PIMS is a radiocarbon measurement technique designed to remove complexities and reduce instrument size common to traditional AMS.

A PIMS system utilizes a plasma source of positive ions that is capable of very large ion beam production. PIMS combines the anion formation and molecule destruction in a thick-isobutane open-ended gas cell that replaces the particle accelerator of AMS.

**Advantages:**
- No Accelerator
- No Graphitization
- No waiting (fast startup)
- No Cesium
- No Cathodes

Visit the NEC booth for more information on PIMS and other NEC products.
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## Table of Contents

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Committees

Meeting Co-chairs
Alex Cherkinsky
Carla Hadden
Jeff Speakman

Conference Coordinator
Justin Cramb

Program Coordinator
Katherine Reinberger

Fundraising Committee
Victor Thompson (chair)
Amanda Thompson

Hospitality Committee
Jennifer Birch (chair)
Kathy Loftis
Travis Jones
Samm Holder

Volunteer Coordinators
Megan Conger
Matthew Colvin

At Large Members
Ravi Prasad
Suzie Birch

Scientific Committee
Stan Ambrose
Dave Anderson
Elisabetta Boaretto
Lucio Calcagnile
Carley Crann
Brendan Culleton
Michael Dee
Nora Franco
Irka Hajdas
Christine Hatté
Tim Jull
Bob Kelly
Sturt Manning
César Méndez
Philip Naysmith
Hans Van der Plicht
Pavel Povinec
Andrzej Rakowski
Paula Reimer
Torben Rick
Guaciara Santos
David Hurst Thomas
Noreen Tuross
Lukas Wacker
Elya Zazovskaya
Antoine Zazzo
Great Research Begins with Exceptional Data

- AMS Radiocarbon Dating
- C, H, N, O, S Isotopes
- XRF Core Scanning
- ICP-MS & ICP-OES
- Sr & Pb Isotopes
- ED-XRF & PXRF
- LA-ICP-MS

UNIVERSITY OF GEORGIA
Center for Applied Isotope Studies
cais.uga.edu
Providing Radiocarbon Dating Since 1968
Meeting Venues

Downtown Athens, Georgia, USA

Known as “the Classic City,” Athens, Georgia has a rich history dating back to the 18th century. A college town built in concurrence with the University of Georgia, Athens is often viewed as the educational and intellectual center of the US south. In addition to its ties to the university, Athens is known for its historic downtown, famed music scene, and eclectic dining options.

The 2019 Radiocarbon and Archaeology Symposium will be held in beautiful and historic downtown Athens Georgia. All presentations will be held at the Athens Classic Center. Lunches on Monday, Tuesday, Thursday, and Friday will be held at the Blind Pig Tavern. The Sunday Evening Ice-Breaker Reception will be held at Creature Comforts Brewery. Downtown Athens abuts the University of Georgia campus and offers dozens of restaurants, shops, and bars where everyone can find something to enjoy.
Meeting Venues

The Classic Center

The Classic Center is northeast Georgia’s premier award winning convention center and performing arts theatre. Located in the heart of downtown Athens, Georgia, The Classic Center provides unique meeting space, outstanding special events services and a wide range of entertainment options, making this unconventional convention center the choice for conferences, meetings and special events!
- classiccenter.com

The Symposium will be held in the Athena Ballroom of the Classic Center.
300 North Thomas St. Athens, GA 30601
Meeting Venues

Transportation

Getting Here

Getting to Athens from anywhere is an easy task thanks to the Hartsfield–Jackson Atlanta International Airport (ATL) in Atlanta, GA. From Atlanta, Groome shuttle service provides transfers to Athens.

Groome Transportation
(706) 612-1155
athensoffice@groometrans.com
https://groometransportation.com/athens/

How to Get Around Town

Most places in Athens are easily walkable from the Classic Center. However, to reach the far ends of the sprawling UGA campus, taking a bus may be a faster option. The UGA bus system runs continuously during the day (7am–7pm). The UGA buses are always free, no pass required. UGA also offers live bus map at uga.edu/map and an interactive bus tracker via the UGA app.

Other transport options in town include the Athens City Bus, Lyft, and Uber.
Meeting Venues

Food and Drink

Informal Happy Hour Locations:

We plan to have informal happy hours each evening at a different local establishment. If you are looking for a place to meet up with fellow attendees please join us at the following locations:

Monday: Allgood Lounge (8)
Tuesday: The Globe (19)
Wednesday: Creature Comforts (33)
Friday: Little Kings (29)
LABORATORY OF ARCHAEOLOGY

OUR MISSION INCLUDES:
- PRESERVING AND CURATING ARCHAEOLOGICAL COLLECTIONS AND ASSOCIATED RECORDS
- FACILITATING RESEARCH FOR PROFESSIONALS AND TRAINING STUDENTS IN ARCHAEOLOGY
- SERVING THE STATE OF GEORGIA

Formally Established in the Fall of 1947, the LABORATORY OF ARCHAEOLOGY at the University of Georgia is the Oldest and one of the Largest Archaeological and Collections Facilities in Georgia.

Franklin College of Arts and Sciences
Department of Anthropology
Laboratory of Archaeology
UNIVERSITY OF GEORGIA

archaeology.uga.edu/archlab/
Events

Ice-Breaker Reception

To welcome attendees from around the world, a reception will be held on **Sunday, May 19th from 4:00pm to 6:00pm** at the Creature Comforts Brewery, in downtown Athens, GA. The reception is free to all attendees including guests and will include light snacks and a drink ticket. A registration booth will be available at the Ice-Breaker, where attendees can check in for the conference.

Creature Comforts Brewing Company is located at 271 West Hancock a short walk from the Classic Center and our partner hotels. Following the Ice-Breaker attendees are encouraged to join us at Ted’s Most Best, an iconic local pizzeria for an informal dinner. Ted’s is located just around the block from Creature Comforts at 254 West Washington Street.

Lab Tours

Tours of the University of Georgia Center for Applied Isotope Studies will be given on Monday from 6:00 PM to 7:00 PM and on Friday from 4:00 PM to 5:00 PM. Combined tours of the Center for Applied Isotope Studies and Laboratory of Archaeology will be given throughout the day on Wednesday (Wednesday tours are only for those not attending the field trip). Transportation between the Classic Center and the laboratories will be provided.

Tour space is limited. Those interested in Laboratory Tours should choose a time slot when they check in for the conference. Registrants should meet at the Athena statue in front of the Classic Center 15 minutes before their tour time slot.

<table>
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<tr>
<th>Laboratory Tour Time Slots</th>
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No shorts or open-toed shoes will be permitted on the lab tours.
Events

Mid-Conference Field Trip to Ocmulgee National Monument and Madison, Georgia  
(Wednesday, May 22nd)

This trip will include transportation to historic Madison, Georgia for site seeing, shopping, and a tour of the Madison–Morgan Cultural Center. This is followed by a trip to Ocmulgee National Monument Native American Mounds and Museum, a bagged lunch, and a tour of the site.

Those who wish to attend the field trip must register in advance. Registrants should gather at the Athena statue in front of the Classic Center at 8:30 AM Wednesday morning. Buses will depart the Classic Center at 9:00 AM.

Madison, Georgia

Once described in the 1845 Guide to Georgia as the “most cultured and aristocratic town on the stagecoach route from Charlestown to New Orleans,” Madison remains a genteel reminder of the country’s southern beauty and grace that was spared General Sherman’s torch in his infamous March to the Sea.

- https://visitmadisonga.com

Madison–Morgan Cultural Center

The Madison–Morgan Cultural Center is a multi-disciplinary non-profit institution that endeavors to enrich the lives of the residents of its immediate community and the broader region by presenting high quality programming and educational opportunities in the fields of visual and performing arts, history, and other humanities. MMCC will preserve and interpret its historical 1895 building and will cooperate with other organizations which have mission compatible goals.

- Http://www.mmcc-arts.org

Images courtesy of savoryexposure and mmcc-arts.org
Events

Ocmulgee National Monument

The trip to Ocmulgee will be guided by archaeologists from the University of Georgia. The visit to this prehistoric mound complex will begin with a bagged lunch. After lunch, attendees will be able to tour the mounds and the on-site museum. The complex is walkable for most, but motorized transport will be available for those not capable of walking the extent of the monument.

This park is a prehistoric American Indian site. American Indians first came here during the Paleo-Indian period hunting Ice Age mammals. Many different American Indian cultures occupied this land for thousands of years. Around 900 CE, the Mississippian Period began. They constructed mounds for their elite, which remain today.

– nps.gov
Events

Gala Dinner (Thursday, May 23rd at 7pm)

The Gala Dinner will be held on Thursday May 23rd at the beautiful State Botanical Gardens of Georgia. Shuttles from the Athena Statue in front of the Classic Center will depart at 6:15PM and 7:00 PM. Guests will be returned to the Classic center following the Gala on shuttles departing at 10:00 PM and 11:00 PM. Please arrive at the shuttle 15 minutes before departure.

Dinner will be served at 8:00 PM and will be followed by music and dancing at 9:00 PM.

A selection of wines and local craft beers from numerous Athens area breweries will be available. A selection of delicious, locally made, southern fare will be provided by Chef Mimi Maumus of Athens local southern kitchen Home.made.

The Gala will include live music by local artists Klezmer Local 42.

Images courtesy of botgarden.uga.edu, Elle Jaye Dee, home.made, and Klezmer Local 42
Student Awards

We are happy to announce that we will be hosting two student presentation awards at the 2019 Radiocarbon and Archaeology meeting. Each of these awards will include a $100 prize.

The Society for Archaeological Sciences

The Society for Archaeological Sciences invites applications for the The Society for Archaeological Sciences Student Researcher Award presented at the 9th International Symposium on Radiocarbon & Archaeology in Athens, Georgia, USA (May 20–24, 2019). This prestigious award acknowledges innovative student contributions to archaeological research through the use of scientific methods and has enhanced the careers of prominent young scholars and professionals for more than a decade. The prize consists of $100 US for the best student presentation, either oral or poster. Eligible student presentations will be judged by the conference scientific committee on the basis of scientific merit, impact on the field, originality, and presentation skills. The award recipient will be announced during the closing session and will be featured on the SAS website and the SAS Bulletin.

The Southeast Archaeology Foundation

The Southeast Archaeology Foundation will sponsor a $100 prize for the best presentation to a graduate or undergraduate student in acknowledgment of outstanding work by a student who is either enrolled in an academic institution within the southeastern United States or is presenting on a topic related to the archaeology of the southeastern United States from any academic institution. Eligible student presentations will be judged by the conference scientific committee on the basis of scientific merit, impact on the field, originality, and presentation skills. The award recipient will be announced during the closing session. The winner will be featured on the SEAF website.
# Meeting Schedule Overview

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*Poster Session A – Calibration and Calibration Records, Time to Eat, ^14^C Labs Past & Present, Archaeology and the Environment, Resolving Ambiguities, Coastal Archaeology, General*

*Poster Session B – Beyond Site Sequences, Developments in Sample Pretreatment, ^14^C and the Protection of Cultural Heritage, Statistical Analysis and Modeling, Latin American Archaeology*
Radiocarbon dating has been a primary tool used by archaeologists to understand human dietary patterns and the domestication of plants and animals over time. Recent studies have applied Bayesian statistical analysis to reexamine these dates and create regional models of when and how food/foodways developed, transformed, and spread. These models have then been used to address larger questions on cultural complexity, community and trade networks, conflict and migration, health, climate change, and environmental impact of humans.

9:40 AM
The Age of Arrival for the Common Bean (Phaseolus vulgaris) in the Eastern Woodlands of North America
Timothy Baumann¹, Tony Krus³, Gary Crites¹
¹ University of Tennessee
² University of South Dakota
Recent scholarship by Monaghan et al. (2014) attempted to map the prehistoric arrival and distribution of the common bean (Phaseolus vulgaris) in eastern North America through directly-dated specimens. In the New World, beans were first domesticated ca. 2400 B.C. in the highlands of Peru and independently domesticated again in central Mexico ca. 2,000 years later (Kaplan and Lynch 1999). These later beans quickly entered North America via the Southwest by 500 B.C., but they did not pass over the Rocky Mountains to the Great Plains and the Eastern Woodlands until after A.D. 1100 (Adams and Fish 2011; Monaghan et al. 2014). Monaghan and his colleagues argued that over the next century beans took a northern route from the Plains into the Great Lakes and Northeast region. From there, beans moved south and west into the Illinois Valley after A.D. 1200 and through the Ohio Valley after A.D. 1300. They suggest that the circular path may reflect the impact of different agricultural practices or cultural boundaries between food producers who employed raised gardens (e.g., Oneota, Iroquois) with mixed plantings of the “three sisters” – maize (Zea mays spp. mays), squash (Cucurbita sp.), and the common bean, and more southern Mississippian agriculturists who utilized large communal fields of maize (Hart 2008; Scarry and Scarry 2005). Using Bayesian analysis, new direct dates of beans from Tennessee and neighboring states are presented to test probable ages and routes of bean adoption into the Eastern Woodlands and the Southeast specifically. It is speculated that the arrival of beans into the south may be linked to a prolonged drought in the midcontinent from AD 1250 to 1350. This rainfall shortage reduced the maize yield and was a prime factor for Mississippian sociopolitical tension, manifested through the appearance of palisades with bastions around towns. After 1350, the major Mississippian sites in the lower Ohio River valley and the Nashville Basin were abandoned, creating the “Vacant Quartet”, with many of their occupants moving south and bringing their beans with them.


The freshwater shell midden at Riņņukalns, Latvia represents an exceptionally rich archive of wild food species (plant remains, fish bones and scales, animal bones, mollusk shells), all apparently deposited within a few decades of c.3400 cal BC (Bērziņš et al. 2014). After a brief evaluation in 2011, we returned to the site in 2017-18; material from the new excavations is currently under analysis. Bones or teeth of 5-6 humans and several domestic dogs associated with the midden phase have been recovered, including 2 undisturbed human burials and 3 articulating sets of human or dog bones. Dating the intact stratigraphic sequence allows precise estimates of dietary \(^{14}\)C reservoir effects to be calculated for the freshly deposited bones, adding another dimension to diet reconstruction. Local freshwater species can already be clearly differentiated from terrestrial fauna using stable isotopes (\(\delta^{15}\)N and \(\delta^{13}\)C) (Meadows et al. 2016; Schmölcke et al. 2016), and we are increasingly confident that the typical freshwater reservoir effect in local fish and mollusks during the 4th millennium cal BC was similar to what it is today, allowing dietary reservoir effects to be used as a proxy for fish consumption.

The shell midden was formed at a time when foragers had remarkably specialized fish-based diets; isotopically, their dogs resemble otters, and even humans were almost as fish-dependent, with dietary reservoir effects up to 70% of those in contemporaneous fish bones. These results raise questions about seasonal scheduling, storage and mobility, potential plant sources of energy macronutrients (e.g. nuts, underground storage organs), and whether human subsistence depended on the systematic exploitation of anadromous and catadromous oily fish, such as eel and lamprey, with potentially confounding isotopic signals. We will present preliminary results of the new project in the light of paleodietary studies of other hunter-gatherer-fisher communities in northern Europe from the same time interval.

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**Monday May 20th**

**Time to Eat: Recalibrating Dietary Changes and Domestication in Human History**

Continued

*Athena Ballroom E*

9:40 - 11:00

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**10:20 AM**

**Eels, Mussels and a Deficit of Lampreys: Dates and Diets of Prehistoric Foragers at Riņņukalns, Latvia**


*¹ Center for Baltic and Scandinavian Archaeology*

*² University of Latvia*

*³ University of Tartu*

The freshwater shell midden at Riņņukalns, Latvia represents an exceptionally rich archive of wild food species (plant remains, fish bones and scales, animal bones, mollusk shells), all apparently deposited within a few decades of c.3400 cal BC (Bērziņš et al. 2014). After a brief evaluation in 2011, we returned to the site in 2017-18; material from the new excavations is currently under analysis. Bones or teeth of 5-6 humans and several domestic dogs associated with the midden phase have been recovered, including 2 undisturbed human burials and 3 articulating sets of human or dog bones. Dating the intact stratigraphic sequence allows precise estimates of dietary \(^{14}\)C reservoir effects to be calculated for the freshly deposited bones, adding another dimension to diet reconstruction. Local freshwater species can already be clearly differentiated from terrestrial fauna using stable isotopes (\(\delta^{15}\)N and \(\delta^{13}\)C) (Meadows et al. 2016; Schmölcke et al. 2016), and we are increasingly confident that the typical freshwater reservoir effect in local fish and mollusks during the 4th millennium cal BC was similar to what it is today, allowing dietary reservoir effects to be used as a proxy for fish consumption.

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**10:40 AM**

**IsoMemo Interdisciplinary Projects to Map Large-Scale Spread of Domesticates and Temporal-Spatial Shifts in Human Dietary Habits**

*Ricardo Fernandes*

¹ Max Planck Institute

The integration of stable isotope and radiocarbon data offers a valuable source of information to investigate the spread of domesticated species and temporal-spatial shifts in human dietary habits. However, until recently there was no coordinated global effort to explore the research potential of a Big Data approach to the large amounts of available stable isotope and radiocarbon data. This was one of the motivations for the establishment of IsoMemo, a Big Data initiative that brings together a consortium of autonomous repositories of isotopic data within the fields of archaeology, ecology, and environmental and life sciences. One of the goals of the IsoMemo initiative is to develop large-scale interdisciplinary projects employing purposely built Bayesian statistical tools to map human and environmental histories at wide spatial and temporal scales. This presentation will provide an update on ongoing IsoMemo projects with particular relevance for the study of the spread of domesticated species and their consumption in Europe and millet production in Mongolia.
Since the first published application in 1949, radiocarbon dating has been the most widely applied analytical approach for dating archaeological and historical materials. Over the past 70 years, numerous radiocarbon labs have opened and/or closed—each with its own unique history, trajectory, and contribution(s). This session provides a forum for documenting the specific histories of radiocarbon laboratories both, past and present, that have existed over the past 70 years. The purpose of this session is to document in one place, the histories of individual laboratories, their major accomplishments and their major contributions to the field, so that as we look to the future of radiocarbon dating in archaeology, we have documented, to some extent, where we have already been.

11:20 AM
Radiocarbon 70 Years of Research: From Dirty Counter to AMS
Alexander Cherkinisky

From the earliest days of natural radiocarbon measurement through the accelerator mass spectrometry (AMS) revolution, accurate and precise radiocarbon dating has developed along with and depended upon technical innovation in physics, chemistry and electronics (A. Long, 1992). 70 years have passed since first publication in Science article “Age Determination by Radiocarbon Content: World –Wide Assay of Natural Radiocarbon” by W.F. Libby, E.C. Anderson, and J.R. Arnold, researchers from the University of Chicago. This research was partly supported by the Viking Fund, Inc. and many other anthropological and archaeological departments and also, American Museum of Natural History and the Byrd and Ronny Antarctic expedition. The first measurements were done using a screen wall counter and required 6g of carbon. The samples were mostly modern wood and shell collected from all around the world. The development of anti-coincidence shielding allowed significantly reduced background. In 1950 the Groningen radiocarbon laboratory was founded by de Vries, which started to use CO₂ gas proportional counter for the dating. Later as a counting matter were used hydrocarbon gases to increase concentration of carbon in the counters. The volume of the counters was a few liters and it was quite difficult to protect them from cosmic rays, so the background was relatively high. In the beginning of 1960s liquid scintillation technique was developed, which allows significantly reduced sample volume and increased the carbon concentration in the counter, with most of the laboratories using benzene as a counting matter. The 1960s-1970s saw a tremendous growth of the radiocarbon laboratories around the world: there were about 100 laboratories and about 2/3 of them were in USA and USSR.

Richard Muller (1977) from Lawrence Berkeley laboratory published the first paper on AMS measurements by cyclotron. It was a revolutionary paper outlawing an entirely different technique for the measurement of radiocarbon. This technique was based on the direct detection of ¹⁴C by AMS instead of measurement of its radioactivity. Muller’s development promised not only measurements on significantly smaller samples, than for radiometric technique, but also a higher precision and predicted to extend the limit beyond 100ka.

A couple years after first publication of the cyclotron it was replaced with tandem Van der Graf accelerator with negative ion source, which completely excluded the additional background from nitrogen atoms. In the end of 1990s group of physicists from ETH and NEC developed the Pelletron tandem accelerator, which increased the precision of the measurements. The voltage and the energy of accelerators was reduced from a 3-5 MV to 200KV in the latest development of the Ionplus MICADAS system. The capacity of a modern AMS laboratory is close 10000 unknown samples per year. Chemists are working on the future improvement of the sample preparation and the dating individual compound. Physicists are improving the existing systems and working on the invention of fundamentally new systems for measurement of radiocarbon.


12:00 PM
Three Generations of Radiocarbon Mass Spectrometry at SUERC
Stewart Freeman¹, Richard Shanks¹, Cameron McIntyre¹, Derek Fabel¹, Pauline Guliver¹, Brian Tripney¹

SUERC operates three types of mass spectrometer for C14 analysis that together have performed >100,000 natural abundance measurements to date. Both the technology development and the establishment of the discrete AMS Laboratory at an institution with a strong focus on applications science have been pioneering. The AMS & PIMS techniques created at this laboratory span two orders of magnitude of ion acceleration, bracketing the traditional and new accelerator-free radiocarbon mass spectrometries. This has contributed to the United Kingdom national capability for C14 mass spectrometry at SUERC having been recommissioned until 2029.

12:20 PM
A Brief History of Radiocarbon Dating at the University of Arizona
A.J. Timothy Jull², Chris Eastoe³, George Burr⁴

The early work of Emil Haury and colleagues on Ventana Cave, where a large amount of cultural material was found sets the stage for radiocarbon dating at the University of Arizona in Tucson. An epic work by Haury and other archaeologists was published in 1950 – it had no radiocarbon dates. However, Haury was already aware of the seminal work of Arnold and Libby (1951), where they had shown the radiocarbon age of Folsom sites in the southwest. Haury had obtained his BA and MA from the University of Arizona in 1927 and 1928, respectively. He left to get a degree from Harvard, but returned to head the Department of Anthropology in 1937. He is well-known for being involved in many famous archaeological excavations in the American Southwest as well as Ventana Cave. When the Ventana Cave volume (Haury et al. 1975, The Stratigraphy and Archaeology of Ventana Cave, Arizona, University of Arizona Press) was republished it included the following: “A number of new additions have been made to the Ventana Cave story since this book first appeared in 1950. Foremost among these new insights are radiocarbon determinations which were not available to us when the excavations were undertaken in the 1940’s…”

Haury had learned from Arnold and Libby – he established a radiocarbon laboratory in 1955 at the University of Arizona beginning a long line of different methods and experts in the field attracted to the University. Haury originally established a “solid carbon line” along the lines of the “solid carbon counter” reported by Arnold and Libby (1949). Unfortunately, this method was strongly affected by nuclear fallout which was becoming a problem at that time. Studier and Wise (1958) set up a gas-counting laboratory, which was redesigned by Paul Damon (who had arrived in 1957) and which survived until 1986 in the basement of what is now called the Hashbarger building. Accelerator mass spectrometry began in 1982 under the supervision of Damon and Douglas Donahue (Physics). In 1986, Austin Long also installed a liquid-scintillation system in an underground counting laboratory, a facility that is still operational in the Gould-Simpson building.

As Shakespeare would say, “the past is just prologue…”
12:40 PM  
A History of Radiocarbon Dating at the University of Georgia  
Robert J. Speakman¹  
¹ University of Georgia  

For more than 50 years the Center for Applied Isotope Studies (CAIS) at the University of Georgia has operated a radiocarbon dating laboratory. The lab was established in July 1968 and operated under the purview of UGA’s Department of Geology. In 1977, the UGA’s Geochronology Laboratory was renamed the Center for Applied Isotope Studies (CAIS) and administratively placed under UGA’s Office of Research Services to better reflect a changing mission that not only included radiocarbon dating, but other aspects of geochemistry. Over the past decade, CAIS has significantly expanded its analytical capability and personnel. This paper provides a brief history of CAIS, its major accomplishments, and current trajectories.
The Archaeology and the Environment session is intended to bring together researchers of environmental sciences who work with archaeological remains. Multidisciplinary studies comprising subjects such as zooarchaeology, past marine reservoir effects, and paleoenvironmental reconstructions are the focus of this session.

2:20 PM
Temporal Variations in the Marine Reservoir Effect off the Coast of Rio de Janeiro
Kita Macario¹, Eduardo Alves², Fabiana Oliveira³, Maria Cristina Tenório¹, Fabio Dias⁴, Rosa Souza⁵, Marcela Muniz⁶, Roberto Meigikov³, André Luiz Belém³
¹ Universidade Federal Fluminense
² Oxford Radiocarbon Unit
³ Universidade Federal do Rio de Janeiro
⁴ Universidade Federal di Sergipe

For radiocarbon based chronological studies, calibration with a robust data set allows for the correct interpretation of the obtained conventional ages by considering spatial and temporal variations in radiocarbon production and distribution. In the case of samples of marine origin, calibration also corrects for the Marine Reservoir Effect (MRE), i.e., the oceanic depletion in carbon 14 concentration when compared to the coeval atmosphere [1]. Since the magnitude of the MRE increases with depth and varies spatially due to ocean dynamics, local corrections, termed ∆R, should be considered. This study is focused on the use of samples from shellmounds on the coast of Rio de Janeiro, Southeastern Brazil, for ∆R calculations. In this region, the counteracting influence of lagoon systems and seasonal upwelling contributes to a rather variable ∆R [2]. At present time, the coastal upwelling near Cabo Frio is responsible, for example, for the lower than average water temperatures in the region and also for increased biological productivity [3]. Previous works based on proxies such as marine sediment and foraminifera have presented evidence of upwelling in the region thousands of years ago with variable intensity [4]. Changes in coastal dynamics are expected to influence the local MRE and, therefore, the calibration of marine radiocarbon ages. Here we study the MRE along the Rio de Janeiro coast from a temporal perspective. The Usiminas shellmound, on the Cabo Frio Island, was studied before by Macario et al. [5] revealing positive ∆R values between 1.6 and 1.2 cal kBP, in agreement with the pre-bomb values calculated by Alves et al. [6]. Other shellmounds in the same region were also studied and revealed negative values with increased freshwater influence before 3 cal kBP [7-9]. In order to evaluate whether such differences were due to local or temporal variations, in this work we have studied the oldest occupational layers of the Usiminas shellmound. Despite a competition between upwelling and freshwater effects may take place for the whole region, our results show a pattern of increasing reservoir age from 4 cal kBP while relative sea-level has been decreasing. We discuss sea-level changes, upwelling, biological productivity and their impact on the human occupation of the Rio de Janeiro coast during the Late Holocene.

2:40 PM
Chronology of Change at a Mangrove Lagoon: Socio-Ecological Landscapes at the Selin Farm Site, Northeast Honduras
Leslie Reeder-Myers¹, Whitney Goodwin²
¹ Temple University
² Southern Methodist University

The Selin Farm site comprises a group of around 30 well-stratified house and shell mounds, occupied AD 300 – 1000, near the Guaimoreto Lagoon on the northeast coast of Honduras. The site documents changing cultural identity, sociopolitical complexity, and foodways as the people at Selin Farm carefully navigated broader regional shifts during the Maya Classic to Postclassic transition. At the same time, exceptionally well-preserved shell mounds, some up to 4.5 meters high, provide a record of Guaimoreto Lagoon’s ecosystem throughout this period, including the effects of sea level rise, climate change, and increasing human predation. Recent field research included LiDAR mapping of the site’s surface underneath the tree canopy, coring to trace the extent of subsurface deposits and the depositional history of the lagoon, and a series of 30 radiocarbon dates to better understand the chronology of socio-ecological change at Guaimoreto Lagoon. Results suggest that there is little overlap in deposition among mounds, with Early Selin deposits primarily at the northeastern mound group and Basic Selin deposits primarily at the southeastern mound group. The exception, Mound I, was used throughout the entire occupation at Selin Farm, but further research is needed to understand why this location was special. Subsurface coring of non-mound areas indicates that the area flooded frequently after, or perhaps concurrent with, the abandonment of the site. This is likely due to a shift in the course of the nearby Selin River, with important ramifications for the ecology of Guaimoreto Lagoon itself. This improved site chronology and depositional history refines our understanding of socio-ecological change on the northeast Honduras coast and helps formulate key hypotheses for future research.

3:00 PM
The Radiocarbon Reservoir Effect in the American Bottom Region of the Mississippi River
Matthew A. Fort¹, Kristin M. Hedman¹, Stanley H. Ambrose²
¹ University of Illinois Urbana-Champaign
² Southern Methodist University

The Radiocarbon Reservoir Effect (RRE) involves the uptake of older carbon into aquatic and terrestrial food webs. Its magnitude varies greatly among rivers and lakes. It can increase radiocarbon ages on consumers of aquatic foods by decades to centuries. RREs of many Eurasian and European rivers and lakes have been thoroughly investigated. However, the RRE of North America’s largest river is unknown. Archaeological RRE studies in Northern Eurasia and Europe have focused on bone collagen and pottery food residues, and on pottery in North America. Measuring the freshwater RRE within the Mississippi River floodplain of southwestern Illinois, an area referred to as the American Bottom, is essential because aquatic foods were important in local pre-Columbian human diets. Accurate and precise dates on bone are important to reconstructing complex chronological sequences of important cultural processes such as the timing of nutrition and adoption of maize agriculture, fluctuations in population size, and chronologies of mound-building in sites spanning the inception, expansion, and dispersal of Mississippian culture (ca. AD 1050-1400).

Our preliminary study of the RRE in the American Bottom shows offsets between paired terrestrial herbivore and aquatic fish bone collagen samples from two sites. The data set includes 9 features from 3 sites. Of the 9 features, 4 yielded aquatic fish bone collagen dates significantly older than their paired terrestrial counterparts. The magnitude of the offsets ranges from 365 to 700 radiocarbon years. We found no correlation between δ13C of aquatic samples and the magnitude of the RRE, unlike sites in Northern Eurasia and Europe. There is however a strong correlation between δ15N offsets and two individuals, which may be attributable to hard water effects in specific water bodies. Hard water effects stem from the contribution of dissolved inorganic carbon.
Afternoon Coffee
3:40-4:00 PM

3:20 PM
Evidence for an Infrequent and Severe Fire Event in Great Basin National Park, NV During the Late 15th Century
Christopher S. Cooper¹, David F. Porinchu², Scott A. Reinemann³, James Q. DeGrand¹, Bryan G. Mark¹
¹ University of Georgia
² Miami University
³ The Ohio State University

Fire is integral to forest ecosystems in the Great Basin. In recent decades, higher temperatures, reduced snowpack and a persistent drying trend have altered the seasonality, frequency and severity of fires throughout the Intermountain West. Sustainable conservation of forest ecosystems in Great Basin National Park (GBNP) requires consideration of not only the complex relations between forest ecosystems and fire but also how this relationship may change in the future. Understanding fire regimes in GBNP has become more urgent given the two recent wildfires: Black Fire (2013) and Strawberry Creek Fire (2016). Multi-proxy analysis of a sediment core recovered from Stella Lake in August 2009 was undertaken to develop long-term fire histories for GBNP. An age-depth model spanning the late Holocene portion of the core was constructed using eight ¹⁴C dates taken from wood fragments, conifer needles, and charcoal fragments. The age model spans the last two millennia and documents a rapid increase in sedimentation rates during the 15th century. Analysis of organic geochemistry (%C, %N, δ¹³C and δ¹⁵N), sedimentary charcoal, and pollen provide evidence that a severe, catchment-wide, disturbance occurred at approximately 1490 CE. Sedimentary charcoal suggests that this disturbance was likely a catchment-scale fire. Palynology suggests that this fire was severe enough to significantly alter vegetation composition within the Stella Lake catchment. The Stella Lake record contains no evidence of a larger or similarly-severe fire event during the last two millennia. Geochemical evidence supports the physical proxies’ evidence of a severe fire event and corresponding vegetation community change. These geochemical data also track well with the chironomid-inferred T (°C) at the site (Reinemann et al. 2014), suggesting that the aquatic community in Stella Lake had been responding primarily to climate until ~1500 CE. It likely that following 1500 CE the aquatic biota responded to the fire event and related changes in the catchment, rather than to changes in temperature. It is currently uncertain how ecosystem dynamics will react to projected changes in climate and disturbance regimes. This study provides valuable information to park managers concerned with how increases in fire severity may affect terrestrial vegetation and aquatic communities.

Radiocarbon and Archaeology 9th International Symposium

This session invites papers on the timing and pace of human dispersal, migration, and settlement of the major landmasses of the world, from the Middle Paleolithic through the settlement of the last inhabitable islands.

4:00 PM
Peopling of Oceania: Demonstrating the Incremental Growth Model Through Radiocarbon and Archaeology
Mike Carson¹
¹ University of Guam

Radiocarbon has been instrumental in clarifying how people came to inhabit the expansive of Pacific Oceania, now supporting an "Incremental growth model" showing a number of long-distance sea-crossing migrations over the last millennia. In the thousands of islands of the Pacific, archaeological layers and environmental impact horizons have preserved the records of when people first settled each island group or archipelago, directly associated with charcoal, shell, and other materials suitable for radiocarbon dating. Refinements have been possible through delineation of stratigraphic layers, dating of individual points or features within those layers, redundant dating of samples in secure contexts, localized and taxon-specific corrections for marine samples, and cross-constraining dating of superimposed layer sequences. The "Incremental growth model" will continue to be refined in terms of its precision and detail, but already the framework can be presented accurately and with examples of how the technical and methodological issues have been addressed.

4:20 PM
Did Modern Human Dispersal Take a Coastal Route into India? Insight into Mode III Assemblages of Saurashtra, Gujarat
Gopesh Jha¹, P. Ajithprasad²
¹ The Maharaka Sayajirao University of Baroda, Vadodara
² Senator John Jentsch History Center

Saurashtra industries have crucial role to play in our understanding of the evolution of modern human behaviour and dispersal of anatomically modern human around the old world. Colonization of anatomically modern human into South Asia has created intense controversy in the light of recent archaeological and genetic research. Recent genetic studies suggest that the earliest modern South Asians migrated from Africa as early as 70,000 years BP (Macaulay et al. 2005). The migration is often assumed to have occurred along the Indian ocean rim and reaches Australia by 60-50kya (Mellars et al. 2006) (Mellars et al. 2013). The state of Gujarat has an advantage of a vast coastline of 1600 kms (approx.) which can be the possible pathway of modern human dispersal. Gujarat also yield lots of well dated late Pleistocene Palaeolithic sites (Baskaran et al. 1986; Marathe 1981).

Based on the current archaeological data from South Asia there exists two conflicting models (Pre-Toba model of Petraglia et al 2007 and Post-Toba model of Mellars et al 2006) that explain the initial modern human presence in the region. There are two conflicting models that explain the whole colonization process. First model is proposed by Sir Paul Mellars where he argues - "the archaeological and genetic evidence points to a single successful dispersal event, which took genetically and culturally modern populations fairly rapidly across southern and South-eastern Asia into Australasia around 60kya - 40kya" (Mellars et al. 2006). Second model is proposed by Michael Petraglia on the basis of recent archaeological evidences from Jwalapuram, where he proposed the pre-Toba model of modern human dispersal along with middle palaeolithic technology (Petraglia et al. 2007).

The recent dates of 385 kya for middle Palaeolithic site at Attirampakkam created more complexities for the emergence of middle Palaeolithic in India as well as globe.

In that case, how will we incorporate this evidence in the story of modern human dispersal. Saurashtra mode III industries could be very crucial in terms modern human dispersal. It’s also significant to check whether these assemblages can be consider as a indicator of modern behaviour or not. Current research defines the nature and regional variability of the levalliosian industries of the Saurashtra, Gujarat. Baskaran, M., A.R. Marathe, S.N. Rajaguru & B.L.K. Somayajulu. 1986. Geochronology of Palaeolithic cultures in the Hiran Valley, Saurashtra. Indian Journal of Archaeological Science 13: 505–14.


4:40 PM
On The (Basin) Edge: Problems and Potentials in Radiometric Dating for Drowned Archaeological Landscapes
Jessica Cook Hale¹
¹ University of Georgia

Now-submerged, formerly coastal landscapes have great potential to render critical information concerning multiple archaeological questions of intense interest, including the timing and nature of human entry into the Western Hemisphere. However, the nature of post-depositional processes at offshore sites, as well as the nature of site deposits themselves, present significant challenges to radiometric dating, including radiocarbon dating. I present here a review of marine basin edge processes for which offshore site prospection and excavation must account, as well as commentary on the limitations of the archaeological materials themselves. I will also suggest potential methods for managing these limitations such that offshore sites, even eroded and deflated ones, can still offer useful information.

5:00 PM
Latest Pleistocene Context and Faunal Occurrences From the Old Vero Site (8IRo9), Florida
C. Andrew Hemmings¹, James M. Adovasio², Frank J. Vento³, John S. Duggan⁴
¹ Aucilla Research Institute
² Senator John Jentsch History Center
³ Clarion University
⁴ Florida Atlantic University

Recent analysis of archeological materials from the Old Vero Site includes directly dated specimens of numerous extinct Pleistocene taxa and non-local marine species, a considerable number of which were recovered from geologically meaningful contexts. About a dozen rarely encountered species are firmly added to the available Pre-Clovis and Clovis age diet and several of these have reasonable contextual association and/or modifications to suggest direct exploitation by early humans in this portion of Florida. These data are discussed within broader advances in our understanding of Late Pleistocene subsistence and diet across Florida and North America.
Plateaus, reversals, and other “wiggles” in the calibration curve that lead to multiple intercepts and ambiguity of radiocarbon age determinations have led scholars of the recent past to question the utility of radiocarbon dating for such periods. Papers in this session will address strategies for dealing with such “messy” portions of the calibration curve and how contemporary scientific, statistical, and archaeological methodologies are overcoming these challenges. Participants are asked to consider both advances in radiocarbon science and the implications of the derived insights on understandings of the archaeological record in the period in question.

9:00 AM
Dating Iroquoia: Methodological Strategies for Building Archaeological Chronologies in the Contact–Era Northeastern Woodlands
Sturt W. Manning¹, Jennifer Birch², Samantha Sanft¹, Megan Anne Conger²
¹ Cornell University
² University of Wisconsin

The authors have been involved in a research program that has begun to significantly refine and redefine the archaeological chronology of Northern Iroquoia, specifically portions of southern Ontario and New York State, through radiocarbon dating and Bayesian chronological modelling. Many of the most significant periods in Northern Iroquoian cultural development, including community aggregation, endemic conflict, confederacy formation, and initial trade with Europeans, took place between ca. A.D. 1300 and 1650 when there is potential for multiple intercepts in the IntCal13 calibration curve. In this paper, we discuss methodological strategies employed in our dating program for resolving ambiguous results caused by “wiggles” in the curve, including modelling of community relocation sequences and employing multi-material models. Our results are then placed into regional context through the discussion of major findings vis-à-vis older schemas, new insights into cultural processes, and future directions moving forward.

9:40 AM
Wiggle–Match Re–Dating of the Hurricane Irma Dugout
Carla S. Hadden¹, Laura G. Smith², Julia B. Duggins³
¹ University of Georgia
² University of Tennessee
³ Paleowest Archaeology

In September 2017 Hurricane Irma made landfall in Florida, unearthing a wooden dugout canoe slightly north of the city of Cocoa. The find was cast in popular media as “a mystery” when initial studies did not reveal a concise and clean narrative of its history. The initial radiocarbon assay (230 ± 25 14C yr BP) corresponded to three discrete possible calendar age ranges: cal AD 1640–1680 (49.5%); cal AD 1760–1810 (37.2%); and cal AD 1930–post-1950 (8.6%). The lack of precision in this age estimation was due to the shape of the radiocarbon calibration curve, which is characterized by numerous inversions, wiggles, and plateaus over this interval. Dendrochronological dating was inconclusive as well. To date, the “Irma Dugout” is the only logboat from Florida that has been identified as red cedar (Juniperus sp.), and a cedar master chronology does not exist for the region. Here we report on the re-dating of the Irma Dugout based on wiggle-match dating by AMS. From the dugout’s 55 rings we collected a total of 11 wood samples, each representing a group of 5 tree rings. Following Hoper et al. (1997), α-cellulose was extracted from the cut tree rings for dating by AMS. Wiggle matching was conducted within a Bayesian framework in OxCal version 4.3.2 (Bronk Ramsey 2017) using the IntCal13 (Reimer et al. 2013) and Bomb13NH2 (Hua et al. 2013) atmospheric curves. The statistics that indicate the quality of fit to the calibration curve are mixed, with a high χ2 test statistic (24.9; 5% critical value at 10 degrees of freedom is 18.3) but an acceptable agreement index (Acombe = 22.2%, with An = 21.3%). The wiggle-matched date for the outermost tree ring was cal AD 1964–1966 (95.4%), suggesting that the mysterious dugout is in fact modern. To our knowledge, this is the first application of wiggle match dating in the Southeastern US, and possibly the first attempt in the world to wiggle-match date a tree-ring series from a dugout canoe.


Schedule

Tuesday May 21st

Resolving Ambiguities In Calibrated Age Determinations
Chairs: Jennifer Birch and Sturt Manning
Athena Ballroom E
9:00–10:40

9:20 AM
Navigating Wiggles and Plateaus: Lessons Learned from Developing Radiocarbon–Based Chronologies in the 1st Millennium Cal BC for Over a Decade
Derek Hamilton¹
¹ SUERC, University of Glasgow

Archaeologists have long avoided using radiocarbon dating throughout much of the European Iron Age. This is due in large part to the occurrence of both wiggles and a plateau, which can lead to wide calibrated date ranges of up to 400 years on even the most recent dates. While material culture has been given primacy in developing local and regional chronologies in continental Europe, in Britain and Ireland, where there is often a paucity of material evidence, we have had to combine different approaches to grouping, ordering, and modelling our data to produce robust chronological frameworks within which to better understand social changes across space.

This paper will explore such things as the impact of sample selection, tailoring modelling solutions to expected archaeological data and questions, and ultimately managing expectations for the results. Using a range of published and soon-to-be-published examples, it will look across research stretching back over a decade, whereby site-based chronological modelling has been used to develop better insights and new understandings into Iron Age (800 cal BC–cal AD 43) society in Britain.
Schedule

Tuesday May 21st

Resolving Ambiguities In Calibrated Age Determinations
Continued
Athena Ballroom E
9:00–10:40

10:00 AM
Legacy Dates and Obscure Periods: Informative Priors Improve Compounding Effects of Old Data and Calibration “Wiggles”
Travis W. Jones¹, Carla S. Hadden¹, Robert J. Speakman¹, Nathan Duke¹
¹ University of Georgia

This study investigates the use of multiple methods, including ceramic frequency seriation to improve legacy radiocarbon dates coinciding with plateaus and reversals in the radiocarbon calibration curve. These “wiggles” in the curve can yield multiple date intercepts that lead to periods for which calibrated ages have lower precision. The problem can be further compounded when the majority of dates available are were measured prior to the widespread adoption of AMS, thus having larger uncertainties; with limited resources to date additional materials, archaeologists must explore new strategies to make the most of a spotty record. Here, a case study from the Northern Plains of North America demonstrates how the incorporation of ceramic frequency seriation, low-resolution legacy dates, and strategically placed high-resolution AMS dates can alleviate issues encountered along a wiggle in the calibration curve between cal AD 1300–1400. By identifying the relative temporal placement of village sites through a regional ceramic seriation, the earliest and latest villages were targeted for high-resolution dating. Using simulated dates, it was determined that as few as 10 and as many as 15 high-resolution AMS radiocarbon dates would be needed for the targeted villages. These new AMS dates were then incorporated into a Bayesian chronological model, serving to constrain a suite of low-resolution legacy dates from the sites of intermediate relative age. This approach successfully narrowed the estimated date ranges of lower-resolution dates falling along the wiggle, improving both site and regional level chronologies. The use of Bayesian chronological modeling can alleviate some of the issues involving the ambiguity of the calibration curve and low-resolution legacy datasets through the addition of a prior assumptions such as stratigraphy and other temporally sensitive information drawn from the archaeological record. When applied appropriately, these informative priors are useful for constructing chronological models able to produce higher-resolution date estimates.

10:20 AM
Exploring the Guale Village and Spanish Mission Occupations at The Sapelo Shell Ring Complex Through Bayesian Analysis
Victor Thompson¹, Richard Jefferies², Christopher Moore³
¹ University of Georgia
² University of Kentucky
³ University of Indianapolis

Bayesian analysis of radiocarbon dates in North American archaeology is increasing, especially among archaeologists working in deeper time. However, historical archaeologists have been slow to embrace these new techniques and there have been only a few examples of the incorporation of calendar dates as informative priors in Bayesian models in such work in the United States. To illustrate the value of Bayesian approaches to sites with both substantial earlier Native American occupations as well as a historic-era European presence, we present the results of our Bayesian analysis of radiocarbon dates from the earlier Guale village and the mission period contexts from the Sapelo Shell Ring Complex (9MC23) in coastal Georgia. Jefferies and Moore have explored the Spanish mission period deposits at this site to better understand the Native American interactions with the Spanish during the 16th and 17th centuries along the Georgia coast. Given the results of our Bayesian modeling, we can say with some degree of confidence that the deposits thus far excavated and sampled contain important information dating to the 17th-century mission on Sapelo Island. In addition, our modeling of new dates suggests the range of the pre-Mission era Guale village. Based on these new dates, we can now say with some degree of certainty which the deposits sampled likely contain information that dates to one of the critical periods of mission period research, the A.D. 1660–1684 period that ushered in the close of mission efforts on the Georgia coast.

Morning Coffee
10:40–11:00 AM

SAS - THE SOCIETY FOR ARCHAEOLOGICAL SCIENCES
Since the first published application in 1949, radiocarbon dating has been the most widely applied analytical approach for dating archaeological and historical materials. Over the past 70 years, numerous radiocarbon labs have opened and/or closed—each with its own unique history, trajectory, and contribution(s). This session provides a forum for documenting the specific histories of radiocarbon laboratories both, past and present, that have existed over the past 70 years. The purpose of this session is to document in one place, the histories of individual laboratories, their major accomplishments and their major contributions to the field, so that as we look to the future of radiocarbon dating in archaeology, we have documented, to some extent, where we have already been.
The Radiocarbon Laboratory of the Institute of Geography Russian Academy of Science: Past and Present

Elya Zazovskaya¹, Olga Chichagov, Vasily Shishkov², Sophiya Turchinskaya³, Sergey Goryachkin¹

¹ Institute of Geography RAS, Moscow, Russia

The Radiocarbon Dating Laboratory (lab code IGAN) was founded at the Institute of Geography of the Russian Academy of Sciences in the 1970s. The laboratory was organized under the leadership of academician I.P. Gerasimov and in different years it was headed by A. Cherkinsky and O Chichagova. Has since continuously in laboratory dated different carbon-containing materials using the liquid scintillation counting method. The first counter were designed at the Institute. Later measurements were taken on a liquid scintillation counter MARK-II (Nuclear Chicago, USA). Nowadays liquid scintillation counter Quantulus-1200 is used in the Laboratory. In 2015, our Laboratory has acquired the Ionplus automated graphitization system – AGE 3, together with a Vario Isotope Cube CHNS elemental analyzer. In early 2018 (with the help of Ionplus specialists), an isotope ratio mass spectrometer was coupled to the AGE 3 and our Laboratory staff members attended a brief training course at Ionplus. Since that time, our laboratory has obtained about 2000 separate graphite samples. Graphite ¹⁴C/¹²C ratios were measured using the CAIS 0.5 MeV Accelerator Mass Spectrometer at the Center for Applied Isotope Studies (CAIS), University of Georgia. As background standards in graphitization process, anthracite and phthalic anhydride were used, with their ages being consistently determined at 44000-49000 BP and 46000-49000 BP, respectively. The OXII and OXI oxalic acids were also used as modern standards in graphitization. An inter-laboratory comparison between IGAN and CAIS was conducted in respect to graphitization and dating of materials of known ages, with the results obtained being highly comparable. Since purchasing the AGE 3 system, the IGAN Lab has prepared graphite samples from the different kind of organic materials: charcoal, wood (cellulose), animal and human bones, soils, sediments of different genesis, peats, varnish from ceramic surfaces, fabrics (linen and silk). Samples for graphitization were prepared by use of standard techniques. Dating of soil organic matter also involved the use of techniques modified by the IGAN Laboratory.

The main specialization of the Laboratory is the dating of soil organic matter, but from the first days of the Laboratory work, we actively cooperated with archaeologists. The number of archaeological materials dating from the Laboratory increases every year. In the Laboratory, for the first time in Russia, began work on studying the effect of a reservoir in dating the collagen of human bones and the diet system of ancient man. During the existence of the Laboratory, about 3000 radiocarbon dates have been obtained only for archaeologists. Currently, thanks to the introduction of AMS technology in the Laboratory, objects from the museum collections of the State Historical Museum, the Museum of the Ryazan Kremlin and other Russian museums are dated. Together with the dendrochronologists of the Institute, work is underway to construct high-resolution chronologies for archeological monuments on tree rings.

12:40-2:00
Lunch

The Blind Pig
The Archaeology and the Environment session is intended to bring together researchers of environmental sciences who work with archaeological remains. Multidisciplinary studies comprising subjects such as zooarchaeology, past marine reservoir effects, and paleoenvironmental reconstructions are the focus of this session.

2:00 PM
Mark Thacker
1 University of Stirling

The former cathedral of Argyll on the island of Lismore has been held up as an exemplar of the challenges faced by scholars seeking to ascribe constructional dates to medieval buildings in western Scotland. Documentary evidence suggests the diocese of Argyll was annexed from neighbouring Dunkeld in the late-12th to early 13th century, but direct references to a cathedral church do not emerge in the documentary record until the early 14th and provide no reliable details of the building’s form until much later. The upstanding east end of the surviving medieval and later structure has been subject to repeated surveys over the last 120 years, and excavation of the west end of the nave in the 1960s indicated that the building was multi-phase with clear evidence for a secondary western tower. Refined and confident interpretation of the overall phasing and chronology of the building, however, has been limited by the simple rectangular plan-form of the main structure, the typological longevity of the architectural detail, and breaks in the stratigraphy of the visible remains. This has resulted in a range of speculative constructional dates for the earliest surviving fabric of the main building, from the mid-13th to the mid-14th century, which is frustrating in a historic period characterised by rapid political change.

The Scottish Medieval Castles & Chapels C14 Project (SMCCCP) promotes a palaeoenvironmental approach to buildings analysis, in addition to more traditional archaeological and art-historical methods. The project has previously investigated several medieval masonry structures in Argyll, including two upstanding castles on the island of Lismore, and presented reasonably refined dates of construction for these buildings by radiocarbon analysis of mortar-entrapped relict limekiln fuels. This radiocarbon data has also allowed a more refined chronological context for the regional exploitation of various building material sources, however, and it is against this research background that the project investigated the surviving fabric of Lismore Cathedral.

The SMCCCP investigation of Lismore Cathedral has included a combined programme of geoarchaeological, archaeobotanical and radiocarbon analysis of a suite of building material samples. Various aspects of the investigation have been challenging, but by adopting a materials-centred approach the study has presented the first independent evidence relating to the constructional chronology of two different phases of the cathedral church, as well as further evidence for the changing cultural and physical environment in which they were constructed. This paper will highlight the intimate relationship between the fabric of historic masonry buildings and changes in the character of the surrounding environment, and suggest that with the increased chronological resolution provided by radiocarbon analysis these archaeological resources should be interpreted together.

2:20 PM
A Study on Beginning of Iron Age in Korean Peninsula by Radiocarbon Dating
Wan Hong, Myungjin Kim, Junghun Park, Gyujun Park, Kilho Sung, Yongjin Park
1 Korea Institute of Geoscience and Mineral Resources
2 Radpion Ltd.
3 University of Science and Technology

Iron Age began in around Anatolia, Southwestern Asia in 3000 BC. However, steeling iron used widely in place of bronze from 1450 BC in Hittite Empire. In South Korea, it has been thought that Iron Age began in the second century BC based on several iron artifacts excavated from Soseo-ri, Hapsong-ri and Namyang-ri, South Korea. In 2007, the oldest iron artifact in South Korea were found from Cheoljeong-ri, Hongcheon. The calibrated radiocarbon age of the sample was 640 – 620 BC. However, the iron-manufacturing facilities of these ages has not been found yet, and the iron artifacts were likely imported from China or Western Asia.

The oldest iron-manufacturing facility in South Korea is a heritage site of iron manufacture of Gaya Dynasty (AD 42 – 562), which located in southern coastal area of Korean Peninsula, and the age of the site was found to be the third century AD. In 2003, another old iron-manufacturing site of Baekje Dynasty (18 BC – AD 660) was found, and the age of the site was measured to be beginning of the third century AD. On the other hand, many studies progressed in North Korea concluded that the beginning of Iron Age was the 7th century in Northern Korean Peninsula. The time gap between South and North seems too large and discussion is going between many archaeologists.

In this study, the charcoal samples excavated from an iron-manufacturing site in Chilgum-dong, Chungju city, South Korea were dated by radiocarbon at KIGAM AMS Laboratory. The ages of these samples are estimated to be the first century AD by preliminary study. 22 samples were collected from blast furnaces. The ages of these samples imply that this site is the oldest iron-manufacturing facility ever found in South Korea. It is thought that Iron artifacts seems to be introduced to South Korea in 7th century BC, but wide and active usage began from the first century AD.

2:40 PM
The Importance of Direct Dating Archaeological Remains in Multiproxy Paleoenvironmental Reconstruction
Suzanne Pilaar Birch
1 University of Georgia

Using global, regional, and local level paleoenvironmental proxies has become standard practice in the interpretation of the archaeological record. Questioning the role of climate change and its influence on human activity in the past has continued to gain momentum in recent years. Understanding landscape scale environmental change has similarly been essential in understanding the ebb and flow of human settlement patterns and economic shifts. A perennial challenge in using multiscalar data, both in time and across space, is the extent to which certain climatic conditions and environments can be detected using different proxies; how these correlate with one another; and how these then correspond to archaeological contexts. These relationships can be challenging to reconstruct, and radiometric dating is crucial for interpretation. Some sources of proxy data tend to be directly dated more than others; for example, lake cores, which provide sediment, pollen, charcoal, insect, and isotopic proxy data. Ice cores, sediment cores, and speleothems are also sources of multiple proxy data (including pollen and isotope data), while organisms such as trees, corals, shells, and teeth can be directly analyzed. When these proxy sources are well dated, they offer a tempting opportunity for archaeologists to interpolate their site- or regional-level findings. In an ideal world, these proxies would be numerous, varied, and located within close range of the archaeological site; in reality, this is often not the case. Stable isotope analysis of teeth and shell that are archaeologically derived have the potential to provide high-resolution data about paleoclimate and paleoenvironment and can allow for both site-level reconstructions as well as enable researchers to more easily correlate this data with dispersed regional records. As these types of analyses increase, however, specimens that are sampled for this isotopic data are not commonly directly dated, and researchers may rely on site chronologies (whether relative or based on radiocarbon dates on other types of materials from multiple contexts). This has implications for the accuracy and validity of arguments based on data derived from these materials.
High-resolution analysis of a 3.80 m long lake sediment core, recovered from Deorital, a mid-elevation lake (located at 2393 m asl in the Garhwal Himalaya of Uttarakhand) was undertaken to document how long-term and abrupt climatic fluctuations may have influenced communities in northern India during the mid-Holocene. Of particular interest is the potential link between abrupt climate change at 4.2 ka and the onset of a step-wise decline of the highly complex Harappan civilization. A robust chronology, based on eleven AMS 14C dates obtained from water chestnut (genus: Trapa) seed cases, indicates that the basal age of the core recovered from Deorital is 5.2 ka. The age-depth model was developed using the open-source R code package BACON. The sedimentation rate, which was 30 years/cm between 5.2 ka and 2.1 ka, increases to 7.3 years/cm from 2.1 ka to the present. Non-destructive imaging approaches, such as X-ray fluorescence (XRF), X-ray, and CT scans are being used to assess the response of the lake system to changing hydroclimatic conditions. The preliminary results of the XRF analysis, as evidenced by anomalous amounts of thorium (Th), rubidium (Rb) and strontium (Sr), suggest that episodes of notable environmental change occurred at 4.9, 4.2 and 3.1 ka. This paleoenvironmental record will provide a longer-term context for understanding the capacity of the Harappa, a highly urbanized and centralized society, to respond to water resource challenges.

Changes in Harappa Civilization Corresponds to an Abrupt Climate Change Event At 4.2 Ka in Northern India

Emily Niederman¹, David Porinchu¹, Robert J. Speakman¹, Bahadur Kotlia²
¹ University of Georgia
² Kumaun University, India

References:
The Turner River Mound Complex is comprised of two parallel rows with over 40 massive shell mounds reaching 7 meters in height, 47 meters in length and 28 meters wide. Archeological investigations aimed to determine temporal and chronological association within regional site settlement patterns; purpose and function of features; and paleoecological history. Zooarchaeological analyses, stable isotope sclerochronology, geological coring and over 100 directly dated radiocarbon samples indicate changes in climatological and hydrological conditions occurred at the Turner River site over time, likely related to changes in sea level and/or precipitation. The settlement persisted through two major climatic events: the warm/wet conditions of the Roman Optimum and the cool/dry conditions of the Vandal Minimum, adapting to changes by terraforming new areas of Shell Works features.

The row of mounds most inland at the site date earlier and are contemporaneous with a higher sea level stand during the Roman Warm period (BC 250 to AD 400); and the row of mounds closest to the river appear to date more recently when sea levels had dropped during the subsequent Vandal Minimum (AD 500 to 850). This case study documents both continuity and change in coastal subsistence over a period of climate change, and that the people living at the Turner River site practiced a long-lived coastal tradition that relied on a suite of taxa that are particularly well-suited for a dynamic environment, with large tolerances for temperature and salinity. Their economy was resilient because it relied on a resilient resource base, one that persisted in spite of major climate shifts.

SCHEDULE

Tuesday May 21st

Poster Session A

A-1 Rapid Atmospheric \(^{14}\text{C}\) Changes in Construction of Absolute Dendrochronological Scale for Pine Tree from Ujście (North–West Poland)

Andrzej Rakowski¹, Marek Krapiec², Matthias Huels³, Jacek Pawłtya¹, Damian Wiktorowski²

¹ Silesian University of Technology
² AGH University of Science and Technology
³ Kiel University

Miyake et al. (2012, 2013 and 2014) described a sudden increase of radiocarbon (\(^{14}\text{C}\)) concentration in annual tree rings of Japanese cedar (Cryptomeria japonica) and Hinoki cypress (Chamaecyparis obtusa) between AD 774 and 775 and between AD 993 and 994. In both analyzed periods, the sudden increase was observed almost in a single year. The increase in the \(^{14}\text{C}\) content was about 12‰ in the period AD 774–775 (Miyake et al. 2012) and about 11.3‰ in the period AD 993-994 (Miyake et al. 2013, 2014). Similar increase was observed in 660 B, with a peak height of about 10‰ (Park et al. 2017). Single-year samples of dendro-chronologically dated tree rings (Quercus robur) from Grabie and Kujawy village near Krakow (SE Poland), were collected and their \(^{14}\text{C}\) content was measured using the AMS system. The results clearly show a rapid increase in the \(^{14}\text{C}\) concentration in tree rings between AD 993/994, AD 774/775 and after 660 BC similar to this observed in literature (Miyake et al. 2012, 2013 and 2014, Park et al. 2017).


A-2 Abrupt Increase of Radiocarbon Concentration in the Past in Tree Rings from Grabie and Kujawy Near Cracow (SE Poland)

Andrzej Rakowski¹, Marek Krapiec², Matthias Huels³, Jacek Pawłtya¹, Damian Wiktorowski²

¹ Silesian University of Technology
² AGH University of Science and Technology
³ Kiel University

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A-4 Annual Radiocarbon Dating of Japanese Tree Rings: Early-Modern and Ancient

Minoru Sakamoto¹, Masataka Hakoizaki², Hiromasa Ozaki³, Fuyuki Tokanai³, Takeshi Nakatsuka⁴

¹ National Museum of Japanese History
² The University of Tokyo
³ University of Oxford
⁴ Rijksdienst Voor Het Culturele Erfgoed

Producing annual measurements on known-age tree-rings is a central component of the ECHOES project at the University of Groningen. More than 300 measurements have already been made, with a large proportion of these focused on existent, or suspected, single-year increases in atmospheric radiocarbon concentration, commonly referred to as Miyake Events. In so doing, minor deviations from the established calibration record have been uncovered, alongside previously hidden substructure in the atmospheric radiocarbon record. Here, we provide a summary of some of the periods analyzed so far, including much of the 3rd, 8th and 10th centuries CE and the mid-16th century BCE. The congruence of our results with other annual records, and the decadal calibration data set, is reviewed and the reasons for potential trends and divergences discussed.

A-3 Annual Radiocarbon Data from Disparate Dendrochronological Archives

Margot Kuitemps¹, Andreas Neocleous¹, Andrea Scifo¹, David Brown¹, Daniel Miles³, Esther Jansma⁴, Michael Dee¹

¹ University of Groningen
² Queen’s University Belfast
³ University of Oxford
⁴ Research Institute for Humanity and Nature, Japan

We are continuing on radiocarbon dating of Japanese tree rings to reveal the fine structures and local offset from IntCal. The former is important in order to carry out \(^{14}\text{C}\) wiggle-matching adapting a small number of samples. We report the results of Japanese cypress of central Japan of the 15th century, from the late 17th to the late 18th century AD of which the biennial data were already presented in the last AMS conference. In this period, certain dispersion was found in another Japanese tree dating and radiocarbon analysis of annual growth rings is possible to use “Wiggle matching” technique to precise determination of the calendar age of samples of pine, from the floating pine chronology (2U_02A) for central Poland. Absolute dating chronology 2U_02A covering 227 year, determined on the basis of 50 individual sequences is of great importance for archaeology of the early Middle Ages. This is particularly important for polish history, as during the period covered by this chronology, evolutionary changes occurred, such us the transition from tribal organization to the state organization and the emergence of a series of fortified towns, which dendrochronology dating without pine standard is difficult. So far, summarized standard curves for pine in Poland date back from the present to 1106 AD for Gdańsk Pomorania (Zielski 1997) and 1081 AD for Lesser Poland (Szyszowska-Krajcze 2010) and does not include the Xth century AD.


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Margot Kuitemps¹, Andreas Neocleous¹, Andrea Scifo¹, David Brown¹, Daniel Miles³, Esther Jansma⁴, Michael Dee¹

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**Radiocarbon and Archaeology 9th International Symposium**

**Schedule**

**Tuesday May 21st**

**Poster Session A Continued**

Athena Ballroom A–C

4:40 – 6:20

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**A–5**

Search for the Potential $^{14}$C Excursions in the Radiocarbon Calibration Curve Data-Potential Problems of Radiocarbon Dating in Archaeology

**Jacek Pawlyta¹, Andrzej Rakowski²**

¹ Silesian University of Technology

² University of Silesia

Miyake discovered and other authors supported this discovery that there were some rapid changes in $^{14}$C concentration in the atmospheric carbon dioxide. Till today there is a discussion about origin of the changes. Nevertheless, all of them should be of radiocarbon community attention because of the potential use in precise radiocarbon dating and problems occurring during when dating samples of single- to five-year resolution. This is specially important for interpretations of radiocarbon dating in archaeology. Previously published results of researches suggest that the changes have been observed for periods no longer than couple of years with the amplitude of several % and rise time of a year or less. We made a survey of available data used to build IntCal 13 radiocarbon calibration curve. Datasets which are potentially suitable for the investigations of rapid $^{14}$C were selected. For some periods of time we tried searching for potential atmospheric $^{14}$C concentration excursions. We propose digital filter for searching of the abrupt $^{14}$C excursions in calibration curve data. We will also present results of the search made with the filter and will evaluate statistical significance of our findings.

**Acknowledgments**

This work was supported by National Science Centre, Poland, grant UMO-2017/25/B/ST10/02329.

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**A–6**

Radiocarbon Dating as A Preliminary Anchoring Step in Multimillennial Tree–Ring Chronology Development and the Determination of Appropriate Error Ranges for Modeling Inner and Outer Ring Dates in Long–Lived Species

**Katharine Napora¹, Alexander Cherkinsky¹, Robert Speakman¹, Victor Thompson¹, Robert Horan², Blaine Tyler³, Craig Jacobs²**

¹ University of Georgia

² Georgia Department of Natural Resources

In this poster, we compare annually determined dates from a subfossil deposit of bald cypress (Taxodium distichum) in coastal Georgia, U.S.A., with the radiocarbon dates we obtained from near-pit and outer ring locations as a preliminary grounding step for the creation of the ringwidth chronology. Many of these trees lived for multiple centuries, and in some cases, over a millennia. Based on known dates determined from ringwidth analyses, we discuss appropriate error ranges to incorporate into calibration models to better guide crossdating in dendrochronological studies utilizing very long-lived tree species, particularly those prone to missing and false ring formation.

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**Time to Eat: Recalibrating Dietary Changes and Domestication in Human History**

**Chair: Timothy Baumann**

Radiocarbon dating has been a primary tool used by archaeologists to understand human dietary patterns and the domestication of plants and animals over time. Recent studies have applied Bayesian statistical analysis to reexamine these dates and create regional models of when and how food/foodways developed, transformed, and spread. These models have then been used to address larger questions on cultural complexity, community and trade networks, conflict and migration, health, climate change, and environmental impact of human.

**B–1**

New Perspectives on the Timing and Dispersion of Archaic Maize in the North American Southwest

**Lori Barkwill Love¹**

¹ University of Texas at San Antonio

Although originally domesticated in Mexico, the initial adoption and spread of maize (Zea mays) is fundamental to understanding the transition from foraging to farming in the North American Southwest, an arid region with considerable ecological diversity. Recent discoveries have pushed back the introduction of maize in the Southwest prior to ca. 2100 Cal. BC. However, the dispersal route(s) and degree of adoption during the Archaic period remain topics of debate. The dispersal of maize has been suggested through various highland and lowland routes. In addition, models of the degree to which maize was incorporated into the Archaic hunter-gatherer’s lifeways range from minimal dependence to a rapid replacement.

Relying on over 300 radiocarbon dates acquired on maize macrobotanicals from 50+ Archaic sites, this poster uses Bayesian chronological modeling and kernel density estimation (KDE) modeling to examine the introduction, dispersal, and adoption of maize in the North American Southwest. For both the Bayesian analysis and KDE analysis, models are created based on ecological regions and elevation levels. The results of the Bayesian models suggest that the initial introduction of maize occurred by the mid-thirty-seventh century Cal. BC. Once introduced into the Southwest, maize dispersed northwards from the lowlands in the Sonoran Desert to the highlands of the Arizona/New Mexico mountain and plateau areas, but this initial dispersal did not occur until around 2500 Cal. BC.

The KDE models suggest that the intensity of maize in the Southwest waxed and waned throughout the Archaic period, but in varying degrees in different ecological regions and elevation levels. This varied intensity may be in response to regional ecological differences as well as the impacts of climate shifts in the Southwest. The KDE models allowed for the examination of trends in the relationship between maize intensity and climate change. In general, there does appear to be a relationship between drier, warmer climate and a decrease in maize intensity. This study highlights the use of using multiple statistical methods from different perspectives to examine large radiocarbon datasets to address issues such as the transition from foraging to farming.

**B–2**

Intensified Management to Sheep/Goat Through the Transition from Bronze Age to Iron Age

**Weimiao Dong¹**

¹ Fudan University

A set of sheep/goat fragments from three burial sites in Eastern Xinjiang, China were isotopically analyzed to find that there is a significant isotopic composition change from Bronze Age to Iron Age. As 37 Bronze Age samples produced a mean $^{13}$C value of $-13.7 ± 0.3‰$ and $^{15}$N value of $8.3 ± 0.3‰$, 02 Iron Age samples output a mean $^{13}$C value of $-13.7 ± 0.3‰$ and $^{15}$N value of $11.0 ± 0.2‰$, the third one with $-16.4 ± 0.2%$ and $8.7 ± 0.2%$ for mean $^{13}$C value and $^{15}$N value, respectively from a site chronologically fall into the gap of those two aforementioned sites. It is detectable that human management to sheep/goat intensified during the transition from Bronze Age to Iron Age (Kruskal-Wallis Test, $X_1 = 52.557$, $P_1 < 0.1$; $X_2 = 42.226$, $P_2 < 0.1$).
Radiocarbon and Archaeology 9th International Symposium

Schedule

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Poster Session A Continued
Athena Ballroom A–C
4:40–6:20

Radiocarbon Laboratories Past & Present
Chairs: Jeff Speakman and Alex Cherkinsky

Since the first published application in 1949, radiocarbon dating has been the most widely applied analytical approach for dating archaeological and historical materials. Over the past 70 years, numerous radiocarbon labs have opened and/or closed—each with its own unique history, trajectory, and contribution(s). This session provides a forum for documenting the specific histories of radiocarbon laboratories both, past and present, that have existed over the past 70 years. The purpose of this session is to document in one place, the histories of individual laboratories, their major accomplishments and their major contributions to the field, so that as we look to the future of radiocarbon dating in archaeology, we have documented, to some extent, where we have already been.

C-1
The Underground Mystery of the "Santo Spirito" Hospital in Lecce: Results of AMS 14C Dating
Lucio Calcagnile¹, Marisa D’ella¹, Gianluca Quarta¹, Lucio Maruccio¹, Giovanna Cacucci², Maria Piccarreta², Eugenia Vantaggiato²

1 University of Salento
2 Belle Arti E Paesaggio Per Le Province di Lecce, Brindisi E Taranto

The building named "Santo Spirito Hospital" (Holy Spirit Hospital) is located in the city center in Lecce, Southern Italy and is the only existing example of a Renaissance hospital in the city. The building, located soon after one of the ancient entrances to the old center of the city, was established in 1392 CE and it was initially dedicated to Saint John Baptist and was managed by the Dominican order. The building was almost entirely demolished and then restored, rebuilt and extended in 1548 CE by Gian Giacomo dell'Acaya, a famous Italian architect and engineer specialized in fortified constructions. The entire historical complex was used during the flourishing period of the Renaissance as an hospital hosting also a church and a monastery. Over the years the building gained importance becoming the most important hospital of the city till the beginning of the 20th century when a new, modern hospital was finally established. In the following years the building was used for military purposes and to host a Tobacco factory. Since 2011 the building was established as the new venue of the local offices of the Ministry for Cultural Heritage and has been interested by extensive restoration works. During the structural recovery of the building an underground cavity was found below the floor of the 17th century church. The cavity takes an area of 150 square meters and its entire volume is full of bones of several hundred of individuals. With the aim of assessing the age of the buried individuals and the different phases of use of the cavity an AMS radiocarbon dating campaign was planned and carried out at the Centre for Applied Physics, Dating and Diagnostics-University of Salento. About 80 bone samples were taken from the cavity and submitted to AMS 14C dating. We present the obtained results which have been used in inter-comparison studies between "known-age" standards and tertiary "in-house" standards. These known-age materials is essential for monitoring the quality of Radiocarbon analyses. The SUERC in-house preparation, measurement and data analysis of appropriate quality assurance samples have already been described, showing the importance of a multidisciplinary approach for the study of complex archaeological contexts.

C-2
Multi Material Radiocarbon Dating and Stable Isotopes Analysis of the "Romito 9" Paleolithic Burial in Grotta Del Romito–Italy
Lucio Calcagnile¹, Gianluca Quarta¹, Domenico Lovetto³, Fabio Martini³, Pierfrancesco Fabbrì¹, Giovanni Zanchetta¹, Monica Bini³, Marisa D’ella¹

1 University of Salento
2 Università Di Firenze
3 Università Di Pisa

Grotta del Romito (Northern Calabria, Italy), with its rare examples of rock art and multiple burials, is one of the most significant Palaeolithic sites on the Italian peninsula. The human frequentation of the cave was almost uninterrupted, spanning from Upper Palaeolithic (24000 - 10000 BP), until the Early Mesolithic (9000 BP). A further frequentation of the cave is attested by scarce remains, which refers to the Middle Neolithic. Recent excavations carried out at the site by the Prehistory Unit of the University of Florence had brought at the discovery of a new Upper Palaeolithic burial (Romito 9) which refers to the Epigravettian culture (19-10000 BP).

"Romito 9", is the oldest among the nine burials found at the site. It belongs to a young individual laid supine, with the legs slightly bent, on a red ochre bed and endowed with a rich ornamentation consisting in thousands of artefacts including almost 1500 pierced marine molluscs shells (Cylope nereites) and a hundred pierced red deer (Cervus elaphus) atrophic canines.

In order to define the chronology of the burial different samples were selected and submitted to AMS (Accelerator Mass Spectrometry) radiocarbon dating at CEDAD-University of Salento. The samples selected for the analyses were: human bones obtained from different parts of the skeleton, charcoal recovered from the archaeological level in which the funeral pit was opened and pierced sea shells (Cylope and Dentalyrum) found in archaeological association with the dated burial. These samples were investigated for preserved composition using XRD and SEM-EDS microscope. Further stable isotopes analyses (carbon and oxygen) are foreseen on these samples and on Cyclope nereites of the ornamentation, for complementing mineralogical observation and better understanding the provenance of the specimens.

AMS measurements were performed at CEDAD by using both the standard procedure consisting in the combustion/graphitisation process and the new IRMS/AMS system, which allowed to obtain information about the bone collagen and the stable isotope ratios (δ13C and δ15N)The obtained results are presented and discussed, showing the importance of a multidisciplinary approach for the study of complex archaeological contexts.

C-3
The AMS Radiocarbon Dating Laboratory of the University of Salento – Italy
Lucio Calcagnile¹, Marisa D’ella¹, Gianluca Quarta¹, Lucio Maruccio¹

1 University of Salento

The Center of Applied Physics, Dating and Diagnostics was established in 2001 at the University of Salento, Italy to become a national Center for research and service in radiocarbon dating by Accelerator Mass Spectrometry. The Center is based on a 3 MV Tandetron (Mod. 4130 HC) by HVEE which is equipped, today, with six experimental lines for AMS analysis, ion implantation and ion beam analysis. After eighteen years the Center has fully accomplished its original mission providing a stable, reliable and accurate radiocarbon dating service to different research communities. We review the instrumental developments of the facility, with the last one consisting in the installation of an EA-IRMS system directly coupled to a hybrid sputtering ion sources. This new set-up, now in fully routine operation, allows to combine C and N elemental analysis, stable isotopes determination on sample with masses in the microgram range. This has resulted in a very powerful tool in cultural heritage studies considering the possibility to reduce the needed amount of material to sample, to have information about the diagenetic state of collagen and about the diet.

The development of combined, multi-technique approaches where different analytical accelerator –based methods are simultaneously used to solve the same problem has been one of the other keys for the success of CEDAD. For instance the use of AMS and IBA analyses, on the same sample or on samples recovered from the same context, allows to combine the chronological information given by 14C dating with the compositional non-destructive, high sensitive compositional analyses achievable by Ion Beam Analysis.

Different case studies are presented and discussed such as the dating of ancient bronze statues, the assessment of the chronology of prehistoric archaeological sites and application in the history of art.

C-4
The Importance of Quality Assurance Data from Radiocarbon Laboratories: Current SUERC Quality Assurance (QA) Data
Elaine Dunbar¹, Brian Tripney¹, Philip Naysmith¹, Marian Scott², Gordon Cook³

1 SUERC Radiocarbon Laboratory
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Preparation, measurement and data analysis of appropriate quality assurance samples is essential for monitoring the quality of Radiocarbon analyses. The SUERC in-house quality assurance program involves the measurement and monitoring of a primary standard, secondary "known-age" standards and tertiary "in-house" standards. These known-age materials have been used in inter-comparison studies between 14C laboratories worldwide and have a well-defined consensus age or activity value.
It is importance for archaeologists to understand the QA procedures and the data produced by their preferred laboratory. The SUERC Radiocarbon Laboratory makes use of 5 known-age standards, referenced directly to the oxalic acid primary standard (SRM-4990C) for the measurement of archaeological samples. The sample details and laboratory values for both the secondary and tertiary standards used in the laboratory are detailed, while the consensus values from the relevant Inter-comparison studies are also listed for comparison. In addition, a detailed explanation is provided to explain the use of each QA standard and the range of values annually achieved from these materials. Within the wider context for the long term preparation and analysis of QA standards, we explain the importance of understanding this QA data and their statistics is clarified.

C-5
The Contribution of Radiocarbon Dating and Ancillary Isotopes to Understanding our Archaeological Heritage
Elaine Dunbar¹, Derek Hamilton¹, Brian Tripney¹, Kerry Sayle¹, Philip Naysmith², Gordon Cook³
¹ SUERC Radiocarbon Laboratory

Since the 1950s, radiocarbon dating has facilitated a means of calculating the age of carbon materials formed within the last 50,000 years, providing an independent method of dating material from our past. Recent advances in radiocarbon science, AMS measurement capability and archaeological statistics have helped develop the technique further so that accurate dates can now be obtained on materials as small as single cereal grains, with decadal precision. Newer applications such as High Performance Liquid Chromatography (HPLC) can isolate and collect defined amino acids from extracted bone collagen. This isolation of a specific dateable fraction from potential contaminant organic material within a sample can potentially facilitate the radiocarbon measurement of low collagen yield bones, or even treated or varnished bone, previously thought non-dateable. Furthermore, the determination of ancillary stable isotopes, δ¹³C, δ¹⁵N and δ³⁴S can also provide a wealth of information to back up sample identification or indicate dietary preferences within bone collagen samples. In addition, the analysis of Sr and O isotopes from the biopatite component within skeletal material can be used as an indicator of human or animal migration. Present here is an overview of the above-mentioned analytical capabilities, all undertaken at SUERC, exploring the advantages that a detailed suite of analyses brings to understanding our national heritage.

C-6
The Movius-Libby Correspondence
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This poster will present analysis of the Movius-Libby correspondence from the late 1940s to the mid 1950s. It will situate it in the wider context of the history of archaeology, and the impact of the technique as part of the first radiocarbon revolution. It will discuss the wider geopolitical context, and the global next work of the researchers which contributed to development of the technique.

C-7
ARTEMIS, The ¹³C AMS Facility of the LMC14 National Laboratory – Status Report
Christophe Moreau¹, Bernard Berthier¹, Stephane Hain¹, Bruno Thellier¹, C. Messager¹, L. Beck¹, I. Caffy¹, E. Delqué-Kolic¹, J.-P. Dumoulin¹, S. Mussard¹, M. Perron¹, V. Setti¹, M. Steudat¹
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The LMC14 National Laboratory is holding the ¹³C ARTEMIS AMS facility and the associated benches for ¹³C sample preparation. ARTEMIS is dedicated to high precision ¹³C measurements. It routinely measures over 4500 samples a year for the French research institutions. ARTEMIS is a 3MV NEC 9SDH-2 Pelletron. It was installed in 2002 in Saclay and gave its first date in April 2003. Since 16 years of C14 dating, the quality control of the measurement is a daily concern.

Quality control procedures are applied in each step of the sample route, from the preparation to the data analysis. Routine procedures are applied to the sample preparation according to the type and size of each sample. An accurate AMS facility tuning procedure is implemented in order to control the carbon beam evolution through the optical elements of the beam line. Each unknown sample is measured with accompanying samples, international standards, blanks and intercomparison samples, which give a powerful set of data to control the quality of each measurement. These quality control samples are consistently chosen according to the type, the species, the size and the period of production of the unknown sample. An homemade database has been created to store the sample information and the evolution of the control samples. This database is the main tool to control the quality of the ¹³C AMS measurement in the LMC14 National Laboratory.

In addition to quality control procedures and tools, the LMC14 laboratory participated to the sixth International Radiocarbon Intercomparison, named SIRI. This radiocarbon laboratory quality assurance programme gives the possibility of comparing every SIRI radiocarbon date coming from ARTEMIS to the SIRI consensus values calculated on all the dates coming from the laboratories involved in the SIRI programme. Statistical tests are then used to appreciate the quality of the preparations and measurements made by the LMC14 national laboratory.

Research and Development programmes are done at the LMC14, in order to develop the preparation benches and the ARTEMIS AMS facility. Since many years, ultra-small samples study is one of the main interests for the LMC14. Very accurate procedures are set up to carry out under good conditions the analysis on such samples. Taking advantage of the ultra-small samples procedures, several applications in Culture Heritage have been made and others are in progress.

C-8
PaleoResearch Institute Radiocarbon Lab
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¹ PaleoResearch Institute, LLC

For more than 10 years prior to starting a radiocarbon lab, we conducted taxonomic identification of charcoal for geologists who wanted to radiocarbon date seismic and/or paleoflood activity. Pressure to perform all analyses lead to starting a radiocarbon dating facility, knowing we would likely never acquire an AMS machine. In the 1990’s and 2000’s there were multiple radiocarbon labs around the world that performed chemical pretreatment and converted the charcoal and other samples to carbon dioxide prior to submitting them to AMS facilities. Under the tutelage of Dr. Thomas W. Stafford, Jr., we embarked on this process, noting that not all charcoal behaved similarly during chemical pretreatment. We ran our first radiocarbon samples in 2004.

As interest expanded to ash-filled archaeological features, we determined we could extract microscopic charcoal for AMS radiocarbon dating. We tested sample pairs, observing that in the vast majority of cases the dates returned were identical or at least fell within two-sigma standard deviations. We employed wet oxidation using nitric acid to ensure that we removed as much contamination as possible and that we were not simply creating the accurate uncertainty of dating humates. We found that our methods yielded reliable dates on microscopic charcoal (< 100 µm) we offered this as an alternative to dating humates. Due to the fact that we ventured into the radiocarbon dating arena with the objective of providing a more seamless service to our clients, adding this service was a logical extension of our ability to provide more accurate radiocarbon dates on features containing only ash and very fine sand sized charcoal and no macroscopic (&gt;2 mm) charcoal.

Our most recent research frontier has been tackling issues of the presence of ancient charcoal in charred food crust and bone samples. We now view these issues as related, much as they are in northern Europe, where ancient carbon from local bedrock and soils, have created significant old-carbon reservoir effects in freshwater streams, environments previously thought devoid of reservoir effects. Although we originally recognized the issue of freshwater offsets and presence of ancient carbon as plaguing charred food crust dates from some regions, e.g., lakes across Minnesota, we have learned that even mammal bones could produce dates offset by a few thousand years. We have used the principles of cooking chemistry to separate charred carbohydrates from uncharred fats/lipids. We have studied the distribution of dates produced by sampling food char from different regions of vessels and conclude that the constituents of charred food crust affect the radiocarbon dates, with carbohydrates producing the most reliable dates, and burned proteins frequently yielding more ancient dates. Recovery of uncharred fats/lipids and proteins from charred food crust yields more age-appropriate dates. Bone collagen and burned bone, as well as meat and fat, may contain ancient carbon in geographic areas containing ancient carbon, making thoroughly calcined bone more likely to yield age-appropriate dates in those areas. PaleoResearch Institute’s continued participation in radiocarbon dating relies heavily on our ability to contribute to research topics such as those mentioned here.
**C-9**
Simultaneous δ¹³C, δ¹⁵N and δ³⁴S Analysis of Archaeological Bone Collagen at the SUERC Radiocarbon Laboratory: A New Analytical Frontier
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² Thermo Fisher Scientific

The use of multi-isotopic analysis (δ¹³C, δ¹⁵N and δ³⁴S) of archaeological bone collagen to assist in the interpretation of diet, movement and mobility of prehistoric populations is gradually increasing, yet many researchers have traditionally avoided analysing sulphur due to its very low concentrations in mammalian collagen. Although δ³⁴S values have proven to be an invaluable additional isotopic marker for ‘unpicking’ diet, the number of studies benefitting from an automated integrated system is still low due to the problems associated with producing, transferring and measuring SO₂ gas. While there is ~40% carbon and ~15% nitrogen in well preserved mammalian bone collagen, sulphur is present in concentrations of only ~0.2% to 0.3%, which poses a significant analytical challenge for simultaneous δ¹³C, δ¹⁵N and δ³⁴S analysis by Elemental Analyser Isotope Ratio Mass Spectrometry (EA-IRMS).

Previously, it was routine within the SUERC Radiocarbon Laboratory to analyse bone collagen samples twice; once for δ¹³C and δ¹⁵N (0.5–1 mg), and then a second time using a much larger sample (10–15 mg) for δ³⁴S. This resulted in longer analytical times and higher costs. However, this study demonstrates that a Thermo Scientific EA-Isolink IRMS system, which has the ability to rapidly heat a gas-chromatography (GC) column and concentrate the sample gas online, can produce δ¹³C, δ¹⁵N and δ³⁴S data from small samples of bone collagen (1–1.5 mg) in a single analysis, which means that the overall cost per sample analysis is reduced and less maintenance is required due to a significantly higher sample throughput. Moreover, the sensitivity and signal-to-noise ratio of the sample gas, especially SO₂, has improved, resulting in precisions of ±0.1% for δ¹³C, ±0.15% for δ¹⁵N and ±0.3% for δ³⁴S.

The ability to rapidly measure δ¹³C, δ¹⁵N and δ³⁴S isotopic values simultaneously in archaeological bone collagen is an attractive option to researchers that want to build larger, more succinct datasets for their sites of interest, at a much-reduced analytical cost and without destroying larger quantities of archaeological material.

**C-10**
A New Accelerator Mass Spectrometry Facility in Qingdao National Laboratory of Marine Science and Technology, China
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¹ Qingdao National Laboratory for Marine Science and Technology

A new accelerator mass spectrometry (AMS) facility has been established in the Center for Isotope Geochemistry and Geochronology at Qingdao National Laboratory for Marine Science and Technology (QNLM) in Qingdao, China. The AMS system is a 0.5 MV Model 1.5SDH-1 pelletron accelerator, manufactured by the National Electrostatics Corporation (NEC) in USA. The AMS system was installed and passed the acceptance tests in November 2018. It has the capability for high precision measurements of ¹⁴C, ³⁵Ar and ³⁶Be. The AMS facility is also supported by a laboratory of stable isotope ratio mass spectrometer (IRMS) and a modern sample preparation graphitization system of AGE3, manufactured by Ionplus of Switzerland. The Center for Isotope Geochemistry and Geochronology at QNLM, with additional major instruments such as TIMS and MC-ICP-MS, is the first such integrated facility in China and is dedicated to provide quality services for isotope and radiocarbon dating measurements for marine science and environmental studies in the years to come.
D–3
The Chronology of Middle Bronze Age at the Eastern Fringe of Carpathian Basin
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³ University of Arizona

We focus on the culturally-diverse Middle Bronze Age Carpathian Basin, the region incorporating the north-eastern part of Hungary, south-east Slovakia and the north-western part of Transylvania. This region sets the scene for the development of a specific culture displaying marked similarities in its bronze working, pottery production and the habitat and environment. In this so called 'tell society' the main unit of the settlement networks are represented by a fortified and multi-layered central settlements known as tellis, surrounded by a ring of satellite plain sites forming an economic and social unity with the tell. The tells could be considered not only multi-layered settlements, but a ‘package’ connecting together central settlement structure, social, economic and certain environmental factors. The well organised, fairly hierarchical tell-communities, with a complex social structure, composed of modular units had mixed intensive farming economy based on agriculture and animal husbandry.

The Middle Bronze Age development of the Western Fringe of the Carpathian Basin (North-Western Transylvania [Romania], North Eastern Hungary, South-Eastern Slovakia) is closely linked from a chronological viewpoint to the evolution of the Otomani-Fűzesabony Cultural Complex. The first phase of the Middle Bronze Age (MB I) precedes the Apa-Hajdusámson type bronze hoard finds period. In the European archaeological literature the MB I is considered concurrent with the final phase of the A1 period in Central-European chronology which traditionally begins sometime after 2100 BC and ends around 1900 BC.

The refined chronology of the Middle Bronze Age was based on local radiocarbon determinations as well as on the radiocarbon data from Wietenberg, Otomani-Gyulavarsánd and Fűzesabony-Otomani, published in the Romanian, Hungarian, and Slovakian archaeological literature. In light of the modelled C14 data, the MB I period can be placed in the 2070–1890 BC interval, the MB II phase in the 1910–1730 BC interval, while the MB III phase can be dated to the 1760–1530 BC period. This refined chronology is the result of detailed Bayesian analysis of C14 published and unpublished radiocarbon data sets from this region.

The research was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2-15-2016-00009 ‘ICER’.

D–4
The Experience of Dating of the Organic Matter of The Soils and Cultural Layers of The Multilayered Settlement Kurilovka 2 (Kursk Reg., Russia)
Svetlana Sycheva¹, Vlasta Rodinkova¹, Elya Zazovskaya¹
¹ Institute of Geography RAS

The settlement Kurilovka 2 is located on the remnant of the first terrace above the floodplain at the confluence of the Sudzha and Psel rivers (Donieper River basin, southern part of the forest-steppe zone). The site has been explored since 2015. The archaeological collection obtained at the settlement includes few finds of the Neolithic and Bronze Periods, but the bulk of the material belongs to the 2nd - 3rd quarters of the 1st millennium AD and the Modern Period. The cultural layer is not stratified. The most of the material is represented by the “early Slavic” handmade pottery, the detailed chronological scale of which has not been developed.

14C-dating was used to clarify the age of the site, the chronological interpretation of specific objects, as well as for the reconstruction of the local paleolandscape situation. Samples were taken from the top and the slope of the remnant occupied by the settlement and from the Sudzha floodplain. A series of radiocarbon dates (21) was obtained for organic matter (OM) from the horizons of buried soils, alluvial interlayers, cultural layers and closed archaeological complexes.

The distribution of 14C dates, their comparison with the stratigraphic position of the soil horizons and archaeological data allow us to make some conclusions about the development of the paleolandscape. The earliest obtained dates are compared, respectively, with the early-Atlantic and late-Atlantic phases of soil formation, which are reflected in the formation of the lower part of the humus horizon underlying the cultural layer. The middle part of the humus horizon, somewhere transformed into a cultural layer, has 14C age of 4000 to 3000 BP, which correlates with the buried soil of the subboreal period.

14C age of 600 to 800 BP (obtained from a depth of 0.5-1.15 m from filling a ditch dug out, according to archaeological data, in the XVII-XVIII centuries, indicate high accumulation speeds of fine earth, characteristic for filling both natural and anthropogenic depressions. Probably it was filled with the material of the upper soil horizons that had the above indicated age.

In the sections laid on the flooded slope of the remnant and on the floodplain, two strata of alluvium are distinguished: young (depth 0.17-0.45 m) with pMC> 100% and older (depth 0.46-0.71 m), having an age of about 400 years BP, which coincides with the first phase of the Small Ice Age. This time is characterized by the increased anthropogenic activity in the region, which resulted in an increase in the rates of alluvial processes and the interruption of soil formation on the floodplain. At present, the bed and surface of the floodplain continue to form.

For the section 7-2016 and pit of excavation 2 in the elevated part of the remnant, dates were obtained that are comparable to the archaeological age of the early Slavic cultural layer. The series of dates obtained for OM, made it possible to expand ideas about the stages of the development of the site and landscape in the Holocene.

D–5
Dietary Estimation and 14C-Dating of Yayoi Human Remains in the Aoya-Kamijichi Site, Japan
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¹ National Museum of Japanese History
² Archaeological Research Center of Tottori Prefecture

The Aoya-Kamijichi site, which is located in the Tottori Prefecture, Japan, is one of the large Yayoi settlement during 2200-1700 BP. The 108 human individuals were excavated from a groove like a ring moat, but most bones were scattered and didn’t keep an original position. The excavated contexts and injury marks on bone surface implied that these human bones were originally buried in a single tomb and were re-buried in another area later. We investigated the contemporaneity of these human remains with 14C dating.

When human remains are used for 14C-dating, it is a problem that the marine reservoir effect through sea-food consumption cause disconceintion of human 14C ages. At that time, the Aoya-kamijichi site was situated next to the Japan Sea. The marine resource remains and various products for fishing activity have been found. Therefore, we needed to perform dietary estimation and to calculate contributing rates of marine resources, and then to correct and calibrate 14C ages. In this study, we also analyzed carbon and nitrogen isotope ratios of terrestrial animals and fish bones excavated from the site to properly evaluate marine resource consumption.

To calibrate 14C ages, we utilized the ShCal 13 and the Marine 13 calibration curves. Although Japan is located in the Northern hemisphere, 14C ages of Japan occasionally demonstrate disaccord with the IntCal calibration curve. Japanese researchers have pointed out that the J-Cal calibration curve during the late Yayoi period shows characteristic 14C fluctuation similar to the Southern hemisphere.

We carried out carbon and nitrogen isotope analysis and 14C-dating for three human individuals. Their diet indicated relatively-low marine resource consumption despite site location. Additionally, our study also revealed that they were alive in the same period. It can be presumed that numerous humans of the same period were buried in some place and re-buried later in a single tomb.

This work is supported by JSPS KAKENHI Grant Number 18H05505.
In Mexico, mollusks were highly appreciated by pre-Columbian cultures and many sites, they are not available, or exists in such a state of degradation, that it is usually preferred. These materials are reliable and representative, however, in When trying to establish the chronology of an archaeological site through $^2$ Universidade Federal Fluminense María Rodríguez-Ceja

Reservoir Effect Determination using Shells from Mexico

Mark Thacker¹

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Located on a steep-sided promontory on the south-east coast of the Isle of Skye, Castle Camus exemplifies several issues which have beset medieval buildings studies across Scotland - and paramount amongst these is chronology. Like many Scottish medieval sites, Castle Camus has been a highly visible focus of regional identity for centuries, with oral histories reporting that this was the location of an important Clan MacLeod stronghold, within which the clan chief had died in 1402. Relating this report to more conventional academic sources, however, is problematic. The castle doesn’t appear in contemporary documentation until later in the 15th-century (by which time the peninsula is held by the rival MacDonals) and although a 19th-century watercolour depicts the castle complex as a substantially upstanding multi-storey structure of at least three ranges, only very limited fragments of those buildings now survive above ground. As a result, architectural characterisations of the earliest surviving structure have been unconvincing, and typologically-speculative or historically-informed constructional chronologies have ranged from the 13th-16th-century.

The Scottish Medieval Castles & Chapels C-14 Project (SMCCCP) is an archaeological research programme seeking to inform our interpretations of Scotland’s medieval buildings by investigating the depositional histories of masonry materials in different physical, cultural and chronological contexts. Characterising variations in resource exploitation and examining palaeoenvironmental potential are a particular focus for the project, and Castle Camus was an early SMCCCP case study site.

During this study, samples of masonry mortar from the primary phase building were subjected to a suite of geoarchaeological, archaeobotanical and radiocarbon analyses. These indicated that the earliest mortar on the site had been manufactured from wood-fired O. edulis shells, tempered with lithic sands and gravels. Comparative analysis indicated that this temper is still consistent with current foreshore compositions, although the O. edulis lime-source has been in narrow decline in Scotland since the 19th-century and is now almost extinct in some areas. The relief fuel assemblage from this primary structure was dominated by high curvature fragments of Botulim with some Quercus and Pinus, and these genera are all represented in locally surviving semi-natural woodland populations and medieval pollen deposits. Five such mortar-entrapped fuel fragments were ultimately submitted for radiocarbon analysis, and these returned a narrow series of dates suggesting a primary phase constructional event in the late 13th to early 14th-century.

As with many other SMCCCP sites, this first independent chronological evidence for the construction of Castle Camus has allowed us to confidently reassess the physical and cultural environment within which this important building was constructed and enabled a more holistic multidisciplinary narrative for the castle’s development to emerge. It would appear likely that the primary phase structure examined here was indeed the castle building within which William Macleod died in 1402, but Castle Camus was also constructed on the very edge of NW European Quercus distributions and within a wider lordship which included a range of different environmental opportunities and constraints.

Reservoir Effect Determination using Shells from Mexico

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When trying to establish the chronology of an archaeological site through radiocarbon dating, terrestrial samples, such as bones, wood, charcoal, etc. are usually preferred. These materials are reliable and representative, however, in many sites, they are not available, or exists in such a state of degradation, that it is impossible to use them for the construction of the chronologies. An alternative to study the chronology of a site is the use of malacological material.

In Mexico, mollusks were highly appreciated by pre-Columbian cultures and were used for many different purposes: diet, artistic, commercial, ritual, tools, construction, and ornamental objects. It is common to find them in bracelets, necklaces and decorative pieces in burial offerings. Mollusks make their shells from carbon dissolved in the ocean or in the aquatic environment where they grow. Radiocarbon activity in aquatic environments is usually different from that of the atmosphere, therefore, organisms that grow in both environments, have different apparent ages even though they are contemporary. This apparent age, known as "reservoir effect", makes radiocarbon ages of marine organisms older than the continental ones. When trying to get a seashell age, it must be considered the reservoir effect at the local level and correct for it. The reservoir effect varies depending on latitude and other local factors and can also vary over time in the same region. Hence, it is necessary to investigate it at the local level. Once determined, the correction factor can be applied to other samples of shells that come from the same site, to obtain the real age.

To determine the reservoir effect, radiocarbon age of a terrestrial sample should be compared to that of a malacological sample that is contemporary and comes from the same context. The difference between the corresponding radiocarbon ages will be assumed as the value of the reservoir age for that area.

Globaly, there is a database (Marine Reservoir Correction database) where new calculated values of reservoir effect around the world are included. When a radiocarbon age is obtained from a shell whose site of provenance is known, this database is used to search the nearest localities and apply the correction. In Mexico, reservoir effect data from the different coasts are scarce, so when dating oceanic shells, is not always possible to apply a reliable reservoir effect correction.

We present results of radiocarbon dating of shell-terrestrial samples' pairs, temporarily associated and found in pre-Columbian burials as well as shells recovered from coastal contexts. Based on both values, it has been possible to determine the local reservoir effect of some coastal locations in Mexico. This will allow for applying the corresponding correction in samples of Mexican shells that come from nearby sites and will serve to enrich the worldwide database.

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Resolving Ambiguities in Calibrated Age Determinations

Chairs: Jennifer Birch and Sturt Manning

Plateaus, reversals, and other “wiggles” in the calibration curve that lead to multiple interpretations and ambiguity of radiocarbon age determinations have led scholars of the recent past to question the utility of radiocarbon dating for such periods. Papers in this session will address strategies for dealing with such “messy” portions of the calibration curve and how contemporary scientific, statistical, and archaeological methodologies are overcoming these challenges. Participants are asked to consider both advances in radiocarbon science and the implications of the derived insights on understandings of the archaeological record in the period in question.

Intercomparison of AMS Data Between Laboratories

Based on Annual Tree–Ring Data Sequences

AJ Timothy Jull¹, Tamas Varga², Irina Fanyushkina³, Fusa Miyake³, Richard Cruz¹, Gregory Hoelgins¹, István Major², Mihaly Molnár³

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We present a detailed analysis of a number of intercomparisons of data between different laboratories, which has grown out of various studies into annual tree-ring series. In general, there is excellent agreement between different laboratories for sequences from 5480BC, 3370BC, 800BC and the 11th century where we have intercomparison data between Debrecen, Arizona, Nagoya as well as other laboratories. Even though there are differences in annual data relative to IntCal, which have been reported by various groups, agreement between laboratories can be assessed from sequences of annual data. We report on our efforts to address this problem from the perspective of our laboratories.

The research at ICER was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2-15-2016-00009 ICER.
Coastal Archaeology
Chair: Susanne Lindauer

Coastal archaeology requires an interdisciplinary approach for a precise chronology and to gain a thorough insight into settlement patterns. Radiocarbon in terrestrial and marine materials plays an important role to provide the temporal aspect of the processes involved. This session invites papers on archaeology at the coast, including reservoir effects and dating of marine and estuarine organisms.

F-1
All Mixed Up: Mixing IntCal, SHCal, and Marine Calibration Curves to Date Polynesian Dogs in the Northern Cook Islands
Justin Cramb¹, Carla S. Hadden¹
¹ University of Georgia

Recent archaeological excavations on Rakahanga atoll, northern Cook Islands, produced one of the first examples of pre-European dog (Canis familiaris) remains found on Polynesian atolls. Direct dating of the dog remains by AMS is complicated by a number of factors. (1) The dogs’ diets consisted of a mix of marine and terrestrial protein. The marine and atmospheric ¹⁴C reservoirs differ by around 400 ¹⁴C years, necessitating the use of a mixed atmospheric/marine calibration curve. (2) Marine carbon is itself a mix of organic and inorganic carbon pools, with offsets from the marine calibration curve that vary over time and space (Petchey et al. 2008). (3) Atmospheric ¹⁴C reservoirs differ by up to ¹⁴C 80 yr between the Northern and Southern Hemispheres (Hogg et al. 2013; Reimer et al. 2013). The island group straddles the Intertropical/South Pacific Convergence Zones (Petchey et al. 2014), causing inter-hemispheric mixing of atmospheric ¹⁴C and necessitating the use of a mixed IntCal/SHCal/marine calibration curve. Marsh et al. (2018) take into account all of the sources of uncertainty outlined above, we calibrated three groups of dates within a Bayesian chronological framework using mixed IntCal/SHCal/marine calibration curves. Each group of dates included a sample of dog bone collagen, as well as paired marine (Pinctada shells) and terrestrial (short-lived botanicals) samples, all recovered from the same archaeological contexts. Stable isotope analyses of the dogs were used to estimate priors for the marine/terrestrial dietary components, and the paired terrestrial and marine samples were included in the model to further constrain local atmospheric and marine carbon offsets. Posterior probabilities indicated a 20/10/70 mix of IntCal/SHCal/marine calibration curves, with the earliest dog dating to ca 1320 – 1480 (85% hyp); shortly after or concurrent with initial colonization of the islands and before European contact.


F-2
Isotopic Character and Ages of Black Carbon in River and Marginal Seas of China
Wenjing Fu¹, Yuanzhi Qi¹, Xuchen Wang¹
¹ Ocean University of China

Rivers play important roles in mobilization and transport black carbon (BC) from land to the ocean. It is estimated that 26.5 ± 1.8 × 10⁶ tons of BC is transported in dissolved phase by the rivers each year, which accounts for ~ 10% of the global flux of dissolved organic carbon (DOC) (Jaffé et al., 2013, Science 340, 345-347). The sources of this large amount of riverine dissolved black carbon (DBC), whether it is from recent biomass burning or from ancient fossil fuel combustion is not clear. Here, we present results from radiocarbon (¹⁴C) measurements of BC in both dissolved and particulate phases transported in several major Chinese rivers, and in coastal seawater and sediments. Our results show that two distinct BC pools (young vs. old) were carried by the rivers. In the rivers, the ¹⁴C ages of DBC were much younger (475 to 1,510 years BP) than the ages of the particulate BC (PBC, 2,675 to 12,600 years BP). The ¹⁴C ages of DBC in seawater and sediment porewater were also much younger than the PBC. Isotopic mass balance calculation indicates that the DBC transported in rivers contained a large fraction BC (> 50%) derived from biomass burning while the PBC comprised mainly fossil fuel combusted BC. The great age differences of the two BC pools suggest that BC derived from biomass burning and fossil fuel combustion have different chemical structure. They also suggest those carbon pools are mobilized in different phases in the rivers, and cycled in different time scales in natural environments.

F-3
Shells from Tell Abraq, UAE: Supporting Chronology and Archaeology
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¹ Austrian Academy of Sciences
² Curt Engelhorn-Centre For Archaeometry
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Tell Abraq is a prehistoric settlement mound located on the coast of the Arabian Gulf at the border of the Emirates of Sharjah and Umm al-Qiwain. The occupation spans from the mid 3rd Mill BCE to the early 1st Mill CE, i.e. from the early Bronze Age and into the early pre-Islamic historic time. Hereby, the site provides the longest and most complete regional archaeological record for this time period. First excavations commenced in 1989 and provided a framework of the mound’s occupation history. Since 2007, renewed investigations in the Sharjah part of the site aim at obtaining a detailed archaeological and chronological sequence of the 2nd and 1st Mill BCE.

In this study we collected Terebralia palustris and Marcia spp. shells together with charcoal fragments (or charred date stone) from various discrete archaeological layers covering a period of around 1000 years. T. palustris could be recovered from all layers, whereas Marcia spp. was only found in two of them. Based on the radiocarbon ages obtained for these sample pairs we modelled a diachronic species-specific reservoir effect for Tell Abraq spanning the Bronze into the Iron Age, 4000 – 3000 cal BP (2060 ± 1050 cal BCE). The reservoir effects vary between 238 ± 39 to 115 ± 141 for T. palustris and from 285 ± 14 to 186 ± 35 for Marcia spp. Comparison of the results to the sea level curve of the Arabian Gulf reflects a pattern that relates sea water exchange with the Gulf of Oman to the reservoir effect of shells from the Arabian Gulf.
General Session

G-1
The Spatial Distribution of Shell $^{14}$C Ages in China
Peng Cheng¹, Jibao Dong¹

¹ Chinese Academy of Sciences

The use of the aragonite shells for $^{14}$C dating is restricted by the well-known limestone problem, many researchers only consider the effect of snail size on absorption of calcium carbonate, ignore the growing environment of snail. In order to further elucidate the possibility of land snail shells for radiocarbon dating, the modern land snail shells were collected from middle part of China to Hainan Island in this work. In the carbonate area, distributed in northern China, the snail shell age is relatively old, ranging from 2400 to 4000 years. However, in the no carbonate area, distributed in southern China, shell $^{14}$C dating results show modern origin. In southern China, soluble salt and carbonate in the soil were leached out, and the calcium content was about 1%. The favorable growth environment in the south encourages snails to eat a lot of plants to make up for the lack of calcium. Therefore, there are many modern carbons from plants in the shell, Brazilian et al., 2017 also found the shell were not affected by old carbon in Brazil. Brazil is in the subtropical region, and the living habits of snails are relatively similar to those in the southern China. Whether the shell can be used as a reliable $^{14}$C dating material, not depends on the size of snail but on the growing environment of snail. In the no carbonate area, reliable $^{14}$C dating can be achieved by using the terrestrial fossils shell discovered in the strata and archaeological sites.

G-2
Comparison of Accelerator Mass Spectrometry and Gas Proportional Counting Techniques for Radiocarbon Dating of Bones
Jakub Kaizer¹, Ivan Kontu¹, Mihály Molnár², Marta Richtáríková³, Alexander Sivo¹, Peter Čech¹, Pavel Povínc⁴

¹ Comenius University
² Isotope Climatology and Environmental Research Centre
³ State Geological Institute of Dionýz Štúr

Although development of accelerator mass spectrometry (AMS) revolutionized radiocarbon dating in archaeology through high throughput capabilities and small samples, there are still some institutes regularly exploiting conventional decay-counting techniques, such as gas proportional counting (GPC). When comparing a typical duration of sample pretreatment protocols, which are not the same but essential for both methods, we can say that they perform rather similarly. Therefore, gas proportional counting has still its place in $^{14}$C determinations, e.g. if one is not limited by sample size and/or measuring time, as well as when results of compound specific $^{14}$C analyses should be compared with analyses of bulk samples.

Radiocarbon dating is by far the most used method for age determination of bones in archaeological studies. In our previous study (Kaizer et al., 2018), we successfully dated 11 well-preserved vertebrate bones by GPC while keeping enough material from each sample to extract collagen, following the adapted version of the VERA-radiocarbon laboratory protocol (Wild et al. 2008). Sample collagen was combusted to obtain CO₂, which was then purified and converted to graphite for AMS measurements which were carried out in ATOMKI (Debrecen) using EnvironMICADAS (Molnár et al. 2013). The aim of the present work has been to compare new $^{14}$C AMS results on extracted collagen with those determined by GPC on total bone samples.


G-3
A Tale of Two Communities During the Late Bronze Age – Early Iron Age at the Site of Velzeke (Prov. of East-Flanders, Belgium)
Guy De Mulder¹, Elisavet Stamatakis², Amanda Sengeløv³, Rica Anneari³, Mathieu Boudin⁴, Giacomo Capuzzo⁵, Sarah Dale¹, Marta Hlad², Ioannis Kontopoulos², Charlotte Sabaux², Kevin Sallese³, Christophe Snoeck², Martine Vercauteren³, Barbara Veselka², Eugène Warmenbol³

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³ Université Libre De Bruxelles
⁴ Royal Institute for Cultural Heritage

The archaeological site of Velzeke is located in the western part of Belgium on a large plateau between two small brooks of the Zwalm river, a tributary of the river Scheldt. Furthermore the plateau is divided in two areas at the southern edge by a large natural channel. In the former century, two umfolds were excavated which were located at both sides of this natural channel. At the so-called umfield Paddestraat, 41 cremations graves were unearthed. The second burial area, Provincebaen, was disturbed by the later Gallo-Roman occupation. Nevertheless eleven cremations and a ring ditch were documented. Radiocarbon dating of the cremated bone showed that the umfield Paddestraat was occupied during the Late Bronze Age – its main phase – and the beginning of the Early Iron Age. The Provincebaen cemetery dated to the final phase of the Late bronze Age and the Early Iron Age. Both cemeteries were during a certain period functioning as a burial place side by side, probably reflecting two different communities. Furthermore, the osteo-archaeological study of the cremated remains showed that the cemetery at the Paddestraat was occupied by all segments of the population while at the Provincebaen only men have been identified next to a few undetermined identifications.

By using Strontium isotope analysis we want to determine the potential relationship between these communities and see if both groups have eventually different origins. At the site of Paddestraat, influence of the so-called ‘group Rhin-Suisse-France orientale’ is visible in the funerary sets used an um of a grave good in the initial phase of the Late Bronze Age. Strontium isotope analysis can offer the opportunity to ascertain if these funerary sets reflect central-European cultural influence or mobility, as has been proposed in hypotheses formulated by De Laet and Mariën in the post WW II-period.


G-4
Radiocarbon Dating of Kohitsugire Calligraphies that have been Thought to be Written in Insei Period (AD1050–AD1190) by Kana Letters
Hirotaka Oda¹, Kazuomi Ikeda²

¹ Nagoya University
² Chuo University

Kana are syllabograms unique to Japan. Kana letters were made by the modification and simplification of Chinese characters and considered to be developed in the early 10th century. Before the development, Japanese literary works were limited to calligraphy. In this work, the kana syllabary, however, gave rise to a constant production of compound specific $^{14}$C analyses should be compared with analyses of bulk samples.

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Radiocarbon and Archaeology 9th International Symposium

Schedule

Tuesday May 21st

Poster Session A Continued
Athena Ballroom A–C
4:40–6:20

G–5
The $^{14}$C and Thermoluminescence (TL) Dating of the Terra–Cotta Warrior
Weijian Zhou¹, Yizhi Zhu¹, Peng Cheng¹
¹ Chinese Academy of Sciences

The Terra-Cotta Warrior in the Qin Imperial Mausoleum at Lintong county, Shaanxi province, has been regarded as one of the “eight wonders of the world” since its discovery in 1974. There are three pits in the Terra-Cotta Warrior museum, among which pit 1 is the largest where charcoal and potsherd were unearthed. In this way, it is advantageous to carry out chronological study in the pit 1. Unfortunately, archaeologists have not yet found the exact historical record of both the time of the construction and destruction of pits. It was speculated that the Terra-Cotta Warrior began to be constructed by the first emperor of Qin in 221 B.C., that is 2207BP after his unification of China, and it was destroyed by peasant uprising in about 207 BC, so it only lasted more than 20 years from its construction to destruction. In order to provide scientific evidence, six charcoal and four potsherd samples collected from pit 1 were dated by the $^{14}$C and thermoluminescence techniques respectively. The results showed that the six $^{14}$C ages ranging from 2160-2250BP, and four TL ages ranging from 2130-2250BP BP, were consistent with each other within error, indicating the ages gained by different dating techniques were reliable. According to archaeological research, after the wooden shed was built, the craftsmen began to make pottery figurine. In this sense, the $^{14}$C age suggested the time of the construction of wooden shed, which can be estimated as the start time of making pottery figurine. Moreover, the dates of different potsherds of Terra-Cotta Warrior indicated different making times. It is probably confirmed that the time of construction was about 2250BP, and the destruction time was between 2130-2160BP. Our chronological results of pit 1 approximately responded to the archeological speculation.

period (the 10th and 11th centuries). Kohitsugire are ancient paper sheets with elegant calligraphy. They were originally leaves of ancient manuscripts written mainly from the 8th to the 15th century. Old manuscripts are rarely discovered as complete books; therefore, kohitsugire can be significant materials for historical studies. Among kohitsugire calligraphy, there are many counterfeits and copies written in several centuries later. However, kohitsugire calligraphies that have been thought that they were copied in Insei period (AD1050-AD1190) is different in circumstance. In elegant calligraphy of Heian period (AD794-AD1185) written by kana letters, there are many cases in which details of the inscription age is not clear. In such a case, it is often to be a calligraphy written in Insei period when is the era after the development of kana syllabary. Therefore, there are possibilities that there are valuable calligraphies written in the older period when corresponds to the development period of kana syllabary mixed in the kohitsugire calligraphies that have been thought to be written in Insei period. Therefore, in this study, we performed radiocarbon dating for three calligraphies of Insei period. Samples were cut from the margin of the kohitsugire sheets. They were soaked in H$_2$O to peel the surface sheets of the calligraphy from the mounted paper sheets forming a lining. The surface sheets were washed in H$_2$O with an ultrasonic cleaner, and treated with 1.2 M HCl, 1.2 M NaOH, 1.2 M HCl (60-70°C). After rinsing with H$_2$O (60-70 °C) and drying in a vacuum desiccator, they were combusted using CuO (850 °C, 3h) to form CO$_2$, and the purified CO$_2$ was reduced to graphite by H$_2$ (cat-Fe, 650 °C, 6h). The radiocarbon ages were measured by CAMS-500 (NEC, USA.) at Paleo Labo Co., Ltd., Japan. Calibrated radiocarbon ages of two kohitsugire calligraphies, Sougana-majiri-misho-uta-gire and Misyo-tirashi-uta-gire, showed about AD1000; it is a rare example precedent to the Insei period and valuable materials with prototype of kana letters. The other one kohitugire calligraphy called Minbu-gire has been regarded as a fragment of the valuable ancient manuscript of Heian period. Calibrated radiocarbon age of Minbu-gire, however, indicated the middle 17th century; it is a copy or counterfeit.
This session examines how recent developments in the analysis of scientific chronologies have related to archaeological narratives. We would like to consider how much new chronological sequences challenge the structure of archaeological chronological narratives. The session invites papers discussing: how we can use chronological approaches to investigate, critique or challenge pre-existing interpretations rather than replicate them; the challenges in producing narratives that tack between precise chronology and areas of relative imprecision; the tensions in dealing with large datasets, the legacy of grand narratives and individual sites; and the challenges in relating unique or exceptional sites to wider narratives of change.

9:00 AM

‘The Stuff of Which Life is Made is Time’. The Late Neolithic Monuments Around Dorchester, Dorset, UK

Peter Marshall, Susan Greaney, Christopher Bronk Ramsey, Elaine Dunbar, Irika Hajdas, Paula Reimer

1 Historic England
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In Wessex in the centuries either side of 2500 cal BC the appearance of great monument complexes around Stonehenge, Avebury, Knowlton, Marden and Dorchester marks this region of Southern Britain as somewhat unique. Between the rivers, Frome and South Winterbourne in Dorset around the Roman and modern town of Dorchester is a cluster of monuments that formed a major Late Neolithic complex. Research and developer-funded excavations throughout the twentieth century have provided evidence for the building and development of these monuments. A recent programme of radiocarbon dating and chronological modelling has refined our understanding of the timings of the structural sequences for these monuments. These new chronologies allow the construction of more precise and intimate archaeological narratives, enabling discussion of personal and social memory, of perceptions of the past and of the wider synchronicity of monument building.

9:20 AM

Large Datasets and Grand Narratives

Seren Griffiths

1 University of Central Lancashire

This presentation will use recent case studies from Holocene north-west Europe to discuss foundational concepts such as ‘events’ and ‘processes’, and how these are integrated into archaeological narratives in terms of causal reasoning. Recent developments in Bayesian statistical modelling have allowed chronologies with unexpected precision to be developed. Other approaches use summary statistics to produce generalising demographic models of change. These new datasets can be integrated into existing narratives. This paper will discuss the tensions between newly precise chronologies and existing temporal structures, and the degree to which big data studies could effectively challenge established narratives. It will suggest that despite increasingly sophisticated post-excavation analysis, palaeo-environmental proxy identification, and chronological modelling that yields increasingly precise analytical scales, workers often do not match these with sufficiently nuanced narrative frameworks.

9:40 AM

Radiocarbon Technique Applied to Key Issues Beyond Chronology in Historical Metallurgy and Archaeology

Jang Sik Park

1 Hongik University

The greatly reduced sample size in radiocarbon measurements with the advent of accelerator mass spectrometry (AMS) allows the little carbon dissolved in iron-carbon alloys to serve as suitable samples for directly dating a given iron object. Despite numerous uncertainties involved in relating the ¹⁴C data thus obtained to actual chronology, an increasing number of iron and steel artifacts are being subjected to radiocarbon analyses. It is significant to note that chronology alone is no longer the single primary target information but constitutes only one of the many objectives of such analyses. Interestingly, important applications of the radiocarbon technique to historical iron metallurgy derive from a variety of potential sources of carbon-contamination that raise skepticism about the use of radiocarbon measurements for dating iron artifacts. One of the recent developments includes confirmation of the technological transition that occurred in the Mongolian cast iron industry during the Khitan period (10th-12th century AD) based on the use of mineral coal instead of charcoal in smelting (Park et al. 2008). It has been established that this transition was carried forward into the subsequent Mongol period to become a dominant practice in the empire’s cast iron industry. Importantly, the pertinent variation in ¹⁴C concentrations produced strong evidence that coal was used only in the smelting of cast iron as opposed to charcoal that was exclusively utilized in other processes such as the smelting of bloomery iron and steelmaking from either bloomery iron or cast iron (Park 2015). Another recent development is found in the identification of early cast iron fragments that were recycled as input for a later steelmaking process in a charcoal-fired atmosphere (Park et al., in press). The factors responsible for the recent developments above, i.e., the use of mineral coal, recycling in later periods and the thermal treatment for steelmaking, all add to the uncertainty involved in the interpretation of the ¹⁴C age for a given iron object. In this presentation, it will be shown that this uncertainty, when combined with metallographic analysis and other lines of chronological evidence, can be clarified in order to provide an improved understanding of the chronology, technology, and diverse uses of an iron object across different time periods – key issues in historical metallurgy and archaeology. This research was financially supported by National Research Foundation of Korea (NRF-2017R1A2B4002082)


Park, J. S., Honeychurch, W., Chunag, A., in press. The technological and chronological implication of ¹⁴C concentrations in carbon samples extracted from Mongolian cast iron artifacts. Radiocarbon.
Chronological assignments within the field of Classical Archaeology are often based on the study of written sources and well-datable artefacts. However, chronological uncertainties may persist when contexts are poor in datable remains, the stratigraphy is unclear or has been disturbed, or when organic artefacts (e.g. bone) are decontextualized. Under these and other circumstances the employment of radiocarbon dating may provide an alternative or a complement for the establishment of absolute chronologies. Furthermore, by employing Bayesian modelling the integration of multiple sources of chronological information (e.g. radiocarbon dates, stratigraphic sequences, and typology) can be explored to obtain more precise chronologies of artefacts or events.

In this presentation, two case studies will be presented that illustrate the potential offered by radiocarbon dating and Bayesian modelling within Classical Archaeology in building more complex historical narratives. At the Oppidum of Monte Bernorio (Spain) combined modelling of radiocarbon measurements, stratigraphic sequences, and typological dating offered unexpected insights into the chronology of burial practices and artefact production and exchange. At a necropolis site in Centocelle (suburb of Imperial Rome) human radiocarbon dates revealed a complex history of site reuse. Chronological information was combined with multi-proxy (bulk collagen, amino acids, bioapatite) stable isotope analyses to provide important insights into the diet, nutrition, and spatial mobility of ancient Romans following the 3rd century crisis.

In this paper we use Bayesian chronological modeling to begin evaluating two differential manifestations of a large-scale, fifteenth-century population abandonment in eastern North America popularly known as the Vacant Quarter; specifically, in the Middle Cumberland River drainage of Tennessee and the Upper Tombigbee River drainage of Mississippi and Alabama. This phenomenon involved the uprooting of hundreds, if not thousands, of sedentary agricultural communities associated with the Mississippian period (ca. A.D. 1000-1500). We present Bayesian chronological models for the Kellytown site in the Middle Cumberland Drainage and three sites in the Upper Tombigbee Drainage (Butler, Lubub Creek, and Yarborough). Combined with the modeling presented in Krus and Cobb (2018), this provides a sample of 10 sites from two distinct Mississippian areas to begin comparing their pre-abandonment histories. Our results suggest that depopulation was nearly complete in the Middle Cumberland Drainage by the fifteenth century at a time when large-scale droughts were afflicting the region, but that more robust sampling is needed to understand the Upper Tombigbee River pre-abandonment chronologies. We further use a Bayesian simulation experiment to estimate the optimal number of samples needed to robustly estimate the pre-abandonment chronology for the Vacant Quarter in these two regions.
This session will cover technical advances in radiocarbon dating archaeological samples, including sample evaluation; contamination detection; novel approaches to dealing with problematic sample types; samples with low carbon concentration; ultra-small samples; and developments in compound-specific approaches.

**11:00 AM**
Assessing AMS Dating of Fiber-Tempered Ceramics: Comparing Bulk Combustion and Isolated Organic Temper (T. usneoides)

K.C. Jones¹, Carla Hadden¹, Travis Jones³, Robert J. Speakman¹

¹ University of Georgia

The lack of stratified contexts and absence of organic remains in surface assemblages at archaeological sites hinders our ability to create local chronologies and contextualize technological and socioeconomic changes. The most durable artifacts found in surface assemblages are typically ceramics and lithics, but methods for absolute dating of these cultural materials are limited. This research proposes an intensive method of directly dating fiber-tempered ceramics, which are often found in surface contexts in the southeastern United States. Direct dating of ceramic body sherds has been used when reliable wood, charcoal, or plant macrofossils are not available for analysis. Late Archaic (5000-3000 cal. BP) site destruction is so severe in the interior Coastal Plain of the southeastern United States that most of the archaeological record dating to this period has been erased from existence, leaving indirect surface scatters of artifacts separated from their original context. Direct dating of the plant fibers (T. usneoides) in these Late Archaic organic-tempered wares is instead used in place of more traditional dating techniques like ceramic seriation.

This study presents a comparative method of ceramic dating using both organic fiber AMS dates as well as low-temperature bulk combustion dates from the same specimen (see Janz et al. 2015). Four separate pretreatment methods were performed for each ceramic specimen: (1) isolation of individual fibers from the ceramic temper followed by standard AAA pretreatment; (2) isolation of individual fibers from the ceramic temper followed by standard AAA pretreatment; (3) standard AAA pretreatment followed by low-temperature bulk combustion of pulverized sherd fragments with exterior and interior vessel surface intact; and (4) standard AAA pretreatment followed by low-temperature bulk combustion of pulverized sherd fragments with vessel interior and exterior manually removed prior to pretreatment.

As a short-lived botanical, T. usneoides is a reliable material used to capture the manufacture date of ceramics. The isolation of individual fibers has been performed for this region and has been proven to produce accurate date ranges. The drawback to this method is its labor-intensive nature of extraction from the clay matrix. Bulk dating was instead considered as a more economical way of mass-producing accurate dates in a more timely fashion; however, precision-testing of this method is underdeveloped. Accurate bulk dating is further complicated by the presence of multiple organic and inorganic carbon fractions present in the clay matrix, each with potentially different 14C activity. Additionally, the presence of carbon bound by clay minerals can significantly reduce the accuracy of bulk dates, with the oldest 14C ages seen in samples with the highest clay content. Preliminary results suggest that dates derived from bulk samples with intact interior and exterior surfaces are in better agreement with those from isolated fibers. We believe this congruence can be explained by pervasive carbon alteration on the vessel surfaces minimizing or offsetting the contribution of clay-bound carbon within the interior of the sample.

**References**


**11:20 AM**
Lime Binders in Archaeological Contexts: Accurate Radiocarbon Dating Based on their Structural Characterization and Thermal Decomposition

Elisabetta Boaretto¹, Lior Begey¹, Eugenia Mintz², Ifat Kaplan-­Ashiri³, Stephan Dubernet³, Michael Toffolo²

² Weizmann Institute of Science
³ Université Bordeaux Montaigne

Pyrogenic carbonate (CaCO₃) has been a challenge for radiocarbon dating due to the presence of several contaminants included in the binder. The type of contaminants includes geological carbonates but also components derived from secondary phases with unknown radiocarbon concentration which are formed upon recrystallization processes and pozzolanic reactions. Several procedures have been proposed with partial success. Here we present a characterization approach to anthropogenic carbonates that includes Fourier transform infrared spectrometry (FTIR), X-ray diffraction (XRD), thin section petrography, and scanning electron microscopy coupled with high-resolution cathodoluminescence (SEM-CL), with which we identified the pyrogenic CaCO₃ fraction in archaeological lime binders from different regions and periods. The pristine pyrogenic carbonate was then isolated by density separation and carbon was recovered through step heating in vacuum. The aliquots obtained at different temperatures are aimed to select the fraction for dating avoiding the phases like the geological one and the secondary one, which decompose at higher and lower temperatures respectively. The obtained radiocarbon ages are in agreement with the radiocarbon dates obtained based on organic material in the binder or based on archaeological consideration.

Determination of the radiocarbon concentration of the non-pristine pyrogenic fraction can provide information about the diagenesis of the archaeological material.

**11:40 AM**
Assessing the Potential of Water-Related Contamination in Low Energy Plasma Radiocarbon Sampling

J. Royce Cox¹, Eric Blinman¹, Lukas Wacker², Marvin W. Rowe¹

¹ Center For New Mexico Archaeology
² ETH Zurich

Low energy plasma radiocarbon sampling is the oxidation of carbon from an object using low pressure, low energy oxygen plasmas (Rowe et al. 2017), collecting 30-100 μg C as CO₂ for direct AMS dating (Wacker et al. 2013). Plasma energy is kept below the carbonate dissociation threshold, and humic acid contamination is removed with a pH 8 phosphate buffer rinse. The principal contamination risk is atmospheric CO₂. High vacuum removes most atmospheric CO₂, and low energy argon plasmas kinetically dislodge lightly bound atmospheric CO₂ from sample and chamber surfaces. CO₂ release is monitored during argon plasma cleaning, and when CO₂ amounts are negligible, sampling with an oxygen plasma proceeds with confidence that CO₂ from the sample is uncontaminated.

A complication occurs if water is released from a sample during argon cleaning. The combined argon-water plasma initiates premature sample oxidation, producing CO₂ that we cannot distinguish from residual contaminating atmospheric CO₂.

An experiment was designed to address the risk of modern CO₂ contamination persisting through water release. TIRI Belfast pine samples are routinely dated and serve as a control. A water-saturated TIRI standard silver was cleaned with four argon-water plasmas, commonly sufficient to remove adhering atmospheric CO₂ contamination in non-water releasing contexts. A dating sample (80 μg C) was then created using only CO₂ evolved by the fifth combined argon-water plasma. Another dating sample was collected using only a water-vapor plasma (95 μg C). In both cases, thorough elimination of adhering contaminating CO₂ could not be assured due to the masking effects of premature oxidation. There was also a slight risk that contamination could be present as modern CO₂ dissolved in water. Dates on these TIRI samples
agree with six earlier dates on dry wood samples, as well as the inter-laboratory consensus dates. Despite the small sample sizes we found no suggestion of modern contamination from atmospheric CO₂ in either date. These results suggest that negligible risk of sample contamination with atmospheric CO₂ under conditions of water release from a sample during argon-plasma cleaning. Five argon plasma exposures appear adequate for eliminating “sticky” atmospheric CO₂ contamination, and water release does not appear to introduce significant CO₂ contamination under conditions of plasma sampling.


12:00 PM
Applications of A New Ninhydrin Protocol to the Radiocarbon Dating of Human Remains
Christian Hamann¹, John Meadows¹, Ricardo Fernandes², Christoph Rinne³, Andreas Nerlich³
¹ Kiel University
² Max Planck Institute
³ University of Munich

Improving the accuracy of radiocarbon dating of archaeological bone collagen has been a major research interest of the radiocarbon community for decades, because of the critical importance of bone material in many archaeological applications, and its complex structure. Pretreatment protocols derived from the method first proposed by Longin (e.g. alkali washes, ultrafiltration, nanofiltration) are routinely applied to remove soil contamination, but occasionally these well-established pretreatment methods do not fully remove contaminants. Compound-specific radiocarbon analysis of single amino acids (AAs) purified by high-performance liquid chromatography (HPLC) has become the preferred approach to dating challenging sample material in recent years (e.g. Fernandes et al. 2017). However, a ninhydrin-based method of isolating carboxylic carbon from AAs was already proposed by D.E. Nelson in 1991. The LSCE in Paris-Saclay is the only radiocarbon laboratory regularly using Nelson’s method, providing impressive results, especially on Pleistocene bones (Tisnérat-Laborde et al. 2016; Dumoulin et al. 2017). We present a new ninhydrin-based protocol, capable of easily being integrated into laboratory routines, allowing for the dating of different proteinaceous materials (e.g. bone collagen, hair keratin, muscle tissue) (Hamann and Santos this issue).

We tested the ninhydrin method by dating bones which were consolidated for conservation (as suggested by (Nelson 1991) and (Dumoulin et al. 2017)) and other applications of interest to archaeology, in which ninhydrin can be a convenient alternative to HPLC. These include as a screening technique to select bones with adequate collagen content for radiocarbon dating; dating low-collagen bones; and dating non-bone proteinaceous samples (hair, skin, leather, flesh), particularly if they have been conserved with consolidants. The differences of carbon stable isotope ratios between bulk collagen and carboxylic carbon from AAs extracted using ninhydrin have been used in dietary studies (Keeling and Nelson 2001). We discuss whether differences in radiocarbon ages between bulk collagen and carboxylic carbon can be expected in bones from omnivores subject to dietary reservoir effects.


Hamann C, Santos GM. This issue.


12:20 PM
Closed Tube Combustion Blanks and the Size Limit of Compound Specific Radiocarbon Analysis
Li Xu¹, Mark Roberts¹, Alan Gognon²
¹ NOSAMS, Woods Hole Oceanographic Institution
² Compound-specific radiocarbon analysis (CSRA) is a powerful tool to study carbon cycling and to obtain contamination free samples for geochronology. In most cases, sample sizes are small due the nature of the method, i.e. the need to obtain pure compounds. Therefore, it is very important to know the uncertainty of the method, especially for ultra-small samples (<25µg C). There are several steps involved in the CSRA, including extraction, derivatization, and separation of single compounds with chromatography methods, followed by oxidation / combustion to CO₂ for radiocarbon analysis. In an effort to expand the applicability of CSRA, we report new measurements of CTC and graphitization blanks. At NOSAMS, we used closed tube combustion (CTC) to produce CO₂ from separated compounds. To determine the lower limit and uncertainty of CSRA for small samples, we prepared small (5 µg to 50 µg C) CO₂ samples from Octacosane (Fm -0.0017, ± 0.0015, n=5) and squalane (Fm 0.9771 ± 0.0019 n=5) with CTC. A series small CO₂ gas samples were also obtained from big (~2 mg C) CTC of these two compounds. The small CTC and gas CO₂ were all reduced to graphite and measured by AMS. The Chi-square statistic was used to estimate the gas blank (graphitization and following steps) to be 0.35 µg C with an Fm of 0.50 and combustion blank (combustion and following steps) to be 0.70 µg C with an Fm of 0.50. The net contribution from combustion step was about 0.35 µg C.
The “Enhancement” of Cultural Heritage by AMS Dating: Ethical Questions and Reference: Huysecom E, Hajdas I, Renold M-A, Synal H-A, and Mayor A. 2017. This paper summarizes the ongoing activities, possible approaches and a call for an interdisciplinary co-operation. 

Other technical developments led to an increase in capacity of existing AMS laboratories. Moreover, new laboratories including specialized satellite laboratories were established. This created more opportunities for the antiquities markets for techniques. Among material studied typically are parchment, textiles, paper, and wood. Developments are made in the analysis of less common materials such as iron, mortar, binding media and pigments.

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The Mayan Codex of México (Grolier Codex): $^{14}$C-AMS Dating Revisited

Corina Solís¹, Miguel Ángel Martínez Carrillo², María Rodríguez-Ceja³, Efrain Chávez³, Andrés Cristhen³, A.J. Timothy Jull³

¹ Universidad Nacional Autónoma De México
² Centro De Investigación En Matemáticas
³ University of Arizona

Mesoamerican codices are written and illustrated documents that describe pre-Columbian cosmogony. After the conquest of Mexico thousands of them were destroyed as they were considered pagans and samples of idolatry, superstition and falsehoods of the demon.

The Mexican Mayan Codex (formerly Grolier), was unveiled in 1971 during the Ancient Maya Calligraphy exhibition at Club Grolier, a private club and bibliophile society in New York.

The Codex Maya of Mexico comprises 10 sheets of bark paper in accordion format, coated with a layer of plaster on both sides. The illustrations show the Venus calendar.

Since the codex was obtained by means of looting practices, data on its manufacture and timing are uncertain. In addition, by the differences in style and content with the known Mayan codices, their authenticity was questioned. Because Mexico and the United States had at that time signed an agreement for the return of archeological material obtained through looting, the recovery of the codex was possible. According to personnel from the Historical Archive of the National Museum of Anthropology in Mexico, the first mention of the codex, was 1974, when Josue Saenz, a pre-Columbian art collector, and the owner of the Codex, asked the director of the National Museum of Anthropology for authentication. Later, in the doubt of authenticity he decided to donate the document to the Library of this museum. In October 2016 it was decided to form a team of specialists to carry out an exhaustive study of the codex with the purpose of determining its temporality and authenticity.

In this work, the pre-Columbian authenticity of the codex is verified by the radiocarbon technique by AMS. A comparison is made between the results of the AMS technique and the archaeological interpretation that produces a specific date of the event narrated in the codex. All the results indicate that the vegetal support is of pre-Columbian origin and place it like the oldest known manuscript of America.

Authors acknowledge Projects CONACYT 294537 and DGAPA PAPIIT UNAM IG100619 for their funding support.
Radiocarbon and Archaeology 9th International Symposium

**Session: Statistical and Model-Based Approaches to Interpreting Radiocarbon Data, such as Data Simulations, Bayesian Chronological Modeling, and the Interpretation of Summed Probability Distributions.**

This session invites papers on statistical and model-based approaches to interpreting radiocarbon data, such as data simulations, Bayesian chronological modeling, and the interpretation of summed probability distributions.

**3:20 PM**

**Bayesian Modelling of Bulk and Amino Acid Isotopic Proxies for Higher-Precision Dietary Estimates and Reservoir Effect Corrections in Human Remains**

Ricardo Fernandes¹

¹ Max Planck Institute

Quantitative estimates of the carbon contributions from aquatic foods are necessary to correct human radiocarbon dates showing a reservoir effect. These are typically based on carbon and nitrogen stable isotope analyses of human bone collagen. Modelling techniques (e.g. Bayesian mixing model FRUITS) are then employed to generate estimates by comparing the isotopic values of human bone collagen and the potential food sources. However, large uncertainties in food isotopic values plus in other modelling parameters (e.g. food to consumer isotopic offsets, biosynthetic pathways) may result in imprecise dietary estimates and reservoir effect corrections. To improve estimate precision a multi isotopic proxy approach can be adopted. In particular, measurements of nitrogen stable isotopes in amino acids isolated from bone collagen offers a dietary proxy that is almost independent of the variability in the food baseline. In this paper, a new Bayesian method to integrate bulk and single amino acid isotopic data for higher-precision dietary estimates will be presented and discussed.

**3:40 PM**

**Tracking Human Presence in North America and Beringia During the Late Pleistocene Using Bayesian Age Modeling**

Lorena Becerra-Valdivia², Katerina Douka¹, Thomas Higham³

¹ University of Oxford
² Max Planck Institute

The bulk of evidence suggests that humans first reached the Americas during the late Pleistocene through, or bordering, ancient Beringia (Meltzer, 2009). Following their arrival, these early colonisers spread across the length and breadth of the continent, adapting to new and changing environments as the last Ice Age gave way to the warmer Holocene. Today, debate in First Americans research focusses, largely, on the antiquity and origin of these early settlers, the number of migrational streams entering the continent, and the manner in which the occupation occurred. These and other questions were effectively answered for most of the 20th century by the ‘Clovis-first’ model, which stipulates that a group of big-game hunters initially entered North America via Beringia ~13,500 years ago, moving southward through an ice-free corridor between the Laurentide and Cordilleran ice sheets. This model has, however, been challenged repeatedly as the archaeological record provides reliable evidence for sites that predate the Clovis complex (dated to 11,050–10,800 BP by Waters and Stafford, 2007), and ii) distinct cultural traditions that are coeval with it and found across the continent. The initial peopling of the Americas is, therefore, a complex process that currently lacks a well-defined model with which to interpret available data.

Considering the variable of time to be fundamental in the study of human dispersal, we employ a large-scale, chronology-building approach (see Higham et al., 2014) that has yet to be applied to the Americas, and incorporate current chronological data for over 40 archaeological sites across North America and Beringia, into Bayesian age models. This allows for the discernment of spatio-temporal patterns associated with past cultural activity in these regions. Results show that humans were likely present in North America before, during, and immediately after the Last Glacial Maximum, and that the occupation of North America and Beringia likely began during Greenland Interstadial 1.


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**Thursday May 23rd**

**Statistical Analysis and Modeling**

Chair: Ricardo Fernandes

Athena Ballroom E

3:20 – 4:20

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**Afternoon Coffee**

4:20–4:40 PM
Beyond Site Sequences

This session examines how recent developments in the analysis of scientific chronologies have related to archaeological narratives. We would like to consider how much new chronological sequences challenge the structure of archaeological chronological narratives. The session invites papers discussing: how can we use chronological approaches to investigate, critique or challenge pre-existing interpretations rather than replicate them; the challenges in producing narratives that connect between precise chronology and areas of relative impression; the tensions in dealing with large datasets, the legacy of grand narratives and individual sites, and the challenges in relating unique or exceptional sites to wider narratives of change.

A–1

The Nature of Hallstatt–Period Cultural Transformation in the North of Central Europe in Light of Radiocarbon Dating of the Late Bronze Age Stronghold At Lubowice Near Racibórz, SW Poland

Marek Krąpiec¹, Jan Chochorowski²

1 AGH University of Science and Technology
2 Jagiellonian University

At the close of the Bronze Age, in the stylistic phase HaB (1050/1020-810/800 BC), a tendency became evident in Central Europe for settlement concentration and rise of territorial communities of the “little homelands” type. This specific, “barbarian” form of synecism (Greek: synoikismos) manifested itself through the fortification of settlements and the establishment, in places marked by the regionally highest concentrations of environmental and cultural resources, of centres (strongholds) serving special economic and social functions. One of the largest sites of this type, nearly 25 ha in area, is the stronghold at Lubowice near Racibórz, situated to the north of the Moravian Gate, a nodal place for communication routes linking the north and south of Central Europe. Archaeological evidence suggests that the stronghold was founded and developed during the stylistic phase HaB, and later met a violent end (burning down) in the Hallstatt period (810/800-520 BC), in a time by which Hallstatt cultural patterns (including a distinct style of pottery manufacture) had already become predominant. In the absence of other clues, this fact was associated with the catastrophic impact of what is known as the Scythian invasions, a wave of nomadic military raids which affected some parts of Central Europe between the last quarter of the 7th century BC (e.g. the destruction of the Smolenice stronghold in SW Slovakia) and 570-550 BC (e.g. the destruction of the Wicina stronghold in Lower Lusatia, in the west of Poland). Since the stronghold in Lubowice lay near the Moravian Gate, which means on a route used by nomads originating from steppe areas of the Great Hungarian Plain, its destruction was believed to have been chronologically connected with one of these raids. However, radiocarbon analyses of charcoal samples from the burnt fortifications have shown that, while the monumental timber and earth fortifications protecting Lubowice were indeed constructed within the stylistic phase HaB (975-850 cal BC), their destruction should be dated much earlier than previously thought (830-800 cal BC). Thus, the fortifications were burnt down at the transition from HaB to HaC or in the very beginnings of HaC (HaC1 = 810/800-720 BC). The spreading of a new, Hallstatt cultural model probably involved a deep transformation of social structures, with the rise of politically strong elites as one of the main features. These processes could have locally brought about much political turmoil, which could have resulted, among other things, in the destruction of some earlier settlement centres, such as the Lubowice stronghold.

A–2

Medieval Gold Mine in Złoty Stok (Sw Poland): The Oldest Traces of Mining and Metallurgy in the Light of the Radiocarbon and Dendrochronological Dating

Marek Krąpiec¹, Elżbieta Szychowska-Krapiecz²

1 AGH University of Science and Technology
2 University of Rzeszów

Studies on the remains of old mines and steel mills in Lower Silesia (SW Poland), conducted for years, allowed for identification of old medieval centers. The gold mine in Złoty Stok is one of the oldest not only in Poland, but in Europe as well. This was fully confirmed by the absolute dating of wood from mining casings and charcoal from metallurgical heaps in Schlakenthal in Złoty Jar. Historic fir wood from the casings was dated dendrochronologically for the years 1238–1288 AD. The radiocarbon dating of charcoal from the original ironworks in Złoty Jar also pointed to the 13th century. Absolute dating of coniferous species (Pinus sylvestris, Picea abies, Abies alba), as well as deciduous Quercus sp., allowed for construction of absolute, dendrochronological coniferous standards, hitherto lacking for this part of Poland. The absolute dating of wooden casings, tools and mining equipment was performed in numerous adits (among others Ochrowa, Lisi, Mistrzów, Nowa Kaszptka, Okrągła), the black ramp, and in the shafts. This allowed to present a history of the progressive mining work in excavations on geotourist routes, their reconstruction and development.

A–3

Changes in the Socio–Religious Landscape of Sicily After Norman Conquest in the Light of Radio–Carbon Dating and Archaeological Research on the Church and Monastery Santa Maria di Campogrosso in Altaivia Milicia Near Palermo

Marek Krąpiec¹, Sławomir Moździioch², Ewa Moździioch³

1 AGH University of Science and Technology
2 Polish Academy of Sciences
3 University of Wroclaw

The excavations of the church and the Italo-Greek monastery Santa Maria di Campogrosso (also known as San Michele del Golfo) were led in the years 2015-2018 by the Centre for Late Antique and Early Medieval Studies in Wroclaw in connection with a broader research pro-grame on the role of the Normans in shaping the cultural image of medieval Europe.

Preliminary results resulted in unravelling the external face of southern wall of the church and the adjacent cemetery. Amongst the graves of adults three children’s graves were encountered. The corpses of children were covered with roof tiles, which refers to ancient graves of ‘a cappuca’-na type. Other finds included fragments of vessels, a few coins, and a portion of stele with a fragment of inscription in Kufic style.

Dating of mortars indicated a relatively long period of the church construction, presumably the 2nd and 3rd quarter of the 12th century. C14 dating of bones of one of the infants buried in the double grave helped to determine the time of burial to the period from the mid-11th to the beginning of the 13th century. It is possible that some of them were associated with the existence of the hypothetical hospital mentioned in 1179. Vessels produced in Arab workshops confirm economic links between the monastery and Arab background, similarly as coins of William I and William II with bilingual inscriptions (Arabic-Latin).

Determining the chronology of the church and possible unearthing of the remains of the monastery, discovery of the remains of Arab settlements, identification of the church and the adjacent cemetery, among other things, in the destruction of some earlier settlement centres, such as the Lubowice stronghold.

A–4

Dynamics of Changes in the Use of a Cult Area ("Zolnik") from the Hillfort of the Scythian Cultural Circle in Chotyniec Near Radymno (South-Eastern Poland) in the Context of Radiocarbon Dating

Marek Krąpiec¹, Sylwester Czopek²

1 AGH University of Science and Technology
2 University of Wroclaw

One of the most important elements of a Scythian cultural circle hillfort is a place of specific, cult and ritual function, known as “zolnik”. Its significance results from the accumulation of layers of charcoal, ash (rus. zol), monuments (including spectacular ones, with high cognitive potential) and post-consumption animal bones, which are the remains of regular ceremonies. Detailed typological and chronological analyses of...
The reconstruction of events that took place within the “zolnik” was made on the basis of field observations and radiocarbon dating. The time span covered by the phases was determined using a Bayesian model allowing for the calculation of probability distribution for the beginning, the end and the possible time span in calendar age.

The oldest date, indicating the 9th/8th century BC, refers back to the time before the arrival of the population from the east identified with the Scythian cultural model. It does not refer to an activity that can be not be associated with any artefacts. Subsequent dates refer to the activity of eastern newcomers with specific rituals, the remainder of which is the “zolnik”. Its oldest phase (I), visible only in the south-eastern part, can be dated within the 8th-7th/6th century BC, and considering the course of historical processes in this part of Europe it should be narrowed to the end of the 7th or the turn of the 7th and 6th century. An important element of the “zolnik” is a clayey embodiment visible in most of the area occupied by this object. Its creation can be dated within the 6th-5th century BC. On it laid the main “zolnik” (II) layer, which can be considered the second phase of use. Dating of the artefacts found there, including a well-fixed chronology of a Greek wine amphora (the first thirty years of the 6th century BC), allow us to narrow this stage to the very beginning of the 6th century. The time between the construction of a conical clayey embankment and the beginning of the second phase may not be chronologically feasible, as these events were immediately consecutive. Dating of phase 2 is well established - in the light of other dates it should refer to the 5th century BC, and after supplementing it with typological conclusions, also up to 6th century. Readable younger stage (2B) can be associated with the turn of the 5th and 4th century BC. The youngest dates (phase 3) indicate 4th-3rd (IV / III) century BC. They date barely preserved (destroyed by ploughing) and stratigraphically the youngest phase of use of the “zolnik”. Thus, the time of functioning of this complex can be estimated at about 250-300 years and placed between 7th/6th and 4th/3rd century BC.

A-5 Bayesian Chronological Models for the Aztalan Site: Challenges and Preliminary Results

Anthony Krus¹, John Richards², Robert Jeske²
¹ University of South Dakota
² University of Wisconsin–Milwaukee

Aztalan is a heavily fortified Mississippian-period center located on the Crawfish River in Wisconsin, representing the northermmost large Mississippian village recorded. A total of 72 radiocarbon measurements have been obtained from the site on samples of wood charcoal, short lived plant charcoal, animal bone, human bone, and pottery residue. These existing measurements have demonstrated that the site is one of the earliest large Mississippian villages, but there have been numerous issues with interpreting this collection of radiocarbon measurements. Specifically, measurements from ceramic residues appear to be slightly offset, and it is further difficult to determine the sample taphonomy for some of the legacy bulk sampled radiocarbon dates. In this paper, we explore how to best interpret this radiocarbon dataset and further use Bayesian chronological modeling to explore multiple possibilities for how to model these dates. Additionally, we compare the Aztalan chronology to that of nearby radiocarbon dated Oneota components (Carcajou Point, Crabapple Point, Crescent Bay Hunt Club, Koshkonong Creek Village, and Schmelting) to derive a more precise and accurate regional archaeological chronology.

A-6 The Influence of Different Archaeological Dating Materials on the Construction of Chronology

Aifeng Zhou¹, Weimiao Dong²
¹ Lanzhou University
² Fudan University

In virtue of its efficiency and accuracy against other dating methods, and of course the availability of dating materials Radiocarbon dating has long been a routine process to pinpoint the precise time of a new-found archaeological site, or to calculate the duration of a site and furthermore the longevities of cultures, especially when dealing with Neolithic sites. Thanks to their abundance and frequency in almost all kinds of archaeological contexts, charcoal and subsequently bones are usually taken as dating materials to approach the chronology of a site. With the widely application of floatation, seeds and other herbal tissues have been recognized to be better dating objects due to their much shorter lives. By means of comparing dates of charcoal and seeds from same archaeological features in Xinjiang, China, it revealed the general existence of time deviation between those dates from charcoal and from seeds, the offset can be as large as 200 years. “Old wood effect” may explain the ubiquitous of charcoal dates older than seeds dates. Therefore, to obtain high quality chronology of a site, radiocarbon dates from different kinds of materials much be cautiously treated.

A-7 Using Radiocarbon Data to Chronologically Control Population Density Estimates Derived from Systematically Collected Intra–Settlement Distributional Data

Brandon Ritchison¹
¹ University of Georgia

Population density is an important variable in the development of social complexity. Estimating population densities in the archaeological record requires combining estimates of population, area, and time (Hassan 1981). Archaeological population estimates tend to be reported as a maximum population derived from the sum total accumulation of discrete archaeological material types, usually ceramics. However, given the palimpsest nature of the archaeological record at recurrently occupied archaeological sites, these maximal, total estimates are, at best, a poor reflection of contemporaneous populations. I present a method for calculating average yearly population densities for occupations at a large, multicomponent site using a combination of distributional data and 60 new radiocarbon dates. By employing this method at other sites in the same region, we will be able to model intra-regional population dynamics at fine time scales.

Kenan Field (9MC67), on Sapelo Island, GA, is a 60 ha, multicomponent site that has been occupied since 4500 BP. Occupation extents and population estimates were calculated using the results of a systematic shovel test survey. Natural neighbor interpolation was used to approximate occupation extents for archaeological phases using the densities of temporally diagnostic ceramics. Population estimates were calculated using two methods: 1) Occupation area, and 2) Ceramic accumulation. Distinct periods of occupation and abandonment were identified from the radiocarbon sample and applied to phase-level population estimates to model the demographic history of Kenan Field and relate it to the regional record of change in settlement and economy on the Georgia Coast.

Three periods of occupation/abandonment are of note at Kenan Field. First, Late Archaic (4500–3100 BP) occupations at the site occur only before and after the shell ring phenomena (Thompson and Andrus 2011) suggesting that shell ring occupations represent a distinct settlement strategy and concentration of sue of particular points on the landscape to the exclusion of previously used locales. Second, the abandonment of the site during the latter portion of the Wilmot phase (1500–1000 BP) coincides with the initial development of ranking in the region (Thomas 2008) and the adoption of a new ceramic type (Ritchison 2018a). Finally, occupational density dramatically increased from the Savannah phase (800–625 BP) to the Irene phase (625–370 BP) with no break in the occupational sequence. This increase in density is likely related to the large-scale immigration event which occurred post-AD 1350 (Ritchison 2018b) and drove the development of new community practices.


Ritchison, B.T., 2018a. Exploring a Bayesian method for examining the regional ceramic sequence along the Georgia Coast. Southeastern Archaeology 37, 12–21.


B-1 Radiocarbon Age of Consolidants and Adhesives Used in Archaeological Conservation

Carley Crann¹, Tara Grant²
¹ A.E. Lalonde AMS Laboratory
² Canadian Conservation Institute

Consolidants and adhesives used to conserve archaeological artifacts must be carefully removed prior to radiocarbon dating of the artifact, otherwise the radiocarbon signature will be compromised. It is therefore paramount to understand how the artifact was conserved and which consolidation products were used in order to determine: (1) the best location on the artifact to sample; (2) how to remove the consolidant physically and/or chemically; and subsequently (3) whether or not the consolidant was successfully removed. The first two considerations are a matter of communication between the archaeologist, the conservator, and the radiocarbon laboratory, but the third consideration can be a bit tricky to determine. The archaeologist usually knows the approximate time period of the artifact given the context in which it was found so when the age is not as expected, it is possible the consolidant was not completely removed. However, it can be purely speculation unless the radiocarbon signature of the consolidant (old or young) is known.

Here we present results from the radiocarbon and stable isotope analyses of 21 consolidants and adhesives commonly used for archaeological conservation. The consolidants and adhesives cover both natural (animal and fish glues, tree resins, starches) and synthetic materials (acrylics, polyvinyl acetate, polyvinyl butyral), polyethylene glycol, glycerol, cellulose ethers, cellulose esters, cyanoacrylates and soluble nylon) and are selected from those commonly in use now, as well as a few that were used historically but are now avoided due to poor aging qualities.

This paper will present data that may indicate in which direction – young or old – consolidation treatments may skew radiocarbon dates, the importance of knowing the conservation history of older samples and how these results should be interpreted. Stable isotope signatures of the consolidants and glues are also provided as the analysis is inexpensive and complimentary to the radiocarbon analysis and could be used to corroborate suspicions of contamination gleaned from offset radiocarbon ages of archaeological samples. Finally, we present the case study that motivated this project: the analysis of carbonized residuals vacuum impregnated with PVA glue.

B-2 Routine Compound Specific Radiocarbon Analysis of Bones at the Oxford Radiocarbon Accelerator Unit

Thibaut Devièse¹, Lorena Becerra Valdivia¹, Daniel Comeskey¹, Thomas Higham²
¹ University of Oxford
² University of Vienna

Radiocarbon dating is the principal method for building chronologies in archaeology. However, for radiocarbon results to be accurate, samples must be free of contamination to a minimal level. This is even more crucial when dating material approaching the radiocarbon age limit of ~50,000 BP, because trace amounts of contamination at this age will drastically affect the accuracy of the results. Contamination can originate from a wide range of sources in the post-depositional environment and post-exavation activities (i.e. with the application of conservation materials) or during laboratory handling. Efficient procedures to remove these contaminants are therefore crucial in the process of radiocarbon dating.

Sample pre-treatment using preparative Liquid Chromatography for Compound Specific Radiocarbon Analysis (CSRA) has been operational at the Oxford Radiocarbon Accelerator Unit since 2006 for the dating of collagen based samples. This method is now routinely applied for AMS radiocarbon dating of heavily contaminated bone samples [1].

Here, we report several recent case studies showing how the application of CSRA on bones can drastically impact on the AMS results, for up to several thousands of years. Such case studies include the latest Neanderthals in Vindija cave (Croatia) [2], the Anzick burials [3], the oldest human skullcap from Salkhit (Mongolia) [4] and the extinction of the Elasmotherium also known as Siberian unicorn [5]. As illustrated by these case studies, CSRA of bones can help refine the ages and therefore advance our understanding of human and animal population dispersals and / or extinctions.


B-3 Technical Aspects of Shell Conchiolin Dating via Wet Oxidation

Carla S. Hadden¹, Hong Sheng¹, Jana M. Carpenter¹
¹ University of Georgia

Carbon isotopes in the carbonate phase of mollusc shells are typically assumed to reflect the inorganic carbon isotopic composition of the animal’s surroundings: dissolved inorganic carbon in aquatic environments; and geological carbonates, atmospheric CO₂, and soil CO₂ in terrestrial environments. In contrast, carbon isotopes in organic tissues of the same animal should reflect its diet: the isotopic composition of the organic compounds at the base of its food web, with predictable levels of isotopic fractionation during metabolic processes. The soft tissues of molluscs generally do not preserve in the archaeological record. Conchiolin, however, is an organic matrix tightly bound into the mineral structure of the shell, sheltered from the external environment and thus relatively protected from diagenetic alteration. In some cases, more accurate radiocarbon ages are obtained from shell conchiolin than from shell carbonate. Here we discuss technical aspects of recovering CO₂ from conchiolin via wet chemical oxidation. This approach requires a two-step process, a modified persulfate oxidation procedure as is used to measure total organic carbon in seawater: (1) acidifying the shell with phosphoric acid to remove the carbonate phase, leaving the bulk shell organics (conchiolin) in solution; and (2) oxidizing the solution with persulfate, and trapping the evolved CO₂. We compare the radiocarbon content of the soft tissue of a modern live-collected oyster (Crassostrea virginica) to shell conchiolin recovered with varying reagent concentrations: 100%, 50%, or 25% H₂O₂ followed by persulfate oxidation with 1M Na₂S₂O₅. At high reagent concentrations we observed the precipitation of sulfate salts (CaSO₄, Na₂SO₄) and low CO₂ yields. No precipitates formed under low reagent concentrations, and the CO₂ yield increased significantly. Most importantly, the CO₂-evolved under the low concentration conditions had 513C and 14C values that most closely matched the values observed in the soft tissues. These observations suggest that the precipitation of sulfate salts at high reagent concentrations interrupts the complete oxidation of the shell organics, resulting in the fractionation of carbon isotopes in the sample gas. For best results, we recommend low concentrations of reagents for the wet oxidation of shell conchiolin.

B-4 Radiocarbon Dating of Amino Acids from Modern Human Hair – Using Ninhydrin

Christian Hamann¹, Guaciara M. Santos²
¹ Kiel University
² California University

Radiocarbon (14C) analyzes of modern human hair to determine year-of-death in forensics have proven to be challenging, because of the difficulty to remove all intrusive carbon from hair care products. Shampoos, conditioners and other regularly containing
petrochemicals in care hair products can potentially lead to artificially “older” radiocarbon ages (De La Torre et al. 2014). Since those products are designed to penetrate the hair scales and embedded themselves within the shaft, removal by assorted chemical pretreatments prove to be difficult (Santos et al. 2015).

Ninhydrin – typically used for bone collagen (Nelson 1991, Tsinérat-Labordre et al. 2003, Dumoulin et al. 2017) – opens the opportunity to only extract the carbon from carboxylic groups of amino acids (AA) prior to 14C dating. These AAs should primarily originate from hair keratin, but could also contain contributions from protein additives in cosmetics, which can fortunately be assumed to be at least approximately contemporaneous to the hair and have no influence on the 14C age determination.

We present a novel extraction protocol and results obtained from bone collagen of well-known 14C signatures to prove the reliability of this method. The method has been successfully applied to ancient bone collagen (Hamann et al. this issue). Measurement performed on hair of three subjects (an adult, an youth, and a toddler), proven to be biased towards older radiocarbon ages (De La Torre et al. 2014), compare well with reference values from fingernail keratin collected at the same time-frame. For 14C analysis of modern human hair the refined ninhydrin method is by far the best to date. Therefore, we assume that the method is reliable to be used on pre-bomb hair fibers. Further analysis would be needed.


**B-5**

**Comparison of ¹⁴C Dates Obtained for the Enamel and Dentin Fraction of Woolly Mammoth Teeth**

István Majör¹, István Futó², Attila Virág², Enikő Magyari², Mihály Gasparik³, Róbert Huszánk⁴, A.J. Timothy Jull⁵, Mihály Molnár²

1 Institute of Nuclear Research, Hungary
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The research was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2-15-2016-00009 IÇER.

**B-6**

**Reliability Of ¹⁴C Dates on Organic Temper Materials (Moss) in Neolithic Pottery**

Dimitri Teetaert¹, Mathieu Boudin², Guy De Mulder³, Philippe Crombé¹

1 Ghent University
2 Royal Institute for Cultural Heritage, Belgium

Fine plant material, in particular moss, is used as temper in pottery by diverse cultural groups of the Final Mesolithic to Early/Middle Neolithic in Northwest Europe (e.g. Constantin & Kuijper 2002). Even after the firing process, some moss fragments can be preserved as charred remains inside the vessels, meaning that short-lived plant material with a direct chronological link to the pottery is available for AMS 14C dating. Direct dates on pottery are usually obtained on food crusts preserved on the internal vessel surface, but these can be affected by a freshwater reservoir effect (FRE) due to fish processing. Our aim is to examine if moss dates are reliable, even when the plant material is extracted from pottery in which aquatic resources were prepared.

In the context of a recent project on the Neolithic transition in the Scheldt river valley (northern Belgium), several fragments of moss-tempered pottery attributed to the Sweffling and Michelsberg Cultures (c. 4500-3800/3600 cal BC) are dated using AMS radiocarbon residue and fine plant material. Moss extraction and sample pretreatment are performed according to the methodology of Gilmore (2015). The 14C dates on moss are compared to dates obtained on associated organic macro-remains (charred cereal grains, charcoal) and food crust dates with and without freshwater reservoir effect.

This allows us to assess whether moss dates are also affected by FRE. If not, moss temper can be used as a reliable source for direct dates on a wide range of Neolithic sites in Northwest Europe. In addition it can help to estimate the reservoir effect on food crust dates within the Scheldt river basin.


**B-7**

**Comparison of Collagen Extraction Methods For Radiocarbon Dating of Bones: A Case Study from a Medieval Context**

Lucia Liccioli¹, Mariaelena Fedi¹, Serena Barone², Francesco Maspero², Pierluigi Girolini³, Marco Martini², Emanuela Sibilia³, Alessandro Riga³

¹ INFN – Sezione DI Firenze
² INFN – Sezione DI Milano Bicocca
³ Soprintendenza ABAP – Firenze, Pistoia, Prato

Bones are one of the most significant materials in archaeology: dating osteological remains allows to “take a picture” of what we are really interested in, i.e. the moment of the organism death.

As it is well known, collagen is the organic fraction to be dated, but its preservation can be seriously damaged by several causes (e.g. high temperatures and humidity, and low pH level of soil can contribute to accelerate the degradation processes). Moreover, the higher the collagen loss, the greater is the probability that the residual collagen is contaminated. To overcome this obstacle, some researchers have suggested the extraction of the dentine fraction of some woolly mammoth (Mammuthus primigenius) teeth found in Hungary. After separation and abrasion, the respective dentin and enamel fractions were chemically treated to extract collagen or remove secondary carbonates. After combustion of collagen or acid treatment of enamel, all the 14C ages were obtained using the EnvironMICADAS AMS device at HEKAL (ICER), Debrecen, Hungary. Finally, the 14C ages of the dentin and enamel fractions were compared to each other to see if any difference can be detected. Based on the preliminary results of the dentin fractions, the ages received range from 14 500 BP to background (~ 44 000 BP). In addition, as supplementary analyses, FTIR measurements were also performed on the enamel fractions.

In this work, we compared our “standard” collagen extraction method, based on the final gelatinization of the whole collagen acidified solution, to a new procedure where the ultra-filtered material is recovered after exploiting high pressure generated by a piston. Sartorius Polyethersulfone filters, with cut-off at 30kD, were chosen. This process can be an alternative to the ultra-filtration method by centrifugation.

We dated human remains (high bones) collected in a burial site next to San Pietro ad Mensulas in Sinalunga (Sienna, Italy), a parish church built since early Middle Ages on an area already occupied by the Romans.
B-8
Testing a Stable Isotope Protocol as Pretreatment for Dating Bone Apatite of Samples from Mexico and Guatemala

Sussane Lindauer¹, Sarah Stinnesbeek², Wolfgang Stinnesbeek³
¹ Curt-Engelhorn-Centre for Archaeometry
² Staatliches Museum Für Naturkunde Karlsruhe
³ Institute of Geosciences

In many areas of the world, archaeologists face the problem of recovering bones from various sites that did not preserve enough collagen to be used for radiocarbon dating without problems. In dry areas like the Arabian Peninsula (Zazzo and Saliège 2011), we tested a simple protocol on bone samples recovered from archaeological sites and caves in Mexico. Because not all laboratories can afford complicated equipment and as we hope that nature prefers simple ways, we tested a simple protocol adapted from stable isotope sample preparation (Koch et al. 1997) with respect to its suitability for radiocarbon dating. This pretreatment consists of a step to remove organic material followed by a step to remove secondary calcites. Fortunately we also had, although few, bones where collagen could be extracted for comparison. The protocol is easy to handle, but shows some deficiencies with respect to determining the real age of the sample. The samples yielded ages that were too old and hence would only allow to be used as maximum age. Including a base step to remove possible humic acid, test on the bone samples, only made it worse and even younger. However, a systematic shift for bones from Mexican cenotes is detected and fits the real age better than the massive deviation on bones recovered from excavations in Guatemala. Koch, P. L., et al. (1997). The Effects of Sample Treatment and Diagenesis on the Isotopic Integrity of Carbonate in Biogenic Hydroxyapatite. Journal of Archaeological Science 24(5): 417-429. Zazzo, A. and J. F. Saliège (2011). Radiocarbon dating of biological apatites: A review. Palaeogeography, Palaeoclimatology, Palaeoecology 310(1-2): 52-61.

B-9
Preliminary Dating Results of Bones Using Ultrafiltration at The LACUFF - Brazil

Fabiana Oliveira¹, Kita Macario¹, Bruna Pereira¹, Ingrid Chanaç¹, Eduardo Alves², Alberto Cid², Rita Scheel-Ybert³, Dayanne Amaral³, Natasha Ribeiro-Pinto³, Luiz C Ruiz Pessenda⁴
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³ CENA USP
⁴ MNUFRJ

Collagen extraction depends on the state of bone preservation and the acidity of Brazilian soils often prevents the use of this material for radiocarbon dating. When available, however, bone samples constitute very important chronological records for both archaeological sites and natural depositional sites of specific animals. In this work, we describe preliminary tests for bone sample preparation at the Radiocarbon Laboratory of Universidade Federal Fluminense, in Brazil. The extraction of collagen was performed using two filters, the first aiming to obtain the known age material are in agreement with the expected and the studied sector of Ancarama shellmound were dated at 4100-3900 years cal AP.

B-10
Development in AMS Graphitization Line in Dendrochronological Laboratory at AGH–UST Krakow

Andrzej Rakowski¹, Marek Krapiec², Matthias Huels³, Jacek Pawlyta¹, Damian Wiktorowski²
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² AGH University of Science and Technology
³ Kiel University

Accelerator mass spectrometry (AMS) technique is the most common technique used in radiocarbon dating. The procedure of age determination with this technique is divided into two parts, sample preparation and measurement. Sample preparation includes mechanical and chemical processes of cleaning, combustion, graphitization and pressing into sample holder. A new system for preparation of graphite targets for AMS measurements of radiocarbon concentration has been built in the Dendrochronological Laboratory at AGH-UST Krakow. This system consists of equipment for mechanical and chemical sample pretreatment, vacuum line for samples, heating and purification of CO₂ and graphitization line, where occurs reduction of CO₂ on iron powder. Performance of the system was tested with samples of NIST Ox-II, IAEA standards (IAEA C₁₃, C₁₄, C₁₅, and C₁₆), and blank samples. The test confirms good reproducibility of results obtained for the samples prepared using this system.

This session invites papers on ¹⁴C in the protection of cultural heritage, Topics include:
1. ¹⁴C of important cultural heritage and their preservation: art works and artifacts;
2. Legal and ethical questions related to ¹⁴C dating of material of insecure provenance;
3. Questions of authenticity and provenance.

C-1
Radiocarbon Dating of Wall Paintings Painted with Lead White

Lucile Beck¹, Cyrielle Messager², Ingrid Caiffy¹, Jean-Pascal Domoulin¹, Emmanuelle Delqué-Kolić³, Solène Mussard¹, Marion Perron¹, Christophe Moreau¹, Christian Degrigny², Vincent Sérneels³
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Lead white is the major white pigment used in European paintings from the Antiquity to the beginning of the 20th century [1]. This pigment is mainly composed of two lead carbonates, cerussite (PbCO₃) and hydrocerussite (2PbCO₃·Pb(OH)₂). Both are synthesized since the Greek period with metallic lead, vineggar and horse manure that release heat and CO₂. Many authors have reported recipes for the production of lead white over time. Theophrastus wrote the first known recipe in the 4th century BC. Isode (13th-14th century) and hydrocerussite (2PbCO₃·Pb(OH)₂) are known for their compiling work and their painting manuals reporting lead white production during the medieval period. The radiocarbon dating of lead white was recently developed by two groups, on ancient cosmetics and easel paintings [2,3]. We propose here to apply the method to wall paintings. Samples were prepared by thermal decomposition at 400°C [4] and carbon isotopes were measured by using the LMC14-AMS ARTEMIS facility [5]. We have tested the robustness of our protocol on painting samples coming from two different medieval wall paintings. The first study case is the wooden core, which is made of charcoal and wood. The second study case is the rood screen of the church of the Cordeliers of Fribourg (end of the 14th century). We successfully dated all the samples and we have obtained for each study case a good agreement with the expected date. We will present in detail our protocol and discuss the results. By using radiocarbon in lead white, we provide a new tool for dating wall paintings.
Radiocarbon dating can give access to the absolute chronology of successive or multiple layers of decoration and can evidence later restorations.

[1] Stols-Witlox, M., Historical recipes for preparatory layers for oil paintings in manuals, manuscripts and handbook in North West Europe, 1500-1600 : analysis and reconstructions 1400-1800, Université d’Amsterdam, 2014

[2] Beck, L. et al., Absolute dating of lead carbonates in ancient cosmetics by radiocarbon, Communications chemistry, 1, 34, 2018


[4] Beck L. et al., accepted in Radiocarbon

C-6
Radiocarbon Dating of Medieval Buildings in the Mountain Part of Ingushetia (Northern Caucasus, Russia)
Vladimir Matokovsky1, Umalat Gadiev2, Andrey Dolgikh1
1 Institute of Geography RAS
2 E.I. Krapnov’s Archaeological Center

Mountain part of Ingushetia Republic in the northern Caucasus is very important for medieval history of the whole Caucasus region, as it is situated in its middle, on the way of many medieval roads, and has many preserved stone medieval buildings. Additionally to 18 accelerated mass spectrometry (AMS) dates that we have already had for this region, we have dated 20 new wood samples by AMS radiocarbon analysis, including 15 samples from nine previously undated buildings and five samples from the buildings which had some inconsistencies in previous dates. The acquired dates were wiggle-matched. Here we report the construction periods for 15 most prominent medieval buildings from the region that contain wood – Christian churches, crypts, temples, sanctuaries, battle towers, and living buildings, – and discuss how these periods correspond to the periods proposed by historians, architects, and archaeologists. The calibrated dates obtained cover the period from AD 662 until recent time with the majority of them concentrated in 15-17 centuries.

The study was supported by the Russian Federation President grant no. MK-3844.2019.5.

C-7
AMS Wiggle-Matching of Two Russian Orthodox Icons from The Trinity Church of Sviyazhsk (16th Century)
Vladimir Matokovsky1, Andrey Dolgikh1, Denis Tishin1, Vera Nemtynova1, Elya Zazovskaya1
1 Institute of Geography RAS
2 Kazan Federal University
3 State Museum of Fine Arts of the Republic of Tatarstan

Here we present the results of radiocarbon accelerated mass spectrometry (AMS) of two medieval icons from the collection of the State Museum of Fine Arts of Tatarstan Republic that originate from the iconostasis of the Trinity Church of Sviyazhsk (construction in 1551) and are painted on wooden panels made from Scots pine (“The Entombment of Christ”) and linden (“Mother of God of Kazan, with the Holidays”). For each icon, the wooden panels were studied by means of dendrochronology. Both icons failed to be reliably cross-dated with the existing master tree-ring chronologies from this region, but were dated by wiggle-matching of radiocarbon dates. In case of the icon “The Entombment of Christ”, the results refine existing wood-art-historical dates. The data suggest that this icon was painted before the construction of the temple and was brought to Sviyazhsk from Central Russia. In case of the icon-frame “Mother of God of Kazan, with the Holidays” the results match art-historical dates. The results confirm the historical data that this large icon could be the original special frame for one of the most revered icon “the Kazan Mother of God” (1579), stolen in 1904 from the Kazan Mother of God Monastery.

The study was supported by the Russian Federation President grant no. MK-3844.2019.5.

C-8
14C Intercomparation Exercise on Some Typical and Precious Historical and Forensic Samples
Mihaly Molnar1, Irka Hajas3, Lucio Calcagnile3, Gianluca Quarta3, Istvan Major1, A.J. Timothy Jull3
1 ICER Centre, MTA Atomki
2 ETHZ
3 CEDAD Laboratory

Besides the traditional applications of 14C dating in archeology and geo-chronology, different studies have shown the potential of the method in Cultural Heritage studies and forensics. Often it is based on the detection of the so-called “bomb spike”, the excess of 14C, released in the atmosphere because of in-air nuclear weapons tests. Its potential appears only partially exploited in the routine forensics practice, although the important advantages of the method are the achievable high chronological resolution, the high accuracy of the used experimental methods.

Our paper is dealing with open issues such as the definition of procedures for samples selection and chemical processing, quality assurance, calibration, data analysis and interpretation, achievable precision and accuracy levels in the framework of a three different AMS laboratory intercomparison exercise (Debrecen HEKAL AMS – ETHZ AMS – CEDAD AMS facilities). Some typical and precious historical and forensic samples such as bone of historical people, blank fossil bone, modern bone, ivory, arrow, paper, pergamen, leaf and parchment were involved in our interlaboratory comparison exercise.

The work was performed under the auspices of IAEA (International Atomic Energy Agency) in the frame of the CRP (Coordinated Research Projects): Enhancing Nuclear Analytical Techniques to Meet the Needs of Forensics Sciences.

The research was supported by the European Union and the State of Hungary, co-financed by the European Regional Development Fund in the project of GINOP-2.3.2-15-2016-00009 ’ICER’.

C-9
Consortium Results on Radiocarbon Dating of St. George’s Rotunda in Nitrianska Blatnica, Slovakia
Pavel Povinec1, Jozef Dorica2, Alexander Cherkinsky3, Irka Hajas4, A.J. Timothy Jull2, Ivan Kontul1, Mihaly Molnar1, Ivo Svetlik1, Eva Maria Wild4
1 Comenius University
2 Restauro Complet
3 University of Georgia
4 ETH, Zurich
5 University of Arizona
6 Institute for Nuclear Physics (Atomki)
7 Institute of Nuclear Physics, Prague
8 University of Vienna

Radiocarbon dating of St. George’s Rotunda in Nitrianska Blatnica (Slovakia) was carried out with the aim to solve discrepancies about its origin preliminary estimated to be between the 10th and 14th century. The Rotunda represents a small object build from stony walls about 80 cm thick, which passed several reconstructions which changed its shape. It has been believed that only walls could represent a building material which was originally used for construction, and which has not been replaced during past reconstructions. An international consortium consisting of radiocarbon laboratories from Athens, Debrecen, Prague, Tucson, Vienna, Zurich, and Bratislava has been organized to so solve the age problem and to provide internationally acceptable age of the Rotunda. Samples of charcoal, thin twigs and mortar found inside the walls, as well as internal coatings were used for radiocarbon analyses. The radiocarbon data obtained by consortium laboratories have been in good agreement resulting in radiocarbon calibrated age of 790-870 AD. The wide age interval has not been influenced only by uncertainties of partial radiocarbon measurements, but mainly by the specific character of the calibration curve (plateau) during this time interval. The obtained radiocarbon age makes the Rotunda probably the oldest existing Christian object in the Central Europe, built (with 95% probability) before arrive of Cyril and Methodius to Great Moravia (863 AD).

C-10
Radiocarbon Ages and Cultural Characteristics in the Mekong Delta of Vietnam
Nguyen QuangMien1, Bui VanLoat2, Nguyen QuangBac3, Vu AnhHung4
1 Institute of Archaeology, VASS
2 Hanoi University of Science, VNU
3 Vinasa Science and Technology Institute
4 Military Technical Academy

The Mekong Delta of Vietnam is famous as the home of the Oc Eo Culture. Also known as the ancient kingdom of Funan, the Oc Eo Culture was one of the earliest civilizations in mainland Southeast. When was the Mekong Delta in Vietnam actually a “well populated human habitat”? A widely accepted view among many archaeologists is that the Mekong Delta was already extensively occupied by about 500 BC. Since the high point of the mid-Holocene sea – level, the Mekong Delta has gradually
The Ransacking of the Ancient Russian City of Yaroslavl at the Beginning of the 13th Century: The Long Journey to Exact Dating
Asya Engovatova¹, Alexander Cherkinsky², Ganna Zaiseva³
¹ Institute of Archaeology RAS
² University of Georgia
³ Institute for The Material Culture History RAS

Yaroslavl was founded at the beginning of 11th century. It is a Russian city on the River Volga, 250km (155 miles) to the north-east of Moscow. We know from historical records that the city was destroyed in the winter of 1237-1238 AD by Mongol invaders led by Batu-Khan. However there were no detailed records concerning this event. Excavation of the Yaroslavl site was conducted by Institute of Archaeology of the Russian Academy of Sciences over 2004-2017. In the course of these studies, nine mass burials were found in different parts of the settlement. The burials were made in the basements of the burnt-out wooden medieval buildings. The bodies of people (men, women, and children — from a few people to a few dozen in each grave) and animals (horses, cows, pgs. red deer and hunting birds) were randomly dumped there. The remains of people carried signs of murder — numerous axe cuts and stab wounds on the bones of the skeleton, and especially the women and children skulls. All the dwellings, in which the burials were made, carried traces of fire.

Analysis of the artifacts found in the burials and ceramics, as well as the stratigraphic data of the burials, helped the researchers to attribute these burials to the 13th century. More accurate dating was obtained after dendrochronological analysis of wood from the burial structures, which has shown that the buildings were erected no later than the end of the 1220s. Accordingly, the event that led to the death of people occurred in the narrow period of 1220-1240 AD.

The anthropological studies of the numerous deadly injuries on the bones of people have shown that the victims of the brutal murders and complete destruction of the city perhaps were the result of the Mongol invasion. However, some of the opponents have said that such burials could have arisen during local princely conflicts more characteristic of Russia in the 14th century. That is why accurate dating was important for interpreting the event. There were 63 bone samples collected for radiocarbon analysis. 23 of these were sent to the Kyiv Radiocarbon laboratory, in Ukraine, for conventional LSC dating and 40 samples were sent to the Center for Applied Isotope Studies, University of Georgia for AMS radiocarbon dating. The dates obtained by LSC technique produced quite a wide range of distribution. They are between 1060±60 and 760±60 BP ¹⁴C years. The AMS data are in a range between 881±10 and 748±20 BP ¹⁴C year with one exception of 332±19 BP ¹⁴C years for the horse bone sample. These results significantly narrowed the possible dating period. All the dates came into the narrow interval of late-12th - early 13th century. A Bayesian approach makes inferences based on the posteriori probability distributions of parameters within the likelihood of the data.

In our case this approach allowed researchers to narrow the interval to the range of the 1221-1259 period. This is in perfect agreement with the time of the destruction of Yaroslavl by Batu Khan.
The Mezquital Valley Project (ENAH-INAH) and the National Laboratory of Mass Spectrometry with Accelerators (LEMA-UNAM) have undertaken the revision of El Maye site to perform absolute dating. For a better understanding of the emergence of Ixmiquilpan and El Maye like altepetl, a series of dates were made by archaeo-magnetism and \(^{14}\)C-AMS dating, to chronologically locate the two twin cities (altepetl) and make comparisons with previous sites and later descriptions that offer us primary sources of information from 17th and 18th century over the region of Ixmiquilpan.

**E-2**

The Oldest Date from Palenque, and Other Early Archaeological Data

Joshua Balcells González¹, Corina Solís², María Rodríguez-Ceja³

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Located in the middle of the jungle of Chiapas in the South of Mexico, Palenque is one of the most emblematic sites of the Mayan culture. This site was occupied during the Mesoamerican Classic Period, between the 5th and 9th centuries. The offerings are an essential element in the burials of pre-Columbian Mexico. The offerings were mainly based on personal items that helped the deceased on his way to the other world. The graves and offerings differed mainly from the economic social situation of the deceased. The rulers and their family had large tombs with offerings richer than ordinary people, with masks, shells, obsidian, ceramics and could even be accompanied by the bodies of some sacrificed persons or animals.

The dated samples come from the central chamber of the funerary complex of the Temple XX, one of the oldest buildings of the site. The complex studied corresponds to an early substructure of the building. Other samples of shell and bone were obtained from a stratigraphic column excavated in the house F of the Palace, the main complex of the archaeological site.

In this paper we present some archaeological interpretations that derive from the analysis of artifacts and skeletal remains from these contexts of the old City of Palenque.

By means of AMS dating of material recovered from excavations, the earliest dates within the history of the site and region refer to the Late Preclassic (300 BC - 250 AD) and the Early Classic (250 AD-500 AD). The dates correspond to the foundation of the site and the emergence of Palenque as the most powerful Maya City in the region.

**E-3**

Study of MRAH Museum Collection Objects from Two Tombs Near Tehuacán – Mexico, Using a Combined Approach

Christophe Moreau¹, Martin Berger², Serge Lemaître³, Solene Mussard¹, Thomas Calligaro⁴

¹ Université Paris – Saclay
² National Museum of World Cultures, Netherlands
³ Royals Museum of Art and History, Brussels
⁴ CNRMF, Palais Du Louvre

The unprovenienced state of pre-Columbian Mesoamerican material in museums is a widespread concern for curators and academics alike. The fact that the large majority of Mesoamerican art objects was looted and sold through the art market, significantly hampers the use of museum collections in academic research. Material analysis can solve part of this problem by providing more detailed information on manufacturing techniques and provenience of materials. This holds true especially for collections from the same original context that have been dispersed among different museums by the practices of the art market.

The Royal Museums of Art and History (MRAH) in Brussels, Belgium, holds an important collection of Postclassic Mesoamerican mosaic-decorated shields, personal adornments and masks, as well as bark paper and other fiber offerings. Together, these materials are said to present the complete contents of two separate Post-Classic Mesoamerican tombs in the Tehuacán Valley in south-Central Mexico. However, since this collection was acquired on the art market in 1968, there is no documentation of its excavation and little is known of the provenience and original cultural context of these objects.

Several other museums worldwide hold collections of similar material, which also consist of the same corpus of material: turquoise mosaics, bark paper and fiber offerings. Like the MRAH collection all of this material is said to come from caves near Tehuacán. Any detailed information on their provenience or cultural context is lacking. Because of this lack of a documented provenience, this entire corpus of material has
never received intensive research attention. Nevertheless, considering the obvious stylistic similarities between these pieces, it is clear that they must derive from the same cultural region and context.

The aim of this study is first to understand the relationship between these objects. Archival and literature research coupled with Radiocarbon dating analysis is a powerful combined approach to provide arguments for a validation of different hypotheses. These arguments give then an idea on the origin of the objects and on the use of the find location in the past.

A perspective of the present combined approach conducted on objects from museum collection is to provide a database of objects well dated and with accurate contextual information. This database will become a tool to test other similar pre-Columbian Mesoamerican materials that reside in different museums around the world. Since many of these collections were assembled around the same time as the Brussels MRAH collections, it might be interesting to have the same study approach and compare them to the Brussels material.

The Tupiguarani people are one of the best-known Brazilian native populations. Among them, the Tupi recognized for their polychromatic painting ceramics [1][2]. Located where is now the central region of Rio, the Marrecas archaeological site brings together records of the presence of natives, African slaves and Europeans. [ref]. Ceramics and tools collected in the foundations of a XVIII century hospice point to the presence of the Tupiguarani culture [1]. Most of the Tupiguarani population was destroyed during the XVI century after the arrival of the Portuguese and their presence within the context of such hospice is intriguing. In the present work, several samples of charcoal and shells collected from this site were measured by means of Accelerator Mass Spectrometry (AMS) technique and carbon stable isotopes were evaluated. Discrepancy between charcoal and shell samples calibrated dates is investigated since very scarce studies are available on local marine reservoir effect in the region.

This session examines how recent developments in the analysis of scientific chronologies have related to archaeological narratives. We would like to consider how much new chronological sequences challenge the structure of archaeological chronological narratives. The session invites papers discussing: how we can use chronological approaches to investigate, critique or challenge pre-existing interpretations rather than replicate them; the challenges in producing narratives that tack between precise chronology and areas of relative imprecision; the tensions in dealing with large datasets, the legacy of grand narratives and individual sites; and the challenges in relating unique or exceptional sites to wider narratives of change.

### Schedule

**Friday May 24th**

**Beyond Site Sequences – B**  
**Chairs: Seren Griffiths and Derek Hamilton**  
**Athena Ballroom E**  
**9:00–11:00**

This session examines how recent developments in the analysis of scientific chronologies have related to archaeological narratives. We would like to consider how much new chronological sequences challenge the structure of archaeological chronological narratives. The session invites papers discussing: how we can use chronological approaches to investigate, critique or challenge pre-existing interpretations rather than replicate them; the challenges in producing narratives that tack between precise chronology and areas of relative imprecision; the tensions in dealing with large datasets, the legacy of grand narratives and individual sites; and the challenges in relating unique or exceptional sites to wider narratives of change.

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<td>Andrew Millard¹</td>
<td>Durham University</td>
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<td>Megan Conger¹</td>
<td>University of Georgia</td>
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<td>New Dimensions in Archaeological Chronology: Using Single-Year Tie-Points</td>
<td>Margot Kuitems¹, Andrea Scifo¹, Andreas Neocleous¹, Michael Dee¹</td>
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Recently, it was discovered that the production of radiocarbon has occasionally increased dramatically in the past. These phenomena are thought to result from intense bursts of cosmic radiation. So far, measurements on known-age (dendrochronological) tree-rings have revealed four such anomalies, including one in the year 775 CE. This paper discusses an approach to radiocarbon dating based on these rapid increases in radiocarbon concentration that can achieve much higher precision than ever possible by traditional methods. The idea is simple: by detecting such a signal in a growth-ring from wood with the bark preserved, one only has to count the number of rings to the edge to know the felling year of the tree. In order to apply this method to its full effect, however, a number of criteria have to be met. As part of the ECHOES project, we have applied this high-precision method to wood from archaeological sites from the 8th century, in order to allow new assessments to be made of their geochronological and archaeological significance. The results demonstrate the suitability and potential of this new method. However, the focus of this paper will be on experimental design and methodological considerations, which concern both archaeologists and radiocarbon laboratory technicians.
Radiocarbon Dating in Minnesota: Interpreting Archaeological Chronologies in A Region Affected by Aquatic, Ancient-Carbon Reservoirs Effects

Linda Scott Cummings¹, R.A. Varney¹, Thomas W. Stafford², Scott Anfinson³, Patricia Emerson³, Robert J. Speakman⁴, John Southon⁵

¹ PaleoResearch Institute
² Stafford Research, LLC
³ Minnesota Historical Society
⁴ University of Georgia
⁵ University of California, Irvine

From 1959 to the present, the State of Minnesota has maintained a radiocarbon database that comprises dates for more than 700 samples. Dates were on charcoal, macrofloral remains, ceramic residues (including charred food crust), and mammal and duck bone. In the previous decade, anomalous dates from sites with Brainerd ceramics raised concerns over the reliability of the database’s numbers. For sites containing Brainerd ceramics, ¹⁴C dates on bone are generally older than 2000 cal BP, while dates on charcoal are more recent than 2000 cal BP. Finally, dates on ceramic residues from co-occurring pottery range from 3500 to 1200 cal BP. PaleoResearch Institute recently evaluated the database to evaluate the reliability of archived dates, and obtain 75 new dates.

Several sites in Minnesota yield chronologies with a sufficient number of ¹⁴C dates to establish a statewide timeline. However, materials dated vary from site to site, thereby making it difficult to assess their accuracy and impossible to establish trends between sites. An example is the LaMoille site, where new dates obtained on charred nutshell, animal bone collagen, and burned and calcined bone highlighted the age discrepancies. The new LaMoille dates indicate that white calcined bone dates are younger than dates on bone collagen, charred bone, and partially calcined (“blue” or “gray”) bone. While previous dates suggest this site dates older than 7300 cal BP, while calcined bones dated less than 5300 BP suggesting a > 2000-year offset for some samples. Further, these calcined bone dates suggest rapid accumulation of material at this site, because they represent a span of 1000 years and are associated with many levels.

To clarify the chronologies, we measured new ¹⁴C dates on historic (1800s AD) and modern (2018 AD) ungulates and rodent bones to assess reservoir effects. Interpreting radiocarbon dates on archaeological materials from a region with numerous wetlands, e.g., Minnesota, requires measuring radiocarbon dates on modern and known-age materials, e.g., bison bone from a historic fort. The greatest antiquity of mammal bone dates compared to dates on contemporaneous charcoal has been surprising. While ancient carbon derived from freshwater reservoirs easily accounts for older dates on fish bone, we posit there are similar age effects when bone is dated from mammals ingesting ancient dissolved organic and inorganic carbon. In addition to overall aquatic reservoir effects, these age offsets are also controlled by N-S and E-W geological gradients in Minnesota.

This paper presents the results from our re-evaluation of the existing radiocarbon data from the State of Minnesota and recent work dating historic and modern large mammal and rodent bones. We suggest that it is possible to build accurate chronological sequences by researching each material separately as opposed to considering all dates as equally accurate. Variability in dates in the Minnesota record suggests that issues of ancient carbon contamination are far more pervasive than first believed and that freshwater reservoir effects are largely determined by local bedrock and soil variations, which vary across Minnesota.
Radiocarbon and Archaeology 9th International Symposium

Schedule

Friday May 24th

Beyond Site Sequences – B
Continued
Athena Ballroom E
9:00–11:00

10:40 AM
Bridging the Gap: Early Intermediate Bronze Age ¹⁴C Dates from Khirbat El-¹²Àlya Northwest, Israel
Ron Lev¹, Omer Shalev², Johanna Regev¹, Issac Paz², Elisabetta Boaretto¹
¹ Weizmann Institute of Science
² Israel Antiquities Authority

The Intermediate Bronze Age (IBA) in the second half of the third millennium BC is an enigmatic period in the history of the southern Levant, and there are still open questions on IBA timeframe and its relation to the preceding Early Bronze III (EB-III) urban culture. Radiocarbon research of recent years have demonstrated that the urban culture of EB-III in the southern Levant ended around 2500 BC, and not around 2300 BC as the previous traditionally held consensus (Regev et al 2012).

On-site sampling was done in the site of Khirbat el-'Alya Northwest (Shalev and Dallasheh 2017) in the Israel Shephelah region. Radiocarbon dating experts personally sampled organic remains on-site. Multiple sediment and control samples were also collected, analyzed and studied, in order to ensure the organic samples are in primary context, so their dating will safely reflect the date of the locus they were found in.

Charred olive pits from secure IBA context in Khirbat el-'Alya Northwest were radiocarbon dated, resulting with calibrated date range around 2500 BC. These dates indicate that in the Mediterranean parts of the Southern Levant, the IBA material culture appeared in close timing to the decline of the preceding culture of EB-III - around 2500 BC or somewhat earlier. IBA settlement pattern in the region is discussed, based on these new dates and on additional EB-III and IBA related research that was done in the same area.


Morning Coffee
11:00–11:20

Pauley's
In 1990s a series of associated charcoals were radiocarbon dated from DVII and Pavlov I, including the famous triple burial from DVII (Klima, 1987; Vandiver et al., 1989). During the 20th century several mammoth ivory and fired clay objects of human and animal figurines, notably from Pavlov Hills, Czech Republic. The region is famed for early examples of carved mammoth ivory and ceramic technology. Palaeoanthropology Brno: Academy of Sciences of the Czech Republic. Journal of Human Evolution 16: 827-830.


Sponheimer M. (2018) Saving Old Bones: a non-destructive method to determine bone collagen and lipid distribution in potsherds. The challenge of correcting for marine reservoir effects (MRE), especially on samples of mixed marine/terrestrial origin, means that lipids deriving from marine fats require further considerations for CSRA.

We studied the site of Bornais in the Outer Hebrides (UK), dated to the Iron Age and Norse periods. Lipid residue analysis and CSRA on the C16:0 and C18:0 fatty acids (FAs) isolated from pottery vessels demonstrated the processing of both marine and terrestrial animal products in the same vessels. The CSRA on pottery vessels required, therefore, corrections using a mixed marine/terrestrial approach. The site revealed numerous marine remains (shells and fish bones) which allowed the calculation of a local ΔR (65 ± 45) using paired measurements on marine and terrestrial organisms. In addition, the δ¹³C values determined for the individual FAs permitted estimation of the percentage of marine fat/oil in pots. Calibrated ages of pottery vessels showed, after correction, an age range in agreement with that of other independently-dated terrestrially-derived materials at the site.

This study demonstrates that CSRA of mixed marine/terrestrial lipids can be corrected for the MRE using a similar approach to that used for bone collagen. Significantly, pottery vessels where lipid residues derive from marine environments can be considered for dating if appropriate corrections are applied.

In 2013, seven of the human bones were sampled for aDNA analysis, including the three skeletons from the triple burial (DV13, DV14, DV15), two skeletons from single burials (Pav1, DV16) and two unarticulated human bones (DV42, DV43) (Fu et al., 2016). Very small amounts of bone material were left over from the aDNA sampling, providing the opportunity to directly date the human bones.

A recent pilot study indicated that near-infrared spectroscopy (NIRS) is an effective method to non-destructively ascertain the level of collagen preservation in archaeological bone (Sponheimer, 2018). NIRS analysis of the human bones from DVII/Pavlov I indicated that sufficient collagen was preserved for radiocarbon dating. We therefore sampled small amounts (32-70 mg) of bone material for collagen extraction and ultrafiltration. Preservation was excellent (8-14% collagen preserved) which allowed us to date each collagen extract multiple times using the AixMICADAS (Bard et al., 2015) with graphite targets (ca. 800 µg C) and the gas ion source (<100 µg C) (Fewlass et al., 2017). The direct dates confirm the Gravettian origin of the human remains and indicate that several of the radiocarbon dates carried out in the 1990s from associated charcoals were likely affected by low-level contamination of modern carbon.


When dating ancient written documents by radiocarbon, what we typically measure is the \(^{14}\text{C}\) content in the support material, either paper or parchment or papyrus, for instance. This can however lead to a possible misinterpretation of results, considering that the support may be older than the writing itself. To solve such a possible ambiguity, the ideal approach would be the direct dating of the organic component in the applied ink. For example, for carbon black inks, we should perfectly isolate the residual charcoals or the ink binder.

Here we propose a systematical study on the possibility to date carbon black inks when deposited on papyrus, one of the most widespread writing supports of the past. We prepared several test samples, using a commercial papyrus, formally produced according to the traditional rules, and a home-made carbon black ink, prepared combining modern charcoals and Arabic gum. As first step, radiocarbon content of all original materials was characterized by AMS measurements. Residual charcoals recovered after extraction in warm water were identified as the most suitable material to be dated, since the soluble fraction of ink binder and the papyrus extractives are very similar and resulted to be hard to be discriminated, as verified thanks to infrared spectroscopy measurements.

\(^{14}\text{C}\) measurements on the collected charcoal fragments were performed using our new dedicated graphitization reactors specifically designed for small size samples (m ~ 50 micrograms). Experimental data have been consistent with the average radiocarbon concentration of the charcoal used to prepare the ink, thus proving that the extraction procedure is successful.
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