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ANSTO

Keynote

Island in the middle: Radiocarbon chronologies, past landscapes, and the human history of Papua New Guinea

The island of New Guinea is a global hotspot of cultural and linguistic diversity, hosting 1/6th of the world's languages on only 0.5% of the world's land surface. Such remarkable diversity is, in part, because of the islands long human history as well as the unique ways people have adapted to living in the equally as diverse highland, lowland, and island environments. Papua New Guinea (the country occupying the eastern half of the island) is uniquely placed to model Pleistocene human expansions, responses to innovative developments such as agriculture, and the Late Holocene maritime colonisation of Oceania. Yet, we still know very little about how, when, and why such remarkable diversity developed. Archaeological syntheses have to some extent been hindered by the relatively small number of excavated sites and the often large distances between them. In some regions a predominant focus on caves, although foundational in establishing long term sequences, has further limited what can be extrapolated about the human past. In this talk I will build on these foundational studies by presenting the results and implications of ongoing archaeological research in highland and island Papua New Guinea focused on building robust radiocarbon chronologies for a range of sites across cultural landscapes.

Presenter

Ben Shaw
School of Culture, History and Language College of Asia
and the Pacific Australian National University

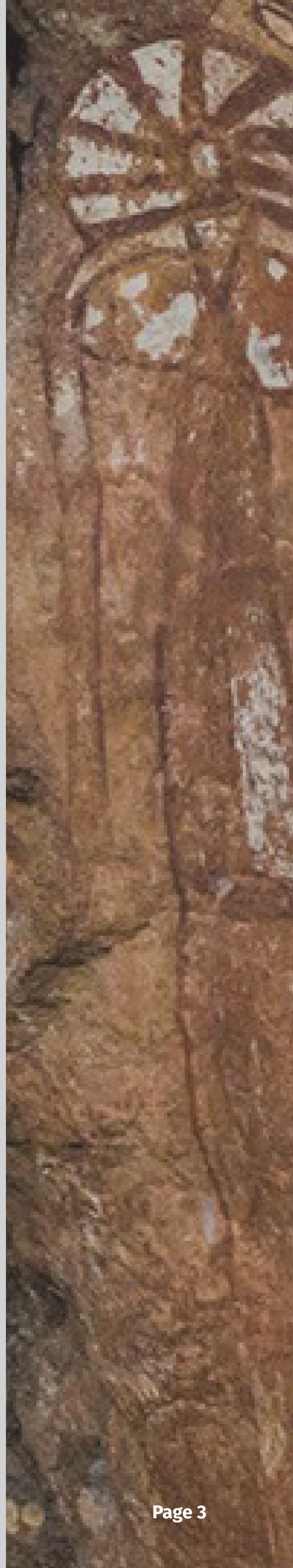
Keynote

Applying advanced science to the care of cultural heritage, and the question of intergenerational legacy

Conservators find themselves in a unique position of responsibility for intergenerational heritage and nation-defining objects, and an expectation that these things will defy chemistry and physics to survive forever. Being a "Conservator" is a different profession in many parts of the world. In some we are closer to traditional restorers, and in others we are closer to being public service administrators. The place we occupy in the lives of heritage is diverse, and there is no one answer to how to define our work. This presentation will be about the "Science of the Conservator" in an Australian context where our geographic isolation and access to advanced instrumentation has resulted in our own approach.
This paper will reflect over fifteen years of ANSTO based experiments on cultural heritage questions that have shaped my understanding of how science can interact in a practical way with the activity of cultural heritage preservation, and shape a different way of thinking about our material heritage and what we choose to try and carry forward into the future.
Advanced cultural heritage experiments are difficult to organize, and are only just beginning to break through into top tier publications – and they are still largely an alien language for many museum curators and museum directors. Using examples from research, this talk will be about taking the risk of starting heritage research projects, give examples of outcomes, and reflect on the broad context of why it matters outside of the science community.

Presenter

David Thurrowgood
Applied Conservation Science Pty Ltd



Keynote

Neutron techniques and new collaborations in the study of South- and Southeast Asian bronzes in the Rijksmuseum

The Rijksmuseum metals conservation department has in past decades focused increasingly on technical study of artworks, and has long recognized the value of neutron-based methods for the analysis of bronze statuary (1, 2) and other objects under its care. Fostered by an atmosphere of collaborative research between art conservators, art historians and scientists, the current project presented here is an investigation of four bronzes from South India and Southeast Asia with neutron-based techniques.

Four bronze statues from the Rijksmuseum and Royal Society of the Friends of Asian Art were taken to neutron facilities for analyses aiming to characterize composition and microstructures, and to provide insight into casting methods and condition. Two of the statues are solid-cast bronzes: Uma and Chandrasekhara, made in the Chola bronze casting tradition unique to South India. The others are hollow-cast bronzes with a clay core and iron armature: Avalokiteshvara and Standing Buddha, recovered from burial in Thailand and Java, respectively.

The statues ranged in size from 40 cm to 86 cm in height. All four statues retained little to no information about burial location or archaeological context. A variety of condition issues including corrosion, old (failing) restorations and cracking bronze provided the impetus for this research, along with the desire for technical investigations of casting methods which could help conservators and art historians place the statues in the correct (art) historical context (3).

Two phases of research were initially planned: white beam tomography and energy selective radiography (Conrad II, Helmholz-Zentrum Berlin), and time-of-flight diffraction (ENGIN-X, ISIS Neutron and Muon Source). The project has since been expanded to include additional rounds of neutron diffraction and gamma spectroscopy (January 2022 at FISH, Reactor Institute, TU Delft).

--Chandrasekhara: an unexpected high-attenuating material was revealed inside the silver inlay necklace requiring further investigation; dendrites growing between parts of the Chandrasekhara and variations in crystal size and lead content provide insight into construction of the wax model and casting position

--Uma: porosity patterns inside the solid-cast bronze show that the bronze is a very high quality casting, and confirm an inclined horizontal face-down casting position.

--Standing Buddha: different attenuation of core material in head vs. torso point to separate modeling of these parts in the wax prior to casting; an unexpected spiral pattern of toolmarks at the groin indicates possible lost inlay and will be investigated further.

--Avalokiteshvara: Cracks in bronze, clay core and corroding iron armatures were documented, providing a baseline reference for monitoring corrosion and dimensional changes. Large amounts of old restoration materials have been located deep inside the sculpture, in some places replacing core material.

Results will be published in a series of papers for the general public (4) as well as the scientific community. They have already been used to inform conservation treatment decisions, and it is hoped that neutron CT-images as well as the insights they generate will be incorporated in a bronze exhibition, now in planning stages. A broader impact is witnessed by the evolution of the project, which began as an informal collaboration between the Rijksmuseum and the CNR in Italy, and has now expanded to include researchers from the TUDelft Reactor institute, who secured NICAS (5) funding to optimize a beamline for cultural heritage and develop advanced gamma spectroscopy techniques.

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3. See for example Slączka, A.A. et al (2019) 'Nataraja informed through text and technique: A study of the monumental Indian bronze at the Rijksmuseum' Rijksmuseum Bulletin, vol 67 No 1. Pp. 4-29.
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Uma (AK-MAK-188 date c.1400-1500, height 74cm) is a solid bronze sculpture with a fine, evenly distributed porosity throughout. NT image collected during the first phase of research, white beam neutron tomography at Helmholz-Zentrum Berlin. Image credit Rijksmuseum (left) and N. Kardjilov, HZB (right).

Presenter

Sara Creange
Rijksmuseum

Presenters

The Invisible Revealed: Art and Nuclear Methods Meet at the Powerhouse Museum

The Powerhouse Museum is a contemporary museum in the heart of Sydney with a focus on arts, science, innovation, and design. It's collection of more than half a million objects tells us much about our material culture but it also inspires many questions. What are our objects made of? How old are they? Is anything hidden inside? Over time, new research and technologies can help us solve these mysteries – and reveal new ones.

The Powerhouse, The University of New South Wales Expanded Perception & Interaction Centre (EPICentre) and ANSTO have partnered to present a 'deep dive' into 26 objects from the collection in a six-month exhibition titled The Invisible Revealed. This exhibit opened to the public on 26th November 2021.

Using a combination of 9 different nuclear reactor, synchrotron and particle-accelerator based technologies, ANSTO's imaging and analytical capabilities show how culturally significant artefacts were manufactured, and how they might be better conserved for decades and centuries to come. To convey these research and conservation outcomes, the artefacts are displayed alongside 3D visualisations and other imagery that reveals the objects' structural detail and give visitors a look into ANSTO's scientific capabilities and technical achievements.

The collaborative study and exhibited works include:

- statues from ancient Egypt, Greece and T'ang dynasty China
- Samurai swords spanning the period 987-1830;
- a Chinese Shang dynasty (1600–1046 BCE) bronze wine vessel;
- textiles from Ancient, Ptolemaic and Roman Egypt
- the world's first handheld calculator, miniature cameras, musical watches

and more.

Incredibly, most of the data acquisition, analyses and planning for this exhibit occurred in mid-2021 during, and despite ongoing lockdowns, state border closures and working-from-home arrangements.

This talk aims to share our insights and opportunities gained through this collaboration of diverse people to achieve Australia's first major exhibit of applied nuclear methods in a national museum. We will present a selection of the objects studied, methods applied, discoveries, and the importance of art and form essential to their portrayal in a museum environment.

Image: Figure of horse, ceramic, China, T'ang period, 618-906 CE. Powerhouse collection. Neutron radiograph by ANSTO

Presenter

Joseph J. Bevitt
ANSTO

Presenters

Accelerator mass spectrometry techniques for cultural heritage studies

ANSTO operates four tandem particle accelerators in the Centre for Accelerator Science (CAS) at its Lucas Heights campus. All these machines are used for accelerator mass spectrometry (AMS) and are radiocarbon capable. Three are used for ion beam analysis (IBA), as described elsewhere in this workshop. Since its establishment, CAS has strived to develop and refine AMS radiocarbon measurements, improving the precision and reliability and reducing the required sample size by a factor of 1000 from a few milligrams (mg) of carbon to just a few micrograms (µg). This 'micro-sample' capability has allowed the application of AMS radiocarbon studies to an ever-widening range of objects and artefacts. To illustrate this, a few of the interesting archaeological and cultural studies undertaken on our 10-million volt Australian National Tandem for Applied Research (ANTARES) accelerator are presented. These include dating of such unique objects as the Venafro chessmen, discovered in 1932 in Venafro, a Roman necropolis in Southern Italy, and the 'Corona Ferrea' (Iron Crown) of Monza (Italy). CAS AMS was heavily involved in establishing reliable dating for the objects from the Egyptian collection from the Nicholson museum in Australia, and for the mediaeval Torah scroll from the rare book collection of Sydney University.

The sophistication of the technique allowing sample sizes in the microgram range, and so the dating of individual chemical constituents of the item, enabled a whole new group of objects to be studied, many of which were not considered suitable previously. This CAS capacity was utilised in several Rock Art studies from Africa to Central Europe, and indeed closer to home for establishing chronology for Rock Art styles in Australian Kimberley and Arnhem Land regions and their Pleistocene antiquity. The 'micro-radiocarbon' capability allowed determining the age of the oldest dated Australian rock motif – a naturalistic depiction of kangaroo – to between 17,500 and 17,100 years ago. Some work has also been undertaken on dating wear and use residues on lithic objects, where the amount of carbon-containing material is very limited.

The AMS facility at CAS is capable of measuring other rare isotopes of intermediate half-life bedsides carbon, and some of these find application in nuclear heritage studies. As an example, we present measurements of cosmogenic in-situ 10Be and 26Al were used to investigate the evolution of the rock shelters in the Kimberley, where the most rock art in the region is found. Exposure dating of collapsed overhang blocks provided minimum and maximum age limits for the art on the fallen blocks and on freshly exposed surfaces. These results are important not only for establishing the time frame of the motifs, but also for assessments of art preservation and survival over time.

Presenter

V.A. Levchenko & A. M. Smith
ANSTO

Presenters

Synchrotron X-ray Imaging for Cultural Heritage Studies

X-ray imaging is one form of visualisation with a proven utility in cultural heritage studies. It allows one to view the internal structures of radiolucent objects non-destructively, by virtue of the penetrating power of high energy x-ray photons. For a given x-ray imaging situation there is usually one illumination wavelength that provides the best image. However laboratory X-ray sources are typically broad band in nature, and are very inefficient at turning power into x-rays. Selecting a narrow band for imaging from such a source implies discarding most of that power. The resulting illuminating flux is necessarily very weak, meaning exposure times for imaging are long.

A synchrotron storage ring source is a highly efficient x-ray source. It produces a very bright broad x-ray spectrum. So monochromation of these sources does provide beams with useable flux for imaging. Furthermore the small size of the radiation source permits exploitation of coherence. The x-ray phase shift can be orders of magnitude more sensitive to density changes in the object, compared to straightforward absorption. Making even subtle material changes visible. This talk will describe the synchrotron imaging facility IMBL at the ANSTO Australian Synchrotron. Some technical details and capabilities will be discussed. A few relevant case studies will be shown to illustrate the utility of our instrument.

Presenter

Chris Hall
ANSTO

Neutron Diffraction for Cultural heritage

Neutrons represent a special interest for studies of objects of cultural heritage due to their high penetration ability. Depending on material they can penetrate up to 10 cm and more providing crystallographic information about material in the interior non-destructively. This cannot be attained by other techniques (x-rays, EBSD, optical microscopy) that can work only on surface and frequently requiring surface preparation/modification. Material such as metals (bronzes and steels of historical weapon blades, gold and silver coins), ceramics and rocks can be studied with neutron diffraction to determine grain crystallographic alignment, phase composition and internal stresses. These characterisations can forensically reveal the processes and conditions of the studied cultural heritage object production.

Several neutron diffraction techniques (and neutron diffraction instruments) are available at the Australian neutron research facility based on the OPAL research reactor at ANSTO (Lucas Heights). The suite of diffractometers includes high-resolution powder diffractometer (ECHIDNA), high-intensity diffractometer (WOMBAT), single-crystal diffractometer (KOALA) and stress/texture diffractometer (KOWARI). Over last years of operation the residual stress diffractometer KOWARI has been steadily used for research of cultural heritage objects and few recent projects will be featured in the presentation.

Presenter
Vladimir Luzin
ANSTO

Presenters

Scanning electron microscope (SEM), focused ion beam (FIB), and transmission electron microscopy (TEM) for Cultural Heritage

Electron microscopy including SEM, FIB and TEM are important techniques for use in Cultural Heritage, Conservation Science and Archaeology. The scanning electron microscope can examine an object without any alteration or physical damage. Surface morphology at very high resolution and chemical composition are possible using this technique. If further information is required, the object can be prepared using the focused ion beam to create a cross section for TEM examination where the same information and more can be extracted at the sub-nanometre level.

Presenter

Joel Davis
ANSTO

Introduction to Neutron Activation Analysis in Cultural Heritage

Neutron Activation Analysis (NAA) is a sensitive method for quantifying the elemental content of samples and has been used in cultural heritage research since its inception several decades ago. While many laboratory and even field-scale alternatives now exist, NAA in its various forms maintains some important advantages over its competitors continues to be used today in cultural heritage. Instrumental Neutron Activation Analysis (INAA) is mostly useful for items that can be sub-sampled, such as pottery shreds or ochre, but also can be used for small whole artefacts such as coins in some cases. The related technique Prompt Gamma Activation Analysis (PGAA) can be applied non-destructively to whole artefacts and in some cases be used simultaneously with neutron imaging.

Presenter
Attila Stopic
ANSTO

X-ray Fluorescence Microscopy Applications in Cultural Heritage

X-ray fluorescence microscopy (XFM) is an imaging technique that is well-suited to the non-invasive observation of spatially-resolved metal compositions in cultural materials. This talk will discuss several conservation projects undertaken at the XFM beamline at the Australian Synchrotron, part of ANSTO. One project, a portrait of Henry VIII on oak panel c. 1535 in the collection of the Art Gallery of New South Wales underwent technical examination to inform questions regarding authorship and the painting's relationship to a group of similar works in the National Portrait Gallery, London and the Society of Antiquaries. High definition elemental mapping of the Tudor painting at the beamline proved vital to guiding its restoration treatment. Another project involved analysis of paint samples extracted from Van Gogh's The Bedroom to help understand the darkening process of chrome yellow pigments with a technique called XANES imaging. An overview of the technique and the technical challenges presented by these objects for synchrotron analysis will be discussed.

Presenter
Daryl Howard
ANSTO

Presenters

Neutron imaging in archaeometry and conservations science

Neutron radiation techniques are a well-established analytical means for the non-invasive investigation of matters. The fundamental properties of the neutron — no electric charge, deep penetration power into matter, and interaction with the nucleus of an atom rather than with the diffuse electron cloud —make this sub-atomic particle the ideal probe to survey the bulk of a variety of materials.

In particular, neutron imaging methods (radiography and tomography) can provide a real space representation of an object or phenomenon in different dimensions. The spatial distribution of matter inside an object can be reconstructed by measuring the transmitted intensity of the probing beam that decreases exponentially along the path length through the sample, depending on the material elemental composition and density. Complementary to the equivalent X-ray method, neutron imaging is used in a wide range of applications; from the characterization of additive manufacturing samples, to the investigation of museum artefacts, through the investigation of dynamic processes such as the flow of fluids in rocks.

In this paper, the most relevant case studies conducted at neutron imaging instrument DINGO at ACNS|ANSTO and undertaken in collaboration with Australian research institutions, universities, and international stakeholders will be showcased with a particular focus on archaeometry and conservation science.
Neutron imaging integrated by neutron diffraction techniques were successfully applied in a series of forensic studies to characterise the structure, morphology, and composition of cultural heritage objects without the need for sampling or invasive procedures enabling to shed new light on the most advanced manufacturing processes developed by different cultures over time.

Presenter

F. Salvemini
ANSTO

Presenters

Scanning Electron Microscopy & Associated Techniques: Applications to Cultural Heritage Research at the UNSW EMU

Electron microscopy can be used to examine a huge range of cultural heritage materials, including ceramics, glass, lithics, bone and textiles. Through a series of case studies, I will provide an overview of advanced electron microscopy imaging and analytical techniques and the information that they can provide to researchers in this field. While my area of technical focus is on scanning electron microscopy (SEM), I will cover the broader range of facilities available to cultural heritage researchers through the University of New South Wales Electron Microscope Unit and the nationwide Microscopy Australia network.

Techniques covered will include: variable-pressure SEM (VP-SEM), energy dispersive spectroscopy (EDS) mapping and point analysis, electron probe microanalysis (EPMA), cathodoluminescence (CL), transmission electron microscopy (TEM) and focused ion beam (FIB) sample preparation and imaging. Case studies will cover topics such as sample condition and provenance1, artefact surface modification (e.g., cutmarks2, usewear), and material fabrication techniques3,4,5.

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Presenter

Karen Privat
University of New South Wales

Presenters

A 'Genuine' 6th century BC Plated Silver Coin from the mint of Athens.

Little is known about the techniques for manufacturing plated coins among the very earliest issues of Greek (and world) money. In this study we present neutron and synchrotron X-ray analyses of a plated silver coin produced in Athens around 525-515 BC. The coin is a tetradrachm, which should have been made with 17.2gm of silver. But this plated coin (with a bronze core) was detected in antiquity and cut in half so that it might not be used again. Analyses show two mysterious gaps in the silver plating. This coin is of particular importance for the study of early coinage because it can be shown through a comparison of the images on obverse and reverse that the dies which produced the coins are shared with other Athenian tetradrachms of normal metal. This demonstrates that the plated coin was produced in the official mint of Athens, and not by a forger, ancient or modern.
Ancient plated coins and ACANS 14A09

Plated coins from antiquity have been readily dismissed as the work of forgers who, in antiquity or modern times, copied the work of state mints. Once a plated coin was detected by modern scholars it was discarded or set aside as a curiosity not to be considered with the official issues. In recent years it has become apparent that early state mints did produce plated coins. Is it possible, however, to detect official 'forgeries' amongst the ancient coins that have come down to us? If we can find plated coins that we minted with the very same dies that produced 'good' coin then the answer is yes. A very rare example (ACANS inv. 14A09) is now presented in this study. This four drachm piece belongs to a well-known series of silver coins with the head of a gorgoneion on the obverse that were manufactured in Athens c.525-515 BC. It was minted with dies attested on other 'genuine' coins.
Analyses

We know little about the techniques for plating early coinage in the empire of Lydia (where western coinage began) and then in the archaic Greek states during the 6th century BC. There has yet to be a comprehensive study of this technology and its application. In this study we outline the evidence for the plating technique of one of the very earliest Greek silver coins for which such a study has been attempted. A non-invasive analysis based on a multi-technique approach has been exploited to clarify the nature of the coin by gathering information at different level of the coin structural material. Bimodal (neutron and synchrotron X-ray) tomography was applied for structural tri-dimensional characterization of the morphology, porosity, mineralisation, and the presence of composite structures. Full-pattern neutron diffraction analysis was conducted for phase determination and quantification. Neutron diffraction texture analysis was used for the characterization of the preferred orientation of the crystalline structure that can be correlated to deformation and temperature dependences of the silver plating and the copper core during manufacture.

Conclusions
The manufacturing processes producing the coin can be inferred from the distinctive macro- and micro-structural features shown by tomography and diffraction analyses. The data, clearly showing the silver copper layers, and strongly suggests the method of manufacture, namely folding a thin foil of silver over the copper core and heating to near the Eutectic temperature. This took significant time and technical skills. The analyzed mass fraction of silver to copper is 1.5:5.2. Thus plating the coins produced 3-4 times as many coins per weight of silver and was evidentially economical viable. Additionally, neutron tomography provided information about the state of conservation of the sample by highlighting both the morphology and the progress of the corrosion penetrating from the cut into the bulk. Another feature identified was the drop-like piercing into the plating that might be interpreted as plugs of a silver-based alloy added in order to repair two holes that, otherwise, would reveal the copper core and thus expose the coin as a 'forgery'.

Presenter

K A Sheedy
Macquarie University

Presenters

Every contact leaves a trace – use of synchrotron FTIR technique to identify trace evidence of past human activity in archaeological sites from NW Australia.

In forensic science, Locard's principle holds that the perpetrator of a crime will bring something into the crime scene and leave with something from it, and both can be used as forensic evidence. The archaeological record is similarly based on an interaction with the environment in such a way that material remains are created and, if preserved and found, can be used to interpret past human behaviour. In both disciplines, trace evidence is used to link people or objects to places, other people or other objects, and often serves as a starting point, or lead, for a particular line of investigation. With the ever-increasing sophistication of the equipment used to examine material remains, there is a growing overlap between archaeology and forensic science and technology.

Archaeology can be viewed as a detective story, in which the investigator has arrived at the scene thousands of years later. However, the scientific techniques used for characterisation of ancient organic and inorganic materials are the same as those used by forensic laboratories. These include micro-analytical techniques, and likewise may involve comparison of a new sample with an existing database of reference samples of known provenance.

In this presentation, I will present two case studies from NW Australia, where Fourier Transform Infrared Microspectroscopy (FTIRM) has been used to identify trace evidence that links the objects left behind by people to their activities in the past. In both applications, the unique capability offered by synchrotron-based FTIRM (SR-FTIRM) at ANSTO – Australian Synchrotron's IRM beamline is shown to be the crucial forensic tool that enables the examination of chemical compositions within these small archaeological samples at micron scales. The use of this highly collimated synchrotron-IR beam in archaeological research is novel in Australia, where to date laboratory-based FTIR technologies have largely been limited for identifying pigments, plant resins and other organic residues that are embedded within heterogeneous matrices.

The first study explores the residues left behind on small stone tools, unearthed from Pleistocene-age cave deposits. The possible identification of these residues as plant resins would provide evidence that the tools were hafted as part of a complex technology that is otherwise considered to have developed much later in Australia. In the second study, the SR-FTIRM was used to explore the heating temperature of bone fragments in micro-morphological thin sections collected from Pleistocene-age archaeological sites in the Pilbara and Kimberley. These thin sections are highly heterogeneous comprising inorganic minerals, plant charcoal and wood ash, and bone fragments that range in size from 10 µm to 500 µm. The SR-FTIRM data could offer insights into the social or subsistent uses of different hearth structures.
We may never know exactly the past, but the forensic approach does at least allow the archaeologist to offer an expert opinion that can be held up to scrutiny and provide a verdict that is hopefully beyond reasonable doubt. We'll let you be the judge!

Presenter

I Ward
University of Western Australia

Presenters

Nuclear and isotopic techniques for evidencing ancient and recent forgeries

Forgeries have existed in many fields. Money, goods, artworks have been imitated since centuries to deceive and make profit. In this talk, I will present three cases where nuclear and isotopic techniques have been used to study past and recent forgeries.

The first example will deal with ancient counterfeit coins. Long considered uninteresting by numismatists, counterfeit coins are nevertheless archeological evidence of ancient metallurgy technologies as well as counterfeiting practices. Many techniques were used to deceive customers with false coins copying official coins. One of them was the use of cheaper metals than those of the official production, while respecting the visual aspect- color, engraving, size- as well as the weight which was directly connected to the value of the coinage. Silver coinage was imitated in the past by replacing silver, partly or entirely, by copper or iron and the visual silvery surface was produced by various manufacturing processes. The technology of the unofficial production of silvered coins was investigated by using fast neutron activation analysis and PIXE for the non-destructive and quantitative determination of the metal content and by Rutherford backscattering spectrometry (RBS) for the surface analysis. The silvering processes used for silver-plated coin forgeries of the 3rd and the 16th centuries will be described.

The second example will deal with recent art forgeries. Investigations to authenticate paintings rely on an advanced knowledge of art history and a collection of scientific techniques. However, accelerator mass spectrometry (AMS) radiocarbon (^{14}C) dating is the only technique that gives access to an absolute time scale. AMS radiocarbon dating was applied to Impressionist paintings of the beginning of 20th century, in the context of an ongoing police investigation. ^{14}C measurements show that the plants used to make the canvas were harvested after 1955, that is to say at least 10 years after the death in the 40s of the supposed artists. These results demonstrate that the paintings are recent forgeries.

Finally, the recent evidence by ^{14}C AMS of the misattribution of the Flora bust (Bode-Museum, Berlin) to Leonardo da Vinci will be presented.

Presenter

Lucile Beck
LMC14, LSCE/IPSL, CEA-CNRS-UVSQ, Université Paris-Saclay - Gif Sur Yvette, France

Presenters

Sydney Analytical: A hub for science in cultural heritage and archaeology

The use of analytical chemistry in cultural heritage and archaeology is a powerful means of investigating a wide array of important issues through the analysis of materials from the biological to inorganic.

Sydney Analytical houses more than 30 high-end instruments and spans multiple vibrational spectroscopic and X-ray techniques, many of which are the most advanced of their kind in Australia and can provide non-destructive, rapid and contactless analysis. Our range of instrumentation covers not only laboratory-based equipment but also portable instruments. Sydney Analytical also engages extensively with industry, including a collaboration with ANSTO to support neutron and synchrotron research.

We aim to create a scientific facility for innovative research, fostering the creation of new knowledge that benefits our cultural heritage community. This platform will strengthen and build the skills base of undergraduate and postgraduate students studying conservation, museum studies or other related fields from Australian institutions. This presentation will outline some of our available technology and a few interesting case studies that we have been privileged to be involved in.

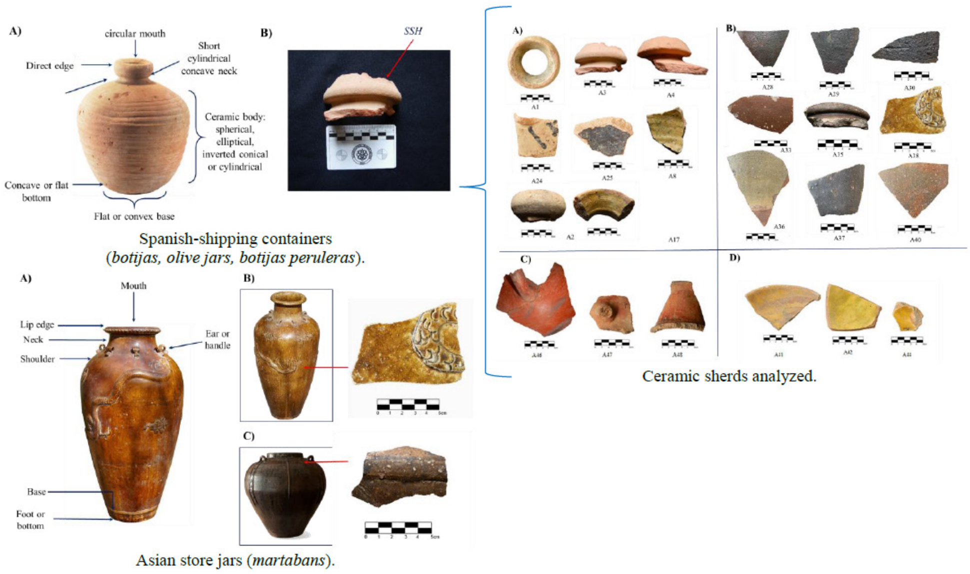
Presenter

Elizabeth (Liz) Carter
Sydney Analytical - Vibrational Spectroscopy Facility

Presenters

Commercial interaction at the port of Acapulco, Mexico, during the Viceregal period: A provenance study of ceramic containers and regional wares

This poster exposes the results of Instrumental Neutron Activation Analysis (INAA) on 46 pottery sherds, fragments of Spanish olive jars (botijas) and stoneware containers (martabans) recovered from archaeological interventions in San Diego fort and Acapulco historic sector, a shipwreck site in the western coast of Baja California peninsula, and shipwrecks beneath of Gulf of Mexico and Caribbean Sea waves. The study was developed to obtain data on the geochemical-composition of pastes, lead-glaze and pitch coatings of the referred pottery sherds collection, with the aim of identifying the geochemical signature of each elementary composition of sherds. So, it was possible to propose a geochemical area of origin (manufacturing provenance) for the sampled ceramic vessels: according achieved results, many analyzed pottery sherds came from the Iberian peninsula, South America and Southeastern Asia, whilst other were locally-produced (namely the Acapulco Red Ware and Acapulco Glaze).



Left: Examples of complete ceramics forms analyzed. Right: sherds analyzed. A) Botijas; B) Martabans; C) Acapulco Red Ware; D) Glazed ware.

Presenter

Saúl Alberto Guerrero Rivero
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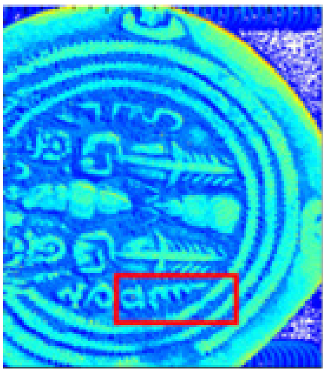
Presenters

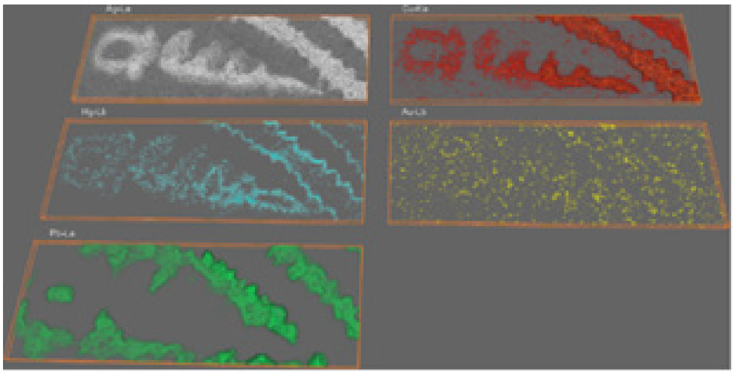
Activities in the IAEA Physics Section to foster the use of x-ray techniques for the characterization of valuable objects

The presentation summarizes recent activities organized in support of the introduction and use of x-ray spectrometry techniques for comprehensive characterization of objects from cultural heritage. A summary of the main actions undertaken for knowledge transfer, training and capacity building and information exchange is presented, highlighting the online resources available to support these activities and future activities planned.

Several examples of applied research conducted in cooperation with external stakeholders are presented to illustrate some of the capabilities of x-ray spectrometry techniques, including portable, laboratory and synchrotron-based instrumentation.

The examples include the study of metal objects, surface decoration layers in ceramics, identification of pigments in wall paintings and oxides used in coloured glass beads, in support of different types analytical problems.





Presenter

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Presenters

Muons to the rescue: application of Muonic X-ray emission spectroscopy (μXES) for non-destructive measurements

Muonic X-ray Emission Spectroscopy (μXES) is a unique technique in the field of cultural heritage science. The first applications of negative muons for the characterization of materials are dated back to the last two decades of the last century, but only in recent years, the technique has started to leave its mark among the scientific community [1-6]. The technique relies on the interaction of a probe of negative muons with matter: muons are captured by the outer shell of the absorbing atom, forming the so-called "muonic atom" [7]. The muonic atom rapidly de-excites by emitting x-ray radiation that can be collected by a detection system. Since the muon mass is almost 207 times greater than the one of the electron, the muonic x-rays are high energetic (up to 6 MeV): this means that they are detected without significant effects of self-absorption. Given that the x-rays are characteristic of the emitting atom, it is possible to perform elemental characterization, even for light atoms (fig. 1). In addition to that, isotopic analysis is feasible: it has been recently observed that for K-lines transitions, there is an isotopic shift in the energy of the muonic X-ray [8]. Along with the multi-elemental analysis, it is possible to perform depth profile studies: by varying the energy of the incoming muon beam, all the different layers present in a sample can be investigated. The range of penetration can vary from 10s nm to a few cm and with a few % resolution. Finally, with μXES, differently from other large scale facility techniques, no residual activity is left on the sample after the measurement. The technique is a very powerful probe for the characterization of archaeological findings and currently, such type of analysis is carried out at the ISIS Neutron and Muon source facility in the UK and MuSiC and J-PARC in Japan [9-10] with developments on-going at other muon facilities.

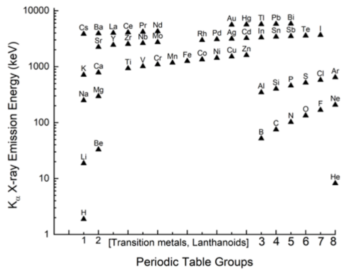
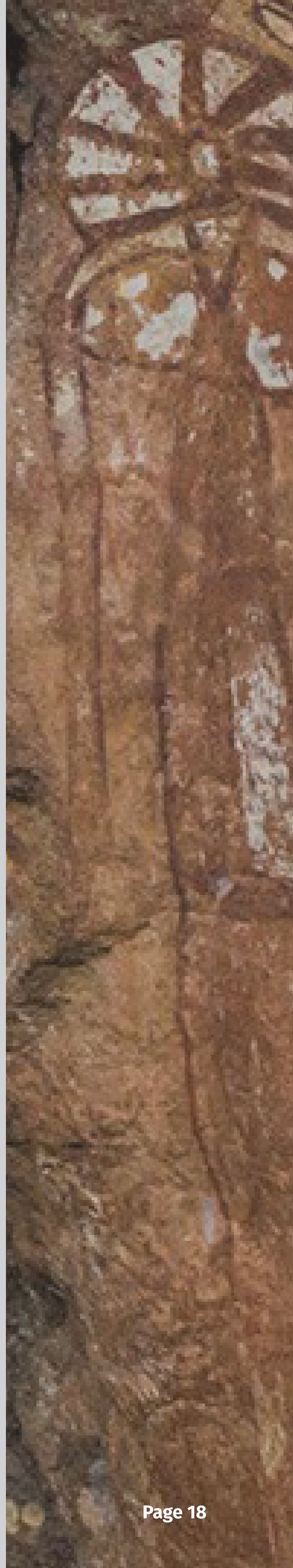


Fig. 1 – Kα emission lines for the elements of the periodic table (data source: [11-12]).

Figures 2 and 3 report an example of the application of this technique to a fragment of an Etruscan Bronze mirror found near the city of Firenze. The mirror was known to be characterized by a tin enriched surface. To detect this variation within the sample, the beam was tuned starting from a momentum of 19 MeV/c to 35 MeV/c. In figure 3 is reported the copper-tin ratio alongside the variation of the nitrogen peak area. Nitrogen, the main component of air, is a good indication of where the beam is compared to the sample: a higher contribution in this element, suggests that most of the x-rays are coming from the surface (or close to the surface) rather than from the inside of the sample. The plot shows that at the lowest momenta, there is a high contribution from the muons stopping in the air- i.e nitrogen- that decreases (to zero) with the increasing of the momentum: this means that for the first runs, the beam was probing close/on the surface. This is also confirmed by the values of aluminium (used for sample placing, not shown), which is present in the first three runs and then goes almost to zero, and by tin. As shown in figure 3 the copper/tin ratio increases along with the momentum. This means that there is a higher concentration of tin on the surface than in the bulk of the sample; on the other hand, copper is in a lower concentration for the first runs and then increases. That means that up to 21 MeV/c, the beam is probing the part of the sample that is richer in tin, while, as the momentum increase, is probing the bulk of the material. Such consideration is in agreement with the presence of a tin enriched layer that served as a reflective mirror surface and is a further confirmation of the goodness of the technique.

Fig. 2 - Fragment of an Etruscan Bronze Mirror (5x3 cm)



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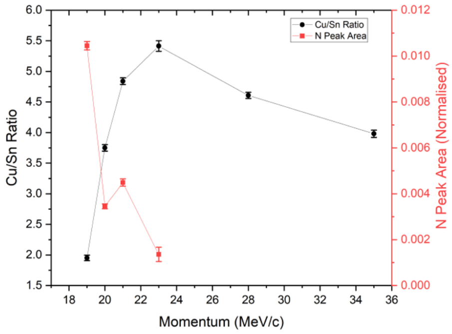

Fig. 3 – Copper/Tin Ratio (black) and nitrogen peak area variation (Red). The peaks used for the data analysis are the 115.9 keV peak for Cu, the 159.8 keV peak for Sn and the 101.0 keV peak for N.

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Presenters

Applications of Ion Beam Analysis to Cultural Heritage materials at UniTO and INFN-TO

One of the advantages of Ion Beam Analysis (IBA) is the possibility to obtain different information from a sample by means of the same nuclear probe. The simultaneous characterisation ranges from chemical composition to structural and luminescent properties. Moreover, when a microbeam is employed, it becomes possible to investigate very small features and to have higher resolution. As an additional advantage, IBA is the perfect technique for studying valuable artworks and archaeological samples, due to its non-invasiveness.

This work is carried out by the Physics for Cultural Heritage group at the University of Torino and by the Torino section of INFN (National Institute for Nuclear Physics), in the framework of CHNet, the Cultural Heritage Network of INFN. During the years, several collaborations have been established with accelerator facilities, both national and international, to perform IBA on different materials of interest in the Cultural Heritage field. Since 2008, μ-PIXE and μ-IBIL have been performed at INFN-LNL (Legnaro, Padova) and INFN-LABEC (Firenze) microbeam lines on lapis lazuli samples. This long-term study aims at searching markers in reference geological rocks [1-3] to build an analytical protocol [4] that can be later applied to ancient artefacts for the provenance determination of the raw material used in antiquity. For the ultimate purpose, measurements on archaeological or artistic lapis lazuli objects are performed in air without sample preparation at the NewAGLAE facility (C2RMF, Paris), thanks to CHARISMA, IPERION CH and IPERION HS European programs. Up to now the protocol can discriminate between four provenances (Afghanistan, Tajikistan, Siberia and Chile) and it has been successfully applied to lapis lazuli samples from museum collections [4-6].

Trace element concentrations can be strong markers for provenance, and can be exploited in the study of various materials, not only natural rocks like lapis lazuli, but also man-made products, such as ceramics. A research on archaeological pottery coatings was started by the Chemistry Department group more than 10 years ago [7], with a focus on the vitrified black slip obtained- according to a technology developed in Greece [8]- in Southern Italian pottery workshops during the sixth to the fourth century BCE [9, 10]. A preliminary investigation with μ-PIXE is now ongoing at INFN-LNL to obtain the quantitative elemental information from the thin black gloss on red-figured vases. The archaeological question is related to the actual possibility of distinguishing the Calabrian from Sicilian objects and it is reasonable to hypothesize that different workshops would have used raw materials from different sources to obtain their products, leading to a different composition of the coating. Hence, the provenance markers are presently searched among the trace elements in the thin (some 20 microns) vitrified coating layer.

Finally, μ-PIXE measurements have been carried out also on sectioned Cisalpine coins, in the framework of a larger project, to identify the distribution of silver and copper in cross-section, with implications in the study of the devaluation of coins through the centuries, in the comparison with Roman currencies and in the possibility to discriminate different typologies of Cisalpine drachmas on the basis of chemical composition [11, 12].

An overview of all the analytical approaches, targeted on the specific sample type, and of the obtained results will be presented and discussed.

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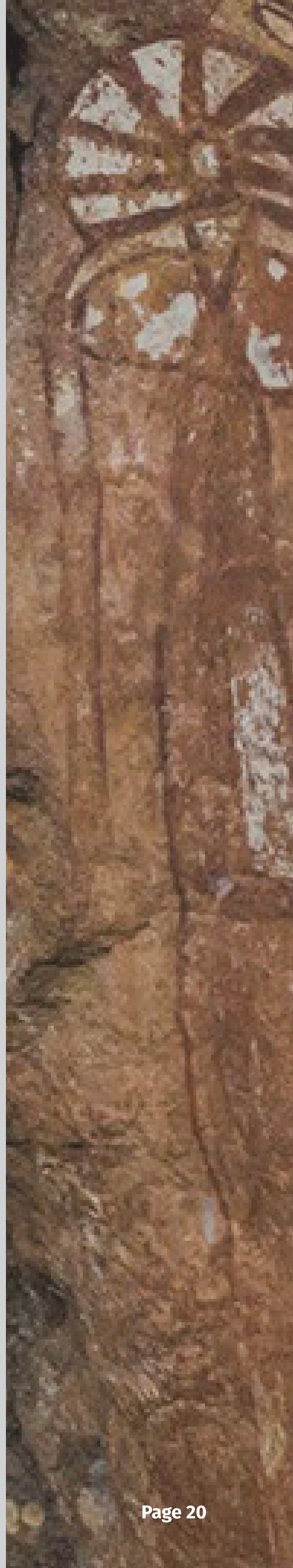

Presenters

The Neutron Resonance Transmission Imaging technique for elemental characterization of inhomogeneous samples

We present the implementation of a non-destructive radiographic technique, named Neutron Resonance Transmission Imaging (NRTI), performed at the INES (Italian Neutron Experimental Station)1 beamline of the ISIS spallation neutron source2.

The NRTI technique is based on the presence of resonance structures in the neutron-induced reaction cross-sections3, and allows the localization of isotopes and elements distribution within 2D (and potentially 3D) maps of the bulk of the analysed sample.

The observed quantity in NRTI measurements is the fraction of the neutron beam that traverses the sample without any interaction. A time and spatial-resolved detector is employed for Time-of-Flight (ToF) measurements of the neutron beam transmitted through the object. The detector is based on the neutron Gas Electron Multiplier technology (nGEM)4, originally developed at CERN5 to achieve high rate, high accuracy detection and localization of fast charged particles in High Energy Physics. However, due to their versatility, they can be properly adapted as neutral particles detectors. The advantage of this technology is the good time resolution (for ToF measurements) combined with a large active area (10 x 10 cm2 for the nGEM detector used at INES).

The peculiarities of NRTI make this technique suitable for the characterization of inhomogeneous samples6,7 and it can be applied in particular for Cultural Heritage studies. In order to deepen the feasibility of NRTI in these applications, a set of crucible fragments connected to bronze and brass production, and dated back between the end of I and the beginning of II century AD8, has been investigated through a combination of the NRTI with other well-consolidated non-destructive techniques.

Crucibles consisted of mass-produced terracotta pots, coated with a thick layer of refractory clay. Inside, the copper and zinc alloy were usually heated up to high temperature, liquefied and then thrown into moulds to make appliques for furniture and ornamental objects. Moreover, the presence of impurities such as tin and iron are connected to the use of scrap materials while lead indicates that the alloy produced was a leaded brass and/or leaded bronze. Some fragments show metallic layers/depositions on their surfaces, while others could contain traces of bronze or brass production inside their volume. Thus, this kind of archaeological sample has a heterogeneous composition that can be revealed by the application of the NRTI.

At present, NRTI analysis returned the qualitative elemental composition of the fragments, disclosing the presence of brass and bronze. In addition, also arsenic, antimony, silver and lead were detected in the bulk of the crucible's fragments. NRTI can provide bidimensional maps of the elemental distribution inside the bulk, which will be useful to reveal the spatial position and the size of the brass inclusion within the crucible fragments.

As an example, Figure 1 shows the transmission map of a crucible fragment which do not present evident metallic deposition on its surface. In the analysed regions, different transmission signals can be distinguished and associated with a different composition (Figure 2).

The NRTI results have been compared with Neutron Resonance Capture Analysis (NRCA), routinely performed at the INES beamline, and Particle Induced X-ray Emission (PIXE) analysis, which has been applied on the metallic depositions present on the fragments surface.

NRCA and PIXE results are helpful in the data analysis of NRTI maps, in order to focus the attention in the data treatment on selected elements.

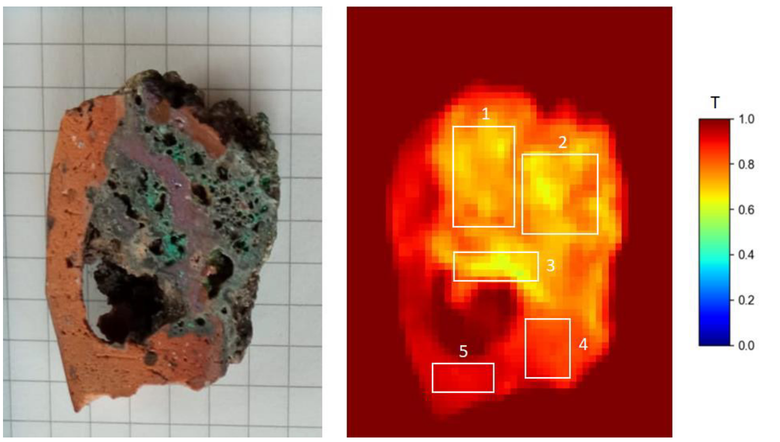

Figure 1. On the left: crucible fragment OT20. On the right: the NRTI transmission map of the fragment. Based on the different transmission level, five Region Of Interest (ROI) are selected in order to determine their composition.

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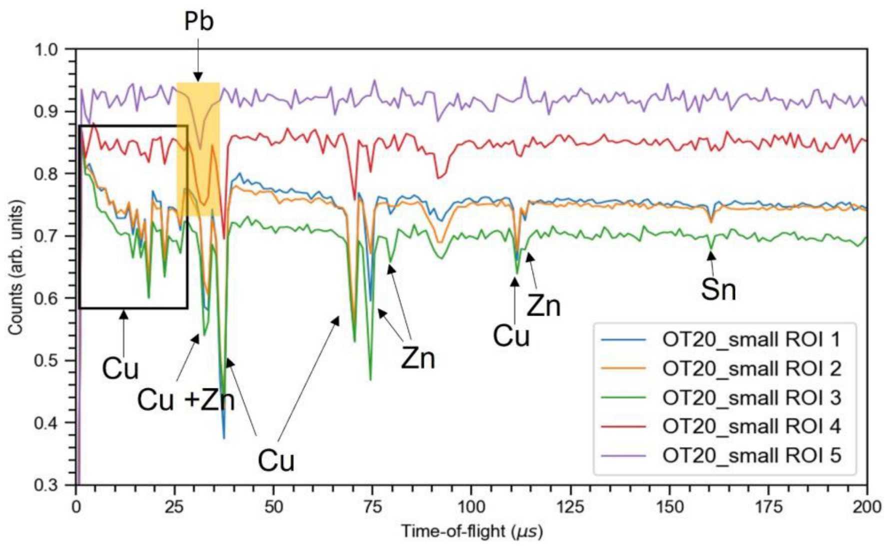

Figure 2. NRTI spectra (up to 200 μs) of the five ROIs selected for sample OT20. Peaks assignment is made in comparison with (n,tot) cross section libraries3 revealing the presence of copper, zinc, tin and lead. The full ToF range of NRTI spectra extends up to 2000 μs.

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Presenters

Application of nuclear techniques in characterization and conservation of cultural heritage artefacts in Sofia University, Bulgaria

This paper gives an overview of the research activities in the University of Sofia, performed by use of nuclear techniques for analysis and conservation of cultural heritage materials. The studies in the field of archaeometry are performed in the Trace Analysis Laboratory at the Faculty of Chemistry and Pharmacy and the Center for Archaeometry with a Laboratory for Restoration and Conservation at the Faculty of History. The available nuclear and isotopic techniques for characterization of artefacts include: XRF, ICP-MS, LA-ICP-MS, Gamma-spectroscopy, SEM, TEM and radiography.

XRF, ICP-MS and LA-ICP-MS were used for multielement characterization of different archaeological finds, such as: archaeological bronze, medieval glass finds, glass mosaic pieces, gold breast plates from ancient Thrace (5th-4th century BC), Thracian golden wreath, bronze medallion with glaze, marble from Adrian villa (Tivoli, Rome), fibulae, icons and wall paintings, mortar from 5th century BC to 13th century AD, etc. The obtained data helped to identify the raw material used, the place and the technology of production and the chemical composition of the pigments. ED-XRF and optical microscopy were used to determine the authenticity of 25 golden appliques, offered to the National Museum of History and dated to 5th-3rd century BC. The obtained results showed that the appliques were fake.

Micro-XRF archaeometrical analysis was performed of roman silver coins part from coin hoard found in Plovdiv (Central South Bulgaria). The obtained data on the concentration of silver, copper, lead and tin were used to estimate the economy of the state during the relevant periods, as well as the technology of coin production and coin circulation within the Roman Empire. The chemical composition of 168 samples of belt accessories from Great Migration Period in Bulgaria was studied by portable XRF. Cluster analysis of the obtained elemental concentrations was performed and three chronological groups of the belt finds were identified, according to the period of their circulation. XRF analysis of helmets, dated from 4th-5th century BC showed the chemical composition of the metal alloys and the rivets and solders, used in their production.

Studies on the side-effects of gamma-irradiation of wood, paper and leather materials were performed within the IAEA CRP F23032, Contract № 20567 “Studying Side-Effects of Gamma Irradiation Treatment for Disinfestation of Cultural Heritage Artefacts” at the Radiochemical Laboratory at the Faculty of Chemistry and Pharmacy. Samples were irradiated with gamma-rays with different absorbed doses and dose rates by using gamma-irradiation facility BULGAMMA, situated at Sopharma JCS. The changes of the morphology and structure were investigated by SEM/EDX, FT-IR, ATR, TG, DSC and ESR methods. Conclusions on the applicability of gamma-rays for disinfestation and conservation of paper, wood and leather materials were made.

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Implementation of New Capabilities In Peru: Computational X-Ray Imaging

X-Ray Fluorescence researchers of cultural heritage have developed sophisticated equipment that allow to obtain beautiful images of XRF, that show the elemental distribution in art work. Most of these researchers are located in some european countries, where facilities of MA-XRF[1,2], Full-field XRF, micro XRF and syncrotron-based XRF are specially designed to scan the whole sample and sum up the spectra to create an image that offers better outlooks of sample composition than other forms of presenting data. Without these equipment, researchers can look for creative ways to create an image, using the resources at hand. At the laboratory of X-Ray Spectrometry of the Peruvian Institute of Nuclear Energy, X-Ray images were obtained with an AMPTEK Experimenter kit with Ag tube and computational algorithms. This equipment does not have a X-Y displacement to scan the sample, but some tricks are applied to the samples to achieve a good data collection.

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Recent development of the external beam line for archaeometric measurements

The external beam line at the Tandetron accelerator has been importantly improved during recent years. The beam is focused by magnetic optics and a 200 nm thick Si_3N_4 foil is used for the exit widow. The proton current is monitored by elastic scattering of protons from a chopper, intersection the beam in vacuum. Optimizing the operation for mapping of the biological samples, the beam spot on the target was below 50 µm [1]. From the point of software, a new X-ray fitting program Xantho is developed for fast and efficient fitting of the X-ray spectra with minimal intervention of the operator. For the analysis of archaeological glass, new algorithms were developed that do not necessary require measurement of the proton number. The argon signal from the air is used to monitor the difference between the assumed and actual experimental geometry. Recent measurements include analysis of archaeological metal in small polished spots and analysis of archaeological glass from the Late-Roman Balkans and Slovenia. A few examples of our studies will be presented.

An interesting series of measurements was carried out on a collection of objects, belonging to a private collector, but planned to be exhibited in a prominent Austrian museum, however with its authenticity still being unclear. With PIXE analyses, we were able to distinguish the real ancient objects from contemporary forgeries in the collection.

A series of glass fragments from an archaeological site in Slovenia was analysed using the PIXE-PIGE method, with gamma rays used for detection of lighter elements (Na, Mg, Al). The elemental composition enabled us to date the fragments to the Roman Imperial and Late Antique period, with natron glass being predominant. One of the fragments turned out to be of much later origin (even recent) and another a naturally occurring mineral.

A series of brooches (fibulas) from different Slovenian archaeological sites was also analysed.

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A preliminary study on the provenance of Ceramic artifacts from the OC EO Archaeological site

The neutron activation analysis (NAA) is one of the most widely used analytical methods for bulkchemical characterization of materials. A comprehensive chemical analysis plays an important role in finding the origin of samples. In the present work, a total of 89 ceramic samples collected from Oc Eo archaeological site have been analysed by NAA method at the Dalat research reactor. 23 elements of As, Ba, Ce, Co, Cr, Cs, Eu, Fe, Hf, La, Lu, Na, Nd, Rb, Sb, Sc, Sm, Ta, Tb, Th, U, Yb, Zn are determined to be the classification of ceramics in provenance studies.

KEYWORDS: k0-NAA; ceramics; REEs; Oc Eo archaeological site

The instrumental neutron activation analysis has become a main-stay for bulk chemical characterization of materials such as ceramic artifacts, clays. The sensitivity, precision, and multi-element capability of this method make it particularly well suited for characterizing these complex materials. Determination of provenance remains the most common application of INAA, and serves as a foundation for addressing a broader range of questions concerning ceramic production and exchange. Increasingly, however, INAA is also being employed to investigate questions of ceramic technology and manufacturing, helping to reconstruct the choices potters made in carrying out their craft.

In the present work, a total of 89 ceramic samples collected from Oc Eo archaeological site have been analysed elemental concentrations by k0-NAA method. The experimental procedures were performed at the rotary specimen rack of the Dalat research reactor with the thermal neutron flux of 3.6 x1012 n.cm-2.s-1. The irradiation time was 10 hours. Measurements of emitted gamma rays from the samples were performed using an HPGe detector of 30% relative efficiency and 2.1 keV energy resolution at the 1332 keV of 60Co. The k0-NAA method was used to analyse the elemental concentrations in samples and multivariate statistical methods allowed to provide information related to classification, grouping and identification of ceramic characteristics.

The obtained results showed that the rare earth element (REEs) group is the typical element group for the data set. The difference in chemical compositions of the indigenous and imported ceramic groups is mainly due to the difference in composition of the REEs group. The REEs group is also significant in mixed materials and clay types.

1. AHC grouping results (Fig. 1): Oc Eo ceramics are divided into 2 main groups: indigenous (local) and imported ceramics. It is noted that imported ceramics are due to the cultural exchange.
• Based on the classification of imported ceramic groups, it can be seen that the Oc-Eo culture has a very wide cultural exchange between neighboring countries, typical India and China.

The cultural exchange time also extended according to the historical development of Oc Eo culture from the 1st century to the 10th century (from the Han dynasty to the Tang and Song dynasties of China).
• Indigenous ceramic group itself also has quite diverse types, from ceramics made from fine clay to clay mixed sand or plant residue, especially crockery. It proved that Oc Eo culture has a certain technical development.
2. To distinguish the difference of material compositions of indigenous and imported ceramics. Figure 2 shows results of PCA analysis.
• Based on the elemental distribution vector, it can be seen that REEs concentrations of Song and Tang dynasties (China) are higher than ones of the indigenous ceramic group.
• Na, As, and Fe in Indian ceramic group are highest.

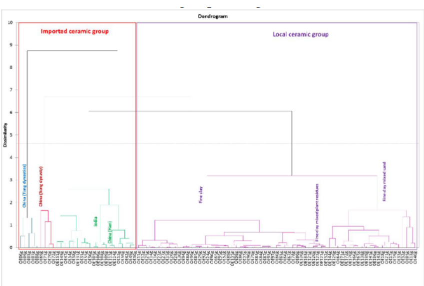

Fig.1 Group analysis using Agglomerative Hierarchical Clustering method.

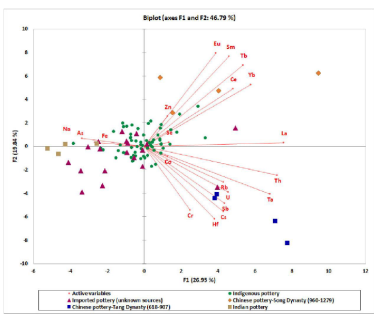

Fig.2 PCA plot showing the effect of elemental variables on PC1 and PC2 axes.

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Presenters

Exploring archaeological brick manufactures in Vietnam: thermoluminescence dating combined with positron annihilation and computer simulation

Abstract: Studying and protecting ancient cultural heritages are urgent tasks for archeological field in Vietnam. However, these are often uneasy and challenging tasks. For instance, collecting organic samples (used for traditional 14C dating method) at some ancient cultural ruins of the old port City (e.g., Oc Eo relics), which have been deeply buried over 2000 years below the Mekong Delta River, has become impossible due to the overlap of the ruins. In addition, the war destruction, farming and excavation also lead to some large deviations of the chronological analysis results in Vietnam. The challenges have even become increasingly for other ancient cultural heritages such as Cat Tien and Ngu Hanh Son Sanctuaries. This has led to the use of advanced physical and nuclear analytical methods for analyzing inorganic mineral samples such as ceramics and bricks.

In this work, the thermoluminescence (TL) dating consistently combined with computer simulation has been used to explore some ancient cultural ruins in Oc Eo relics and Cat Tien Sanctuary in Vietnam. In particular, the positron annihilation lifetime (PAL), doppler broadening (DB) and electron momentum distribution (EMD) measurements have been carried out, for the first time, to study the manufacturing processes of archaeological bricks at these cultural heritages. Our preliminarily results indicated that the combination of those methods is important and can provide more precise information on the structure of ancient cultural heritages in Vietnam.

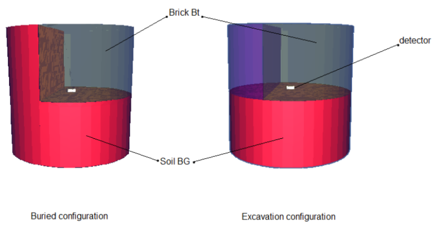

Figure 1. *Computer simulation of the possible configurations (buried or excavated) that can affect the thermoluminescence dating results.*

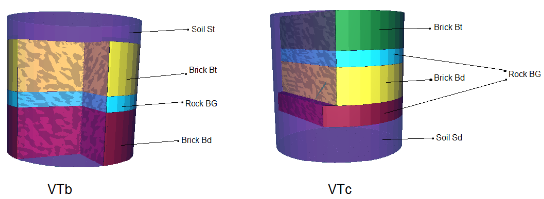

Figure 2. *Computer simulation of different buried configurations that can affect the dating thermoluminescence result.*

Figure 3. *Practical sampling sites at Oc Eo relics.*

Presenter

Luu Anh Tuyen
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Presenters

Overview of the IAEA Accelerator programme for heritage science

The IAEA Physics Section is pursuing efforts on utilizing ion beam accelerators to support fundamental and applied research, as well as provide education and training world-wide.

The main field of accelerator applications are materials science, environmental science, heritage science and forensic science. There are various tools and mechanisms to foster accelerator science and technology, knowledge transfer and knowledge sharing with the scientific community, stakeholders and the public.

As a main hub of accelerator scientists, the IAEA Accelerator Knowledge Portal serves the scientific and industrial community with various accelerator databases and specialized topical pages and workspaces.

The talk will give an insight of the IAEA Physics Section programmatic priorities and key activities with special emphasis on activities towards preservation of cultural and natural heritage.

Presenter
Aliz Simon
IAEA

Presenters

Setting up the IAEA Collaborating Center Atoms for Heritage at Université Paris-Saclay

The International Atomic Energy Agency (IAEA) has been designated Université Paris-Saclay as the first IAEA Atoms for Heritage Collaborating Centre in heritage sciences on Friday 17 September 2021. The new centre will focus on five key themes linked to heritage conservation: characterising and dating materials; developing safe analysis methods; analysing and sharing data in accordance with Open Science strategies; educating and raising awareness among the public and future generations about heritage issues; and combatting the illicit trafficking of heritage objects.

The Collaborating Centre builds on a unique ecosystem of networks and infrastructure. The Collaborating Centre works closely with three of the University's Graduate Schools (Humanities and Heritage Sciences, Physics and Chemistry), and in coordination with two interdisciplinary programmes (The Interdisciplinary Institute of Materials and Palabre).

Through the Atoms for Heritage Collaborating Centre, the IAEA and Université Paris-Saclay, alongside its partner organisations, aim to play a key role in the development and application of physical, chemical and digital techniques to study and improve the preservation of heritage objects, whether they are cultural artefacts such as monuments and paintings, or natural objects such as fossils.
The support of the IAEA will facilitate the hosting of international scientists, curators and technical personnel who will all come to Paris-Saclay for training, creating opportunities to establish and intensify international research collaborations through the arrival of experts from around the world as part of the University's programmes.

Peaceful applications of nuclear science for development and cooperation
Two years after Université Paris-Saclay co-signed the Paris Declaration on "Heritage, Sciences and Technologies: An Opportunity for our Societies and the Global Economy" at the Institut de France (https://www.dim-map.fr/en/heritage-and-ancients-materials/paris-declaration/), the launch of the Collaborating Centre for heritage preservation will play a key role in promoting peaceful nuclear applications sustainably for the benefit of society.

Presenter

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Images of Real japanese samurai sword and sheath on wooden board

Images of Wandijina Kimberley Indigenous rock art

We acknowledge the Traditional Owners of the places in which we live and work. We recognise and respect the enduring relationship they have with their lands and waters, and honour the Elders, past and present.