1st Workshop for Young Researchers in Archaeometry and Conservation Studies

11th and 12th September 2017

Institute for Geosciences,
Goethe University Frankfurt

Gesellschaft für
Naturwissenschaftliche
Archäologie
ARCHAEOMETRIE e.V.

Programme on Monday, 11.09.2017

9:00 *Registration Opens*

10:00 *Welcome*

10:15 *S. Klein (Bochum)*
Applied Mineralogy: Geochemical Methods for Archaeometry (Keynote)

11:00 *Coffee break*

Session „Ceramics“ (Moderation: T. Rose)

11:30 *T. Kiemle (Tübingen)*
Potentiale moderner nichtzerstörender und hoch ortsaufgelöster Materialanalysen in der Archäometrie am Beispiel attischer Keramiken

11:50 *K. S. Park (Berlin)*
Ceramic Pottery Production in the North Caucasus in the Bronze- and the Iron Age: Distribution and Social Context of Technological Styles of Pottery Production

12:10 *T. Miki (Berlin)*
The Chalcolithic Pottery Production in Marv Dasht Plain, Southwest Iran: The Chemical and Petrographic Perspectives

12:30 *K. Kuntz (Berlin)*
Poster Presentation: Die Frühislamische Keramik des Tacht-e Soleiman - Herkunft und Technologie

12:35 *M. Mishmastnehi (Berlin)*
Poster Presentation: New Results of Elamite Archaeometallurgy Based on Analysis of Copper Slags from Haft Tappeh, Iran

12:40 *Lunch Break*

Session „Methods“ (Moderation: M. Holly)

14:00 *D. Wilke (Wennigsen)*
Quantitative, Non-Destructive XRF Analysis of Pottery - Why Does Accuracy Matter and How To Achieve It?

14:20 *A. Steyer (Köln)*
Die Computertomographie als zerstörungsfreie Untersuchungsmethode für Kunst- und Kulturgut aus Stein. Möglichkeiten und Grenzen am Beispiel der großen Mainzer Jupitersäule

14:40 *M. Andrews (Southampton)*
Modelling Tribological Processes To Examine the Use-Intensity of Bronze Age Palstave Axes

15:00 *G. Renner (Krefeld)*
Entwicklung eines transportablen Probenahme-Systems zur Analyse der metallischen Oberfläche historischer Artefakte auf Basis elektrochemischer Anreicherung

15:20 *Coffee Break*

15:35 *Open Discussion (Moderation: K. Westner, T. Rose)*
Dream and Reality: Archaeological Objects between Analysis and Conservation

17:00 *Barbecue*

Programme on Tuesday, 12.09.2017

8:30 *Conference Room Open*

9:00 *M. Aubin (Paris/Mainz)*
Revealing the Composition of Ancient Preparations Containing Heavy Metals. How To Study Ancient Eye Medicines? (Keynote)

Session „Metal I“ (Moderation: K. Westner)

9:45 *L. Rietmaier-Naef (Zürich)*
Vom Erz zum Metall: Untersuchungen zur prähistorischen Kupferproduktion im Oberhalbstein (Graubünden, CH)

10:05 *T. Rose (Frankfurt)*
Diffusion-Induced Stable Metal Isotope Fractionation: Implications for Archaeometallurgy

10:25 *Coffee Break*

Session „Metal II“ (Moderation: F. Ströbele)

11:00 *R. Müller (Pohlheim)*
Application Possibilities of Lead Isotope Analyses in Archaeology

11:20 *E. Salzmann (Frankfurt)*
Provenance Studies of Copper-, Bronze-, and Silver Artefacts from the Royal Tombs of Ur, Mid 3rd Millenium BC

11:40 *K. Westner (Frankfurt)*
Silver Sources of Roman Republican Coinage Retraced by Geochemical Analysis

12:00 *V. Mozgai (Budapest)*
Multi-Analytical Examination of the Late Roman Seuso Hoard and Contemporary Silver Artefacts from Pannonia Province, Hungary

12:20 *Lunch Break*

14:00 *Open Discussion (Moderation: M. Holly, T. Rose)*
Building Bridges: Research and Networking in the Interplay of Conservation and Archaeometry

15:30 *Roundup and Farewell*

Modelling Tribological Processes To Examine the Use-Intensity of Bronze Age Palstave Axes

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Historically, wear on metal artefacts has not received as much attention as other material types, e.g., lithics and bone. This is reflected in the slow development of materials science approaches, quantitative analysis, and robust systematic methodologies, in the field of metal use-wear investigation. Furthermore, research has been focused, almost exclusively, around the functionality of objects.
This project is a response to the gaps that exist within the experimental protocol of the aforementioned field, investigating a new dimension of use – the sum amount sustained by the artefact – which has been termed the 'use-intensity'.
To test this new directive, replica Bronze Age palstave axes were subjected to systematic wear in laboratory settings by repetitive wood-cutting in an 'impact tower'. An algorithm in the rig was used to assess the optimum sharpening interval, at which point the axes were resharpened, and the experimental phase repeated. Sequential and quantitative examination by Vickers hardness testing demonstrated an incremental increase in hardness of the axe blades due to both use and sharpening.
The results of the project may be used to estimate the overall degree of use of prehistoric axes and the number of sharpening phases. More generally, the project represents the potential for establishing artefact-specific methodologies to evaluate use-intensity.

Keywords: Bronze, axes, use-wear, materials science, engineering, methodology

Revealing the Composition of Ancient Preparations Containing Heavy Metals. How To Study Ancient Eye Medicines?

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In the Antiquity, oculists (eye care-specialised physicians) mixed mineral, vegetal and animal substances to prepare elaborate solid medicines termed collyria. In an interdisciplinary work, we investigated the chemical composition, the inorganic phases' structure and the manufacturing process of such collyria. The implemented analytical techniques were Raman spectroscopy, X-ray fluorescence (XRF) and X-ray diffraction (XRD). The stability of metallic salts based replicas prepared according to ancient texts recipes was studied in order to identify the pristine phases. Four collections of archaeological collyria (Musée Gallo-Romain de Lyon, Musée d'Archéologie Nationale, Cabinet des Médailles de la BnF, Musée Atestino d'Este) were studied *on site*, using portable devices. A methodology combining XRF and XRD results was developed to quantify the inorganic phases' distribution. For the first time, a straight relationship was established between compositions obtained by physico-chemical analysis and ancient recipes.

Keywords: Raman spectrometry, µ-XRF-XRD, portable devices, ancient medicine, metals

Potentiale moderner nichtzerstörender und hoch ortsaufgelöster Materialanalysen in der Archäometrie am Beispiel attischer Keramiken

Potentials of Modern Non-Destructive and Highly Space-Resolved Material Analysis in Archaeometry Using the Example of Attic Ceramics

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Die Bandbreite analytischer Methoden, die heute im Bereich der materialwissenschaftlichen Archäometrie zum Einsatz kommen, findet sich in kaum einem anderen Wissenschaftsbereich wieder. Dies ist sowohl der Vielfalt der untersuchten Materialien, als auch der Komplexität ihrer Herstellungsprozesse geschuldet.
Dank erheblicher technischer Fortschritte in den letzten 15 Jahren stehen modernen archäometrischen Laboratorien heute hochentwickelte Analyseverfahren zur Verfügung, welche die Untersuchung archäologischer Artefakte in Bezug auf ihre chemische und mineralogische Zusammensetzung, Struktur und Textur mit hoher Ortsauflösung innerhalb sehr kurzer Messzeiten ermöglichen. Mit Hilfe der so gewonnenen Daten können einerseits die verwendeten Rohstoffe und Herstellungs- und Bearbeitungsprozesse identifiziert werden, z.B. um Herkunft, Echtheit und mögliche Handelswege nachzuvollziehen, aber auch der Verfall von Fundstücken kann besser verstanden werden. Diese Erkenntnisse erlauben dann wiederum Rückschlüsse auf zeitabhängige kulturelle und technologische Entwicklungen und liefern Hinweise für den Erhalt und gegebenenfalls die Restaurierung der Funde.
Im Rahmen unserer Präsentation werden wir einen Überblick über die aktuell am CCA-BW vorhandenen analytischen Möglichkeiten geben. Am Beispiel von attischen Keramiken soll zudem gezeigt werden, wie durch die Kombination moderner Analyseverfahren zeit- und ortsabhängige kulturelle und technologische Entwicklungen aufgedeckt werden können, die früher nicht oder nur mit sehr hohem Aufwand zugänglich waren.

Keywords: Keramik, Methodologie
Ceramic, methodology

Applied Mineralogy: Geochemical Methods for Archaeometry

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The Royal Tombs of Ur in Mesopotamia depict a perfect example of the great variety of materials in archaeology. The excavations at Ur from 1921 to 1934 by Sir Leonard Woolley brought to light countless artefacts such as jewellery, hair decoration, weapons, tools, vessels, figurines, seals, or containers, all made of gold, silver, alabaster, lapis lazuli, and carnelian, and also shell halves filled with green, blue, white, red and black pigment mixtures. This surprisingly rich suite of materials is in contrary to the fact that Mesopotamia is void of mineral deposits. The identification of the geological sources by geochemical methods thus has a key position to decipher the interactions between Mesopotamia and its neighboring regions.
Based on the concrete example of Ur, the presentation gives an overview of the spectrum of analytical methods, which are applicable for archaeometry. Abrigded introduction to the most crucial inorganic methods and their applications are tightly related in this talk to common discussion of sample consuming vs. non-destructive methods, homo- vs. heterogeneity of objects and samples and the including of reference data for interpretation.

Literature:
Hauptmann, H., Klein, S., Zettler, R., La Niece, S., Benzel, K., Armbruster, B/, Jansen, M., Salzmann, E., 2016, The Royal Tombs of Ur, Mesopotamia. Collection of Contributions from a Workshop. Metalla, 2016, Nb. 22.1, 77-146.
Jansen, M., Aulbach, S., Hauptmann, A., Höfer, H.E., Klein, S., Krüger, M., Zettler, R.L., 2016, Platinum group placer minerals in ancient gold artifacts – Geochemistry and osmium isotopes of inclusions in Early Bronze Age gold from Ur/Mesopotamia. Journal of Archaeological Science, 68, 2016, 12-23.

Keywords: Geochemistry, material analysis, isotopes

Die Frühislamische Keramik des Tacht-e Soleiman - Herkunft und Technologie
Early Islamic Ceramics of the Tacht-e Soleiman - Origin and Technology

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Der Tacht-e Soleiman (Thron des Salomo) ist ein natürlich entstandenes Kalksinterplateau im iranischen Hochplateau der Provinz West-Aserbaidschan, das mit Unterbrechungen von achämenidischer bis in nach-ilkhanidische Zeit besiedelt war. In den 1960er und 1970er Jahren führte das Deutsche Archäologische Institut Grabungen am Tacht-e Soleiman durch. Ein beträchtlicher Teil der ergrabenen diagnostischen Keramik befindet sich am Museum für Islamische Kunst in Berlin.
Das Dissertationsprojekt zielt auf eine umfangreiche wissenschaftliche Bearbeitung des wenig beschriebenen und erforschten Materials ab. Der Fokus der systematischen Untersuchung von etwa 2500 Scherben und einigen kompletten Gefäßen liegt dabei zeitlich auf der frühislamischen Keramik und thematisch auf der Identifizierung von regionalen Eigenschaften. Die Keramik wird in den Aspekten Materialzusammensetzung, Herstellungstechnik, Dekoration und Form untersucht. Vergleichende archäokeramologische Untersuchungen von Keramik und Glasur sowohl an Gefäßscherben als auch an Brennzubehör und Fehlbränden sollen die regionale Materialkultur naturwissenschaftlich in Form eines „Fingerabdrucks“ sichtbar machen.

Keywords: Archäokeramologie, Iran, Tacht-e Soleiman, frühislamische Zeit
Archaeoceramology, Iran, Tacht-e Soleiman, Early Islamic Period

The Chalcolithic Pottery Production in Marv Dasht Plain, Southwest Iran: The Chemical and Petrographic Perspectives

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Ceramic production during the Chalcolithic period (c. 5,000 - 4,000 BCE) in Marv Dasht plain, southwest Iran is one of the most important clues for retracing of the development of craft specialization and social organization in that region. In order to understand the temporal change of clay acquisition, procurement and use of temper, and pottery firing, this paper presents the combined results of Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES) analysis, X-Ray Diffraction (XRD), and thin-section petrographic analysis. This paper analyses 60 ceramics samples from five sites of three different phases of the so-called Bakun period (early: Tall-e Jari A and Tall-e Bakun B; middle: Tall-e Gap and Tappe Rahmatabad; late: Tall-e Bakun A). ICP-AES analysis suggests that the clay acquisition changed over time. From the XRD analysis it is suggested that the firing temperature increased over time. These changes corresponded to a notable increase in the amount of produced pottery. In addition, petrographic observations contribute to the characterisation of mineral temper in coarse ceramics and the possible sources of the minerals.

Keywords: Ceramics, southwest Iran, Chalcolithic Period, inductively coupled plasma atomic emission spectrometry analysis, ceramic petrography

New Results of Elamite Archaeometallurgy Based on Analysis of Copper Slags from Haft Tappeh, Iran

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Iran is an ore-rich area with a long history of archaeometallurgy. The lowland of southwest Iran is the region in which the Elamite culture was born, flourished and devastated between the 4th and the 1st millenniums BC. Haft Tappeh, the capital of the Middle Elamite period, was excavated from 1964 to 2013; unearthing a large number of constructions and objects including products, by-products and wasted materials of copper metallurgy. Some of them have been studied before, but a clear picture of Elamite archaeometallurgy requires more scientific investigation.
Presence of several copper and bronze objects, slags and furnaces in Haft Tappeh, exhibit a chain of archaeometallurgical activity in this site. In order to clarify an important section of this chain, we studied the chemical and mineralogical composition of copper slags with a multi analytical approach by WD-XRF, SEM and EMPA. The assessment of primary results shows that copper slags variate in bulk chemical and mineralogical composition based on the silicate, iron and copper contents, demonstrating different types of smelting/melting slags. Furthermore, focusing on the chemical composition of crystals and copper prills provides strong evidence to distinguish distinct steps of archaeometallurgy of the Middle Elamite period in Haft Tappeh.

Keywords: Iran, Middle Elamite period, Haft Tappeh, archaeometallurgy, slags

Multi-Analytical Examination of the Late Roman Seuso Hoard and Contemporary Silver Artefacts from Pannonia Province, Hungary

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The objects of the Late Roman Seuso hoard and other contemporary silver artefacts found in Pannonia province and now preserved in the Hungarian National Museum were analysed non-destructively with hXRF in order to measure their chemical composition and map their chemical inhomogeneity. The objects were made from high-quality silver (94-96 wt%) alloyed with copper. According to the Bi content, the objects form three groups, indicating the use of different silver ingots and/or silver ores. In order to define the source of the used raw material, trace element and lead isotope analyses were also performed.
The decoration of the objects was also examined. The niello inlays of the Seuso Platter and Geometric Platter were made of silver sulphide according to hXRF and PIXE analyses. Besides the homogeneous silver sulphide niello, two Late Roman objects (a silver augur staff and a silver belt set) are decorated with inhomogeneous silver-copper sulphide niello as well. According to these results, it is probable that two-metal sulphide niello was used 300 years earlier than the previous studies indicated. During the analyses of gilding, mercury was also detected indicating the use of fire-gilding. Tin and lead content of solders shows that soft-solder was used.

Keywords: Late Roman, silver, niello, gilding, soldering, hXRF, PIXE, Pannonia province, trace elements, lead isotopes

Application Possibilities of Lead Isotope Analyses in Archaeology

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The presentations objective is to discuss the prospects of using lead isotope analyses within archaeology, exceeding the mere identification of metal provenance. So far lead isotope analysis has mostly been used to determine the metal provenance of single or more objects from a certain find context or period, in order to gain information about the artefacts' historical (economic and social) background. Subsequently it shall be examined, to what extend lead isotope analyses can also be used as a tool for dating artefacts and verifying (or falsifying) their origins respectively their assigned find spots. Due to their properties – lead being the main material component, typological-chronological relevant characteristics, occasionally bearing inscriptions – lead sling bullets happen to be a most promising artefact group for this endeavor. Hence sling bullets, dating from the 4th century BC up to the 2nd century AD, within a distribution area ranging from the western coast of the Black Sea up to southern Scotland were analyzed and examined in this respect.

Keywords: Lead isotope analyses, sling bullets

Ceramic Pottery Production in the North Caucasus in the Bronze- and the Iron Age: Distribution and Social Context of Technological Styles of Pottery Production

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In order of figuring out the resource for the ceramic paste and the firing conditions, so far some selected pottery sherds from an archaeological site in the North Caucasian Mountains (Middle/Late Bronze Age) were analyzed and compared to ceramic samples from the Mius peninsular and its near environment in Russia (Late Bronze Age). Chemical and mineralogical/petrological properties of the grains/matrix and microstructures from the original resource and pyrometamorphism were investigated and classified using image analysis, X-ray powder diffraction, polarized light microscopy, scanning electron microscopy coupled with energy/wavelength-dispersive spectroscopy and Fourier transform infrared spectroscopy. According to the phyllosilicates, the firing products such as mullite, hematite and gehlenite and the microstructural changes, the samples could be classified into four groups of firing temperature (under 750/800, 750-850, 850- 950, 950-1050 ° C). Mineralogical/chemical composition, size distribution and angularity of the sand grains show characteristics of local soils in the mountains and alluvial zones but also the possible use of different resources by potters. These results will be combined with other processes of the ceramic pottery production to unravel different technological styles that reflect the potter's practical choices.

Keywords: Ceramic pottery production, raw materials, local sands, firing conditions, mineralogical transformation, chemical distribution, microstructural changes

Vom Erz zum Metall: Untersuchungen zur prähistorischen Kupferproduktion im Oberhalbstein (Graubünden, CH)

From Ore to Metal: Investigation of Prehistoric Copper Production at Oberhalbstein (Graubünden, CH)

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Seit Jahrzehnten beschäftigt sich die archäometallurgische Forschung mit der exakten Entschlüsselung und Rekonstruktion des alpinen Kupferverhüttungsprozesses. Spätestens seit der Mittelbronzezeit wurde das Metall in einem mehrstufigen Verfahren – bestehend aus oxidierenden und reduzierenden pyrotechnischen Prozessschritten – aus sulfidischen Kupfererzen (i.d.R. «Kupferkies» (Chalkopyrit) oder «Fahlerz» (Tennantit/Tetraedrit)) gewonnen. Die genaue Prozessführung, die Abfolge der Arbeitsschritte, die Zusammensetzung der Ofenchargen sowie das hergestellte (Zwischen)Produkt bleiben jedoch Gegenstand eines kontroversen Forschungsdiskurses.
Mithilfe unterschiedlicher Methoden wird auch für das bisher wenig erforschte zentralalpine Oberhalbstein (Graubünden, Schweiz) im Rahmen einer Dissertation eine Prozessrekonstruktion erarbeitet. Neben ausgedehnter Geländeprospektion und geomagnetischen Messungen wurden in diesem Kontext auch zahlreiche geochemische und mineralogische Untersuchungen an Erzen und Schlacken durchgeführt, deren Resultate im vorliegenden Beitrag präsentiert und diskutiert werden sollen.
Als Verbindungsglied zwischen der Makroebene (grossflächige archäologische Geländearbeit) und der Mikroebene (archäometallurgische Analysen) wurde zudem eine ausführliche typologische und morphologische Studie des gesamten, mehrere tausend Fragmente umfassenden Schlackenmaterials durchgeführt. Die Verknüpfung aller Forschungsergebnisse soll zusammen mit absoluten Datierungen der Fundstellen sowohl einen Rekonstruktionsvorschlag der «chaîne opératoire» wie auch eine relative Quantifizierung der Produktivität in Zeit und Raum ermöglichen.

Keywords: Copper smelting, Grisons (Switzerland), Late Bronze Age / Early Iron Age, smelting slags, copper ores, chaîne opératoire

Entwicklung eines transportablen Probenahme-Systems zur Analyse der metallischen Oberfläche historischer Artefakte auf Basis elektrochemischer Anreicherung

Development of a Portable Sampling System for the Analysis of Metallic Surfaces of Historical Artefacts on the Basis of Electrochemical Enrichment

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Die chemische Analyse historischer Metall-Artefakte ist oft nur mit stark zerstörenden\aufschließenden Messmethoden durchführbar, da sich an der Objektoberfläche in der Regel eine Korrosionsschicht ausbildet, die für viele zerstörungsfreie Messmethoden wie Röntgenfluoreszenz oder Raman-Spektroskopie undurchdringlich ist. Die Verwendung dieser genannten Oberflächenanalyse-Systeme ist daher für die chemische Charakterisierung des eigentlichen Objektes ohne Abtrag der Oberfläche oftmals unzureichend. Es ist jedoch nicht immer möglich historische Objekte für Forschungszwecke zu zerstören, da viele Objekte als einzigartig eingestuft werden. Für die Untersuchung solcher Proben ist in der hier vorgestellten Arbeit eine hoch praktikable Probenahme-Technik entwickelt worden, die für den Feldeinsatz geeignet ist und eine minimal invasive und sehr schnelle Beprobung des metallisch leitenden Substrats ermöglicht. Die für direkte Messverfahren störende Korrosionsschicht bleibt bei der neuen Probenahme-Technik nahezu unverändert bestehen.
Die Grundidee der hier vorgestellten Probenahme-Technik basiert auf der anodischen Oxidation von Metallkationen innerhalb einer Zwei-Elektrodenanordnung, wobei das historische Metallartefakt als Anode dient. Die beiden Elektroden sind lediglich über einen kleinen Tropfen Elektrolytlösung verbunden, welcher die poröse Korrosionsschicht der Objektoberfläche durchdringt. Bei angelegtem elektrischen Potential werden Bestandteile der metallischen Oberfläche oxidiert und elektromigrieren als Kation über den Elektrolyttropfen zur Katode. Wird der Stromfluss jedoch unterbrochen, verbleibt ein Großteil der ionischen Metallbestandteile im Elektrolyttropfen und kann bis zur eigentlichen Messung in einem geeigneten Gefäß zwischengelagert werden.
Das Verfahren benötigt nur 10 µL eines Ammoniumnitrat Elektrolyten, wodurch nur ein sehr kleiner Bereich von etwa 2-3 mm Durchmesser beprobt wird. Dadurch ist sichergestellt, dass das historische Metallartefakt nur minimalst der anodischen Oxidation ausgesetzt ist. Des Weiteren fließt nur ein sehr geringer und möglichst schonender elektrischer Strom mit einer absoluten Ladungsmenge von 100 mAs. Die anodische Oxidation wird so lang aufrechterhalten, bis die gewünschte Ladungsmenge erreicht ist und stoppt anschließend automatisch. Der Tropfen kann mittels Hubkolbenpipette eingesammelt und in einem geeigneten Gefäß gelagert werden. In der hier vorgestellten Arbeit werden die Messergebnisse verschiedenster historischer Metallobjekte mit den vollaufschließenden Referenzanalyseverfahren verglichen.

Keywords: Probenahme, Metalle, Minimalinvasiv, Transportabel
Sampling, metals, minimal-invasive, portable

Diffusion-Induced Stable Isotope Fractionation: Implications for Archaeometallurgy

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Compositional heterogeneity of metals is long known in archaeometallurgy. However the isotopic composition of metals is commonly regarded as homogeneous. While this holds true for lead isotopes, it has not been examined yet for stable metal isotopes like copper or zinc. Investigation in this direction is urged by the application of new isotope systems and laser ablation analysis. This is the more important, as material scientists have reported diffusion-induced metal isotope fractionation, the so called 'isotope effect', since the late sixties. Moreover, potential fractionation of stable metal isotopes is known from other diffusion processes like Soret diffusion. Their effect in archaeometallurgically important metals is poorly understood.
For the first time, copper reguli produced in a lab-scale smelting experiment were examined and a substantial variation in their copper isotope composition was detected. The observed variation can be explained by the combination of stable isotope fractionation theory and different diffusion processes. They imply an enrichment of the heavier isotope in the colder, earlier crystallised areas of the solidified melt.
These observations have important implications for the sampling, analysis, and interpretation of metal objects. If such variation is not homogenised in further metal processing, the link between the isotopic composition of the ore and the metal must be questioned. At least, it is heavily relied on representative sampling or in-situ analyses. Additionally, processing of the metal like casting might induce additional fractionation. This would further complicate the reconstruction of the ore from the object. But at the same time, it opens up possibilities for new applications in archaeometallurgical research.

Keywords: Stable metal isotopes, fractionation, diffusion, isotope effect, smelting, archaeometallurgy

Provenance Studies of Copper-, Bronze-, and Silver Artefacts from the Royal Tombs of Ur, Mid 3rd Millenium BC

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The excavations of the Royal Tombs of Ur (1922-1934) [Woolley 1934], dated to the Early Dynastic period (mid to late 3rd millennium BC [Helwing 2014, Pollock 1985]) bestowed large amounts of metal finds. Besides prominent gold objects, plenty of arsenical copper high in nickel, tin bronze and silver objects were found. The great number of metal objects surprised, because Ur is located in the flood area of Euphrat and Tigris and is void of metal resources. This geological fact indicates an import of metals [Zettler & Horne 1998].
The Penn Museum, Philadelphia, provided more than 100 artefacts of silver, copper and bronze for analytical investigations. The samples are currently investigated at the laboratories of Frankfurt and Bochum regarding the analysis of major and trace elements with geochemical methods as well as lead and copper isotopes.
The main goals of this project are: 1.) Identification of natural and artificial alloys and 2.) Origin of the metals and ores used for making the artefacts. The Royal Tombs of Ur were buried in the "Age of Exchange" [Amiet 1986] when metal production boomed in widely spread regions, which all have to be taken into consideration as possible sources. The scientific investigations are accompanied by a close cooperation with Assyriologists and Archaeologists to consider not only the scientific but also the archaeological and textual evidence. Our results contribute to a better understanding of trade and exchange in the Early Bronze Age Middle East within the different disciplines.

Keywords: Provenance, copper, silver, bronze, lead isotopes, trace elements, copper isotopes, Mesopotamia, Royal Tombs, Ur

Die Computertomographie als zerstörungsfreie Untersuchungsmethode für Kunst- und Kulturgut aus Stein. Möglichkeiten und Grenzen am Beispiel der großen Mainzer Jupitersäule
Computer Tomography as Non-Destructive Investigation Method for Objects of Cultural and Artistic Value. Possibilities and Limitations Using the Example of the Great Jupiter Column at Mainz

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Die Computertomographie ist mittlerweile eine etablierte, zerstörungsfreie Untersuchungsmethode für Kunst- und Kulturgut. Innerhalb der Konservierungswissenschaften für Stein konnte sich die Methode bis dato noch nicht durchsetzen. Das Verfahren ergänzt die zerstörungsfreie Diagnostik und ermöglicht einen Blick in das Innere des Objekts. Der Stand der Forschung stellt in Aussicht, den Bestand, die Konstruktion und die Schäden eines Objekts detektieren und lokalisiren zu können. Anhand von CT-Aufnahmen der großen Mainzer Jupitersäule werden die Möglichkeiten und Grenzen der Untersuchungsmethode mit Fokus auf der Anwendung in der Steinkonservierung aufgezeigt.

Keywords: Zerstörungsfreie Untersuchungsmethode, Computertomographie, Steinkonservierung
Non-destructive investigation method, computer tomography, stone conservation

Silver Sources of Roman Republican Coinage Retraced by Geochemical Analysis

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We analysed drilling chips of Roman silver coins (n=70) dating between 310-300 and 101 BCE for their major and trace element composition and Pb isotope signatures by EPMA, LA-ICP-MS and MC-ICP-MS, respectively.
The Pb isotope signatures of Roman silver coinage minted before 209 BCE overlap with those of coins from Magna Graecia being in agreement with Ag ores from the Aegean (Attica, Chalkidiki, Western Anatolia) and Rhodope region (Birch et al., in press; Birch et al., in prep.). The majority of coins issued after this date show a different trend and form a mixing line extending between the Tertiary mineralisations of southeastern Spain and the Variscan deposits in the southwestern part of the Iberian Peninsula. Carthaginian silver coinage (n=2) from the 4th century BCE as well shows Pb isotope data being indicative of mixed metal sources from the Iberian Peninsula. Silver fineness of the Roman coinage dating after 209 BCE in contrast to earlier minted coins generally is in excess of 96 wt % and further strengthens the hypothesis of a secured supply of metal bullion.
Overall, our results suggest that the massive influx of silver in the form of booty, tributes and war indemnities during and after the 2nd Punic War, respectively, significantly contributed to Rome's rise to the dominating power in the Mediterranean World.

Keywords: Silver coinage, Pb isotopes, trace elements, Rome, 2nd Punic War

Quantitative, Non-Destructive XRF Analysis of Pottery - Why Does Accuracy Matter and How To Achieve It?

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Portable X-ray fluorescence analysers have received increasing attention for a fast and cost-efficient compositional analysis of ceramics, sediments and rock samples. At the same time the debate on accuracy, inter-laboratory comparability of the data and the use of intact, non-powdered sample material goes on for years. Indeed complaints are justified when scholars use the method without any analytical training or specific consideration of photon physics, but there are also pure prejudices uttered by individual opinion leaders. Several examples of compositional analysis of settlement contexts shall demonstrate the importance of cross-user and cross-instrument comparable quantitative results. In the absence of a validated protocol which is fine-tuned for the respective study task, there is a considerable risk that, due to the overall similarity of clays, meaningful conclusions cannot be drawn at all. Thus a matrix-specific instrument calibration and interference correction is mandatory for the discriminative minor and trace elements to be quantified. If this is not possible due to instrument or software limitations, the restricted data quality and its fit for purpose needs to be clearly indicated – at least for submissions to peer-reviewed journals. For details and literature cited *cf* Wilke, D, Some updated quality concerns on non-destructive geochemical analysis with XRF spectrometry, *Advances in Applied Science Research*, 2017, 8:2, 90-94 (open access).

Keywords: pXRF, calibration, pottery, clays

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