiated from wheel-shaped (*i.e.* coil-built + wheel-turned) and coil-built vessels through the mean angle of inclination of the objects.

Further results are also presented from a case study of late Roman/early Medieval pottery from the former Roman province of Pannonia, western Hungary. In this period, the disintegration of Roman administration was resulted in profound political and economic transformations.

Although a significant decrease in long-distance pottery distribution, and the emergence of more local/regional production are hypothesized. Consequently, the more technological aspects of these changes, including archaeological science analysis of the applied forming techniques have not been studied before. In this first case study we successfully use non-destructive analysis by SANS to identify the forming techniques of a series of c. 4<sup>th</sup>-6<sup>th</sup> vessels.



## IDENTIFYING THE USE OF IRON AGE POTTERY FROM TEPE SAGZABAD (IRAN): RESULTS FROM THE FIRST ANALYSIS OF POTTERY RESIDUES

GHALEH M.<sup>1,\*</sup>, EFTEKHARI N.<sup>1</sup>, DEPAHLAVAN M.<sup>2</sup>, MARROCCHINO E.<sup>1</sup>, VACCARO C.<sup>1</sup>

<sup>1</sup>Department of Environmental and Prevention Science, University of Ferrara, Italy

<sup>2</sup>Department of Literature and Human Sciences, University of Tehran, Iran

\*[monabagheri077@gmail.com](mailto:monabagheri077@gmail.com)

Keywords: Tepe Sagzabad, distillation apparatus, SEM-EDS

The Qazvin plain located in the northwestern part of the central plateau of Iran. Three major prehistoric sites (Tepe) lie on the plain: Zagheh, Ghabristan, and Sagzabad. The site of Tepe Sagzabad includes the most important evidences from the Bronze Age to the Iron Age III or even the historical period and was also located along the main eastern-western trade route on the Iranian Plateau. One of the main objectives of the recent excavations at this historical site, was to focus on the intact Iron Age III in this site, and to learn more about the condition of these layers. 2.5 hectares of geophysical surveying were completed prior to excavation. Thereafter, the trenches 5 and 6 were opened. Trench 6 was started at a size of 3 x 10 meters and following the appearance of the architectural features, it was extended to the dimensions of 12 x 5 meters. The context associated with a kiln structure (6006 and 6004) which was found in the east and center of this trench in different dimensions. Both structures are similar, and traces of heat are obvious in their context and sections. These two structures were filled with diverse accumulations. Within the studied context (6006), there was an assemblage of heated soils, ash, and veins of charcoal in orderly and layered manner. To determine the function of this kiln, other special finds in trench 6 were examined. The large, extraordinary oval-shaped pottery was identified in this context 6006, but unfortunately, the lower part of the object has been destroyed, though possibly the whole vessel could be 75 cm high.

The difference between this pottery and other pottery was its unusual form. The closed-head form of pottery (knob-shaped) with two handles evokes a pot lid, and a hole (5 cm) is set in the center of the upper part to be used as a spout and possibly a reed as a tube. The shape and size of this unusual pottery and the position of the spout allow assuming that to work as a traditional alembic, comparable to the modern from copper made versions. In particular, the comparison with the Iranian tradition at the rosewater festival, which still uses similar equipment to extract rosewater and essential oil, made possible the function of this extraordinary pottery as part of a distillation apparatus. Moreover, findings from Assyrian seals in the Segzabad site indicate cultural interaction between these two regions and it can be assumed that ancient knowledge such as distillation came to this region from Mesopotamia.

To preliminarily investigate and identify the application of this pottery, five powdery samples were taken from the inner and from lower part of the pottery. Based on the results obtained from microscopic observations, SEM-EDS analysis and micro-Raman spectroscopy studies, this study will provide information that can be used to identify the residue inside the pottery and also its possible application.

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## THE ARCHAEOOMETRY OF CERAMICS: A QUANTITATIVE REVIEW OF THE LITERATURE BY BIBLIOMETRIC

GRIFA C.<sup>1-2,\*</sup>, GERMINARIO C.<sup>1</sup>

<sup>1</sup> Department of Science and Technology, University of Sannio, Italy

<sup>2</sup> C.R.A.C.S., Center of Research on Archaeometry and Conservation Science, Naples, Italy

\*[celestino.grifa@unisannio.it](mailto:celestino.grifa@unisannio.it)

Keywords: Archaeometry, bibliometrix, quantitative bibliometrics, archaeological ceramics

Archaeological ceramics are undoubtedly the most studied archaeological material due to the several pieces of information kept in a single or a group of objects. Most of this information can be disclosed by applying scientific analytical techniques.

Various analytical approaches involving STEM disciplines have been explored so far to respond to general and specific archaeological demands, such as provenance, technology, and application. All the scientific interest in such a fascinating material has flowed into a vast literature available on the most diffused scientific database (WoS, Scopus, etc.). However, a large part is also grey literature published in books and conference papers with limited diffusion.

This contribution aims to carry on an extensive quantitative bibliometric analysis of what can be called the “archaeometry of ceramics” strand of literature, with the aim to quantify the research field, snapshot trends of research themes over time, identify the different disciplines involved, map of scientific collaboration among scholars and institutions and the research-front of scientific domains.

A first attempt at applying bibliometric methods to the archaeometry of ceramics was carried out by Peña-Poza and co-authors with the paper “The archaeometric study of ceramic materials in JCR journals and conference proceedings during the last decade (2000-2010)”. It found some primitive indications concerning high level of interdisciplinary and a major contribution by authors from Europe and the USA were emphasised. However, the time span and source considered were limited.

In the present study, data were extracted from Scopus, inserting the keywords potter\* OR ceramic\* AND archaeolog\* AND analy\* in the string “Title, Keywords and Abstract”. The query was launched on 25 January 2023 and rendered 4097 documents. Worth to note that some filtering criteria were included, that is, language (only English) and type of documents (articles and books). So, conference papers and book series were excluded. The analysis was performed via Bibliometrix, an open-source software for automating data analysis and visualisation stages.

The first appearance of a document with the searched keywords is dated back to 1933 by Forster W. in the Journal of Chemical Education; however, a significant scientific production only started in the late 90s; in 2007 in which more than 100 articles were published, and the maximum was reached in 2021 with 320 documents.

The scientific production involves 10190 authors with 0.402 documents per author and 2.49 authors and 3.75 co-authors per document; the sources (journals and books) are 904. The authors and source’s data highlighted the high fragmentation of scientific production due to the multidisciplinary nature and the several scientific fields involved in this topic. However, core sources can be identified regarding H-index, total documents and total citations: Journal of Archaeological Science and Archaeometry plays the most significant role, although the source dynamics also highlight an important contribution of Journal of Archaeological Science Reports since 2013.

The most productive country is the USA with 2010 documents; nevertheless, scientific production is strongly polarized in Europe with Italy (1123 docs), the UK (901), Spain (717), France (503), and Germany (464); China has produced 370 documents.

Considering single authors’ performance, in most global and local cited documents, a wide separation can be observed in the whole data set, the most cited and most productive authors work in the field of organic residues analyses with performances up to 30% higher than average author’s production and H-index up to 50% higher than

other authors. This also signs a sharp division in the conceptual structure of the field, which highlights the topics covered by scholars and what are the most important issues. Co-word analysis, visualized through trend topics diagrams and thematic maps, showed that archaeometry of ceramics has strictly followed advances in technologies and analytical approaches. In particular, if considered in specific time frames, the evolution of peculiar themes from emerging to basic, as in the case of petrographic and mineralogical methods, was demonstrated. Former niche themes have become motor or basic themes, as in the case of residue analyses.

The analysis of the social structure, *i.e.* the co-authorship networks, points out a strong fragmentation in small groups of scholars with long-lasting collaboration. Finally, the intellectual structure expressed by the co-citation analysis highlighted that few discrete clusters of papers express the ceramic topics' fundamental theories and methodological schemes.

All these arguments are essential not only for mapping the research but also for feeding the debate, even in the EMAC community, for opening and inspiring new research trends (particularly for early-stage researchers), good policy-making and the practice of science.

## COMPARISON OF RAPID PREPARATION METHODS FOR LEAD ISOTOPE ANALYSIS OF HIGH-LEAD CERAMIC GLAZES – A CASE STUDY OF THE LATE MEDIEVAL ‘BESZTERCEBÁNYA/BANSKÁ BYSTRICA-TYPE’ STOVE TILES

HORVÁTH A.<sup>1-2</sup>, BAJNÓCZI B.<sup>3, \*</sup>, GYÖRKÖS D.<sup>1-3-4</sup> & PALCSU L.<sup>1</sup>

<sup>1</sup>Isotope Climatology and Environmental Research Centre (ICER), Institute for Nuclear Research, Hungary

<sup>2</sup>University of Debrecen, Doctoral School of Physics, Hungary

<sup>3</sup>Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungary,

<sup>4</sup>Laboratory for Applied Research, Hungarian National Museum, Hungary.

\*[bajnoczi.bernadett@csfk.org](mailto:bajnoczi.bernadett@csfk.org)

Keywords: High-lead glaze, lead isotope analysis, stove tile

A unique collection of high-quality late Medieval (15-16th century) so-called ‘Besztercebánya/Banská Bystrica-type’ stove tiles were excavated in the northern part of the Carpathian Basin and its surroundings, in the present-day Hungary, Slovakia and the Czech Republic. A systematic archaeometric research was recently performed to determine the raw materials and production technology of the ceramic body and the high-lead glaze of the tiles. One hundred and twenty tile fragments found at seven archaeological sites were classified into three groups indicating that the stove tiles were produced in at least three different workshops in the region: (1) tiles from Besztercebánya/Banská Bystrica (Slovakia), (2) tiles from Eger, Salgó, Szécsény (northern Hungary) and Fülekk/Fil’akovo (Slovakia), and (3) tiles from Csábrág/Čabrad’ and Ipolyság/Šahy (Slovakia).

In this research we determined the lead isotope composition of the tile glazes with the aims to identify the provenance of lead flux used in the production of the glaze of stove tiles and to elaborate and evaluate a fast preparation processes to measure lead isotope ratios in high-lead glazes.

From methodological point of view, we have compared three different methods of preparation. Method-1 consisted of the dissolution of bulk chips of glaze, dilution of the solution and mass spectrometer analysis without lead purification. Method-2 collected the lead from the surface of the glaze with acid-impregnated swabs, subsequent dilution and direct analysis of the sample solution. Method-3 utilized solutions from method-1, extraction of lead by ion-exchange chromatography and analysis of the purified lead. Results were demonstrate that the lead isotope ratios are independent of the preparation methods used. Therefore, we recommend using the simplest method of surface sampling of high-lead glazes with swabs (method-2). It is a fast procedure that requires less effort in the laboratory with the benefit of preserving the integrity of cultural heritage objects.

Regardless of the archaeological site, most of the tile glazes form one group based on their lead isotope ratios. Comparing lead isotope ratios of the tile glazes with the lead isotope ratios of the lead ores shows a strong overlap with the lead ore deposits of the Krakow-Silesia mining region. Lead imported from Poland was used in the liquation process to separate silver from the copper ore mined in the territory of the Slovak Ore Mountains, and it seems that Polish lead was also involved in the preparation process of the glazes of most of the stove tiles analysed. The lead ore locally mined in the Slovakian Ore Mountains may have been used, possibly mixed with Polish lead, only for the green glazes of some Csábrág/Čabrad’ and Ipolyság/Šahy tiles. The lead isotope ratio of some of the tiles excavated in Eger is similar to the lead isotope data of the Triassic Bleiberg-type lead-zinc ore deposits indicating a potential use of lead imported from Austria.

## DISCOVERING PEOPLES, CULTURES, AND TECHNOLOGIES: DEVELOPMENT OF A NON-INVASIVE APPROACH ON S'ARCU 'E IS FORROS AMPHORA (SARDINIA)

MORABITO G.<sup>1,\*</sup>, MARINONI N.<sup>1</sup>, COLOMBO C.<sup>2</sup>, CATRAMBONE M.<sup>2</sup>, PEDRAZZI T.<sup>2</sup>, GATTA G.D.<sup>1</sup>

<sup>1</sup>Dipartimento di Scienze della Terra A. Desio, Università degli Studi di Milano, Italy

<sup>2</sup>Istituto di Scienze del Patrimonio Culturale (ISPC) Milano- Consiglio Nazionale delle Ricerche (CNR), Italy

\*[giulia.morabito@unimi.it](mailto:giulia.morabito@unimi.it)

Keywords: Non-invasive, pXRF, XRD

Archaeological ceramics are among the most investigated and studied samples in the field of archaeometry. The reason for this is that they hold a huge amount of information by means of which it is possible to reconstruct the cultural and technological context of the artifact's production. On the other hand, however, studying ceramic artifacts very often requires an invasive and destructive approach, compromising the study of all those artifacts that are musealized and of high archaeological and artistic value. In order to overcome these limitations, this study aims to provide a multi-analytical and non-invasive protocol applied on an eastern-sourced amphora to allow the full characterization of the ceramic body.

S'Arcu 'e is Forros amphora is an artifact found in the territory of Villagrande Strisaili (NU) (Archaeological context dated back to XII-VII sec. B.C.), at the foot of Gennargentu mountain, during the 2011 archaeological excavation campaigns. Some amphora's fragment, unused for its restoration, were employed for preliminary conventional invasive analysis, such as Optical Microscopy on petrographic thin-section under the polarised light, X-Ray powder diffraction with Rietveld full-profile fit to the diffraction pattern (in order to provide quantitative phase analysis), textural and chemical investigations with Scanning Electron Microscopy (SEM-EDS, EPMA-WDS) and benchtop XRF.

Here we present some preliminary and comparative data obtained by non-invasive analytical techniques, such as XRD and pXRF analysis without any sample preparation, with the purpose to evaluate reliability and validity of the experimental data when compared with the results obtained applying invasive techniques on the same sample, and then to set-up the procedure for establishing a final non-invasive analytical protocol.

The present work is part of a larger project aimed to consolidate the use of a multi-methodological approach to provide valuable information on production, trade and technology of ceramics in ancient societies, offering a valuable tool for archaeologist and conservation scientists to approach the Past minimizing the manufactures damages.

## TOWARDS REALISTIC PHASE ANALYSIS OF LOW-FIRED CERAMICS: NEW EXPERIMENTAL AND MICRO-ANALYTICAL APPROACHES

NICKEL K.G.<sup>1,\*</sup>, FLICKER A.<sup>1</sup> & BERTHOLD C.<sup>1</sup>

<sup>1</sup>Competence Center Archaeometry-Baden Württemberg, Eberhard-Karls-Universität Tübingen, Germany

\*[klaus.nickel@uni-tuebingen.de](mailto:klaus.nickel@uni-tuebingen.de)

Keywords: Firing, gradients, high-resolution profiles

In many ancient firing techniques with maximum temperatures up to 1000°C the problem of gradients in temperature and atmospheric conditions within the firing place as well as inside the ceramic is well known.

Following the arguments of Maggetti et al. (2011) the prediction of firing temperatures from phase assemblages in experimental tests are not always successful and theoretically difficult because of a multitude of influencing parameters (T, PO<sub>2</sub>, grain size, porosity, soaking time, changes in thermal conductivity during firing; Drebuschak et al., 2018). Therefore, we aim to develop a methodology to improve the investigation of the microstructure of heterogeneously fired ceramics.

The procedure presented here focusses on modern m-XRD<sup>2</sup> analytics capable of realizing spot sizes with a few tens of mm, to perform a high-resolution phase mapping of a profile from the outside to the core of a ceramic. We consider this to be an improved approach beside petrographic analytics with its optical limitations to obtain a more detailed identification of the phases and phase transformations from a particular zone in the fired ceramic. Naturally other microanalytical techniques (μ-Raman, μ-FTIR, μ-XRF) can be combined with this investigation.

Experimentally we aim to determine the true temperature distribution during the firing from thermocouples not only in the furnace but also located at the surface and inside the ceramic samples. Ceramic blocks of varying sizes and raw materials are then subjected to a set of firing conditions. Subsequently cross sections are prepared and analysed.

In our presentation we present the first results. Further improvements are envisaged by the use of in-situ balance furnaces with controlled atmospheric conditions. The obtained cut blocks are also considered to be a good material to investigate the alteration of heterogeneous fired ceramics due to storage and reaction with burial environments.

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## CERAMIC CHRONOLOGY BY LUMINESCENCE DATING - A TOOL FOR A BETTER UNDERSTANDING OF INFILL DYNAMICS IN NEGATIVE ARCHAEOLOGICAL STRUCTURES

RODRIGUES A.L.<sup>1,\*</sup>, MARQUES R.<sup>1,2</sup>, DIAS M.I.<sup>1-2</sup>, PRUDÊNCIO M. I.<sup>1</sup> & VALERA A.C.<sup>3-4</sup>

<sup>1</sup>Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>2</sup>Departamento de Engenharia e Ciências Nucleares (DECN), Instituto Superior Técnico, Universidade de Lisboa, Portugal

<sup>3</sup>ERA Arqueologia S.A., Portugal

<sup>4</sup> Interdisciplinary Center for Archaeology and Evolution of Human Behavior (ICArHEB), Universidade do Algarve, Portugal

\*[alsr@ctn.tecnico.ulisboa.pt](mailto:alsr@ctn.tecnico.ulisboa.pt)

Keywords: Luminescence Dating; infill dynamic; Negative archaeological structures

The fill dynamics in negative archaeological structures is an important source of debate among the archaeologist's society. To better establish the filling process, this work contributes with new information, complementing the dosimetry and dating studies by luminescence on sediments with the luminescence dating of ceramics. Infill materials from a Perdigões ditch were addressed as a case study. Perdigões site is one of the most important Chalcolithic/Bronze Age sites of the Southwest Iberia, comprising a set of ditched enclosures and several hundred circular pits excavated in the diorites and gabbros of the Reguengos de Monsaraz massif.

In general, the archaeological records and the absolute chronology show that Perdigões was a site of long duration, beginning in the late Middle Neolithic and reaching the transition Chalcolithic/Bronze Age. The studied ditch (ditch 6) is attributed to Late Neolithic and the infill sequence comprises fine layers of weathered materials from the geological background, some of them with high calcite content and evidence of natural "slope wash" events. Luminescence protocols, using optical and thermal stimulation, were applied to the quartz coarse grains extracted from the ceramic paste in order to evaluate the absorbed dose. For the estimative of the age, the dose rate was achieved based on the contents of K, Rb, Th and U, obtained by instrumental neutron activation analysis (INAA) and in situ gamma spectrometry. Complementing the luminescence dating, compositional studies were performed by INAA and the determination of mineralogical composition by X-ray diffraction.

In the present study, the single aliquot regenerative optically stimulated luminescence protocol was the most suitable protocol to achieve the absorbed dose for luminescence dating, due to the lower uncertainties obtained. Additionally, it is not evident an increase of the determined luminescence age with depth. The mineralogical composition comprises, in general, phyllosilicates and quartz as main minerals, associated with plagioclase, K-feldspars and amphibole. Regarding the chemical composition, the main differences observed between samples are the chemical contents of Rb, Cs, Ba, Lu, Ta and W that allows some differentiation of samples from different stratigraphic units.

Combining the compositional and chronological studies performed, it is possible to reinforce the idea that after the ditch abandonment in late Neolithic, it was filled with older materials, as previously observed by the sediment's analysis. The infill process could have occurred by natural/anthropic events, with no sufficient time to clear the old luminescence signal (relatively fast event), interfering in the luminescence measurements of the chronological sequences of the deposited materials.

## WHAT HAS P-XRF EVER DONE FOR US?! HOW STATISTICAL PROCEDURES CAN HELP TO OVERCOME PREJUDICES AGAINST AN ANALYTICAL METHOD

SCHAUER M.

Dept for Cultural Studies and Antiquity at Ludwig-Maximilians-Universität Munich, Near Eastern and Prehistoric Archaeology, Germany, [m.schauer@campus.lmu.de](mailto:m.schauer@campus.lmu.de)

Keywords: p-XRF, precision, accuracy

Portable energy dispersive X-ray fluorescence (p-XRF) is viewed with great suspicion in archaeology. This is especially true when it is applied to very inhomogeneous materials such as pottery, despite the fact that its potential for insight into recipes and origins of pottery is well known. The greatest criticism relates to the assumed low precision and accuracy of the method - the validity of the results produced with p-XRF is therefore often doubted.

New, extensive studies have shown that with the help of statistical procedures and the setting of empirically determined threshold values, both criteria can not only be defined more precisely, but for the first time also enable exact comparisons of these categories between devices and with laboratory methods.

This talk will therefore describe in more detail how, in the eyes of the presenter, coefficients of variation, nominal values, standard deviations, coefficients of determination, (relative) standard errors of the estimates and bootstrap algorithms can also contribute to the (so far mostly missing) definition of precision and accuracy of the p-XRF method as well as to the improvement of its accuracy. Looking further ahead, the application of the here presented procedures by other specialists can be an important cornerstone for a new perception of the method in the archaeological community and also considerably increase its significance and relevance for studies on ancient pottery.

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## **SAMPLE PREPARATION FOR NEUTRON ACTIVATION ANALYSIS - PITFALLS AND BEST PRACTICES**

STERBA J.H.<sup>1,\*</sup>, NEMETZ M.<sup>1</sup>, FOSTER M.<sup>1</sup>

<sup>1</sup>Center for Labelling and Isotope Production, TRIGA Center Atominstitut, Austria

\*[johannes.sterba@tuwien.ac.at](mailto:johannes.sterba@tuwien.ac.at)

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Neutron Activation Analysis (NAA) is a well-established technique for the bulk-chemical analysis of archaeological ceramics for the purpose of establishing provenance. Following the generally accepted idea that the elemental concentration pattern measurable by NAA is indicative of the production center, it is very important to perform the analysis as cleanly and reproducible as possible.

As is the case with any type of analytical procedure, no matter how well the methodology works, if the sample introduced is for some reason faulty, the results will be unusable at best and misleading at worst. Thus, well performed sample preparation is extremely important.

The most impactful mistakes possible during sample preparation for NAA are:

- contamination (with other samples or sampling tools)
- representativeness.

At the Center for Labelling and Isotope Production (CLIP), 5-600 samples are measured by NAA each year, and NAA has been performed at CLIP for more than a decade. Common pitfalls and best practices as they are implemented will be discussed and illustrated with several examples.