The first Irano-German International Symposium on the Archaeometry

Abstract Book

The first Irano-German International Symposium on Archaometry

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The first Irano-German International Symposium on Archaeometry

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Foreword by Tabriz Islamic Art University

As an interdisciplinary and prolific branch of archeology, Archaeometry draws on basic and natural sciences like mathematics, physics, chemistry, geology and metallurgy to answer archeological questions which the methodological foundations of archeology fail to provide an answer for. The social, cultural, historical and artistic fields in archeology give rise to questions for scholars whose answers can only be sought for in the natural science laboratories.

It has been more than eight decades since Iranians first Archaeological efforts to understand the cultural heritage of the ancient Iran. Yet, despite the establishment in 1937 of the department of archeology in University of Tehran and dozens of other related departments that began to spread across the country since the 1990s as well as the presence of the Iranian Center for Archaeological Research, Archaeometry has been the missing link in the past eventful eight decades of Iranian Archaeology.

Archaeometry was finally established as a discipline in 2012 in Tabriz, the forerunner city of Iran in many respects, following two years of strenuous efforts on the part of the core fellows of Tabriz Islamic Art University in cooperation with the core fellows of University of Tehran, University of Tabriz and Sahand University of Technology in Tabriz and through the unsparing support of Prof. Dr. *Mohammad Ali Key'Nejad*, the Chancellor of Tabriz Islamic Art University and member of the Iranian Supreme Council of Cultural Revolution. The first MA program of the field was started with the admittance of undergraduates of conversation of cultural properties. The syllables of the MA program for Archaeometry was designed after consulting the syllables of twenty American and European universities especially that of Germany, and it received the final stamp of approval in 2015 by the Iranian Ministry of Science, Research and Technology. These syllables are now the official and legal guideline for the nationwide expansion of Archaeometry. Furthermore, in 2013, Tabriz Islamic Art University hosted the first national conference on the application of scientific analyses to Archaeometry and

the conservation of cultural heritage, during which the so-called strategic document of 'Tabriz Declaration' was drawn up in consultation with scholars from University of Tehran, University of Tabriz, Art University of Isfahan, ICHHTO and the then vice-president of the named organization; the document was registered in the Supreme Council of Cultural Revolution (Oct. 2013) as the official document for the promulgation of Archaeometry and was communicated to the Iranian Ministry of Science, Research and Technology.

Fortunately for the department of Archaeometry at Tabriz Islamic Art University, as the founder and pioneer of and the authority in the Archaeometry in Iran, it enjoyed from the very beginning the strong support of its chancellor and the senate. In this regard, not only the library and laboratories of the university have become increasingly well-equipped, but also expansion of international cooperation and benefiting from the trans- regional potentials of the city of Tabriz is among the basic strategies of Tabriz Islamic Art University.

Accordingly, Dr. Judith Thomalsky, the director of German Institute of Archaeology in Iran, paid a visit to the university in October 2015 to sign a memorandum of understanding to foster scientific and technical cooperation between Tabriz and Germany in archeological sciences, research on cultural heritage and Islamic art, conservation, and Iranian studies. Archaeometry is an essential part of the said memorandum.

Positive reputation has been the dearest asset of Germany in Azerbaijan, especially in Tabriz, and luckily DAI being fully aware of the fact, has taken some steady steps towards implementing the bilateral memorandum of understanding.

After holding a technical training workshop and organizing some lectures during the year following the agreement, Tabriz is now hosting the first international symposium on Archaeometry jointly held by Iran and Germany. Furthermore, some long-term and medium-term research projects have also been planned in Tabriz and its environs in cooperation with the German institute as part of the strategic plan of Tabriz 2018 event.

Tabriz Islamic Art University has organized and held two national symposiums on the application of scientific analyses to Archaeometry and the conservation of cultural heritage. The university is just to convene the joint *Irano-German symposium on Archaeometry*. The permanent secretariat of the symposium was established in the Archaeometry Department of Tabriz Islamic Art University following the approval of the university's chancellor. The forthcoming second symposium is to be held in Germany by the DAI.

Apart from the third national symposium on the application of scientific analyses to Archaeometry and the conservation of t cultural heritage in May 2017, the current international symposium is a prequel to the *First International Congress on the Iranian Archaeometry* which is going to be hosted in *2018* by Tabriz Islamic Art University on the occasion of the Tabriz *2018*, according to what is stipulated in 'Tabriz Declaration' and will be preceded by national and international call for papers.

Dr. Bahram Ajorloo
The Head of the Research Institute
for the Conservation of Historic-
Cultural Monuments & Quarters

Foreword by German Institute of Archaeology

Archaeometric science incorporates natural sciences particularly chemistry, geosciences, physics and biology and obtains increasing significance as an independent and professional field in universities. Though, Archaeometry often is determined as an additive resource for analytical Archaeological studies or the work of restaurateurs and conservators; effectively in mostly all countries of the world. Wealth importance lies in the bridging character between natural sciences and the fields of humanities and arts and Tabriz Islamic Art University is one of only three universities in Iran that offer the opportunity to study Archaeometry in a professional environment - even in an independent and expert faculty.

This *first Irano–German Symposium on Archaeometry* in the departments of Archaeometry and Conservation in the faculty of applied arts, Tabriz Islamic Art University, is a first step to establish an expert platform to discuss the wide opportunities and how to implement the miscellaneous methods and applications of Archaeometry in universities and faculties. Worth needed is the exchange of experiences of scientists and students, and to develop and design this innovative and modern scientific branch for future. It is further necessary to generate valuable reference and standards for Archaeometric studies, applications and fields of research and methods. Natural science and humanities and arts should create a round table and discuss their – often very – variable and differing approaches and aims.

The first Irano–German Symposium on Archaeometry in TABRIZIAU is giving a first and unique occasion for scientists and experts from different research fields associated with Archaeometric studies from Iran and Germany; and aims to establish such a cooperative and innovative and sustainable network.

In view of the overall energetic facilities and motivation and good company of Tabriz Islamic Art University, of which we all will benefit in future, and without this Symposium would no doubt not have been realized, German Archaeological Institute and I personally appreciate to express deepest thanks and admiration.

Dr. Judith Thomalsky
The head of the German Institute
of Archaeology, Iran, Tehran

Foreword by ICHHTO

The value of the cultural heritage of Iran and Azerbaijan and particularly Tabriz transcends the national boundaries, so that there are few authentic scientific sources on the Ancient East and Islamic world history that fails to speak of Tabriz. Today, our Tabriz has received the legacy of a history that goes back to the Neolithic Age. When we talk about the Ilkhanid Tabriz, we are in fact talking about strong scholarship centers of Islamic world, that is Rabʿi Rashidi and Shanb Ghāzān, the precious spiritual legacy of Khawja Rashid al-Din Fazullah, the well-known architect, Khawja Alishāh of Tabriz and the lasting and prideful Arch of Alishah or Ark-i Tabriz. Today, when we talk about the glorious Timurid history and its influence on the Islamic world, and even Europe and Asia, it is impossible for an eagle-eyed listener not to think of the Blue Mosque (*Masjid-i Kabūd*)—the masterpiece of Islamic tile working and calligraphy and the Eastern architecture.

It goes without saying that at the time I carry the weighty responsibility of conserving the cultural heritage and historic reminders of not only Iran and Iran-ness but also those of the East, Islam and Shi'ism; fulfilling such a formidable task will not be possible without the sympathy, assistance and cooperation of well-known international cultural heritage scholars and experts, not least those in the field of Archaeometry.

I am honored to announce that Tabriz Islamic Art University, with its academically developed infrastructure, being the core of Archaeometry in Iran, and its unique research institute for the conservation of historic monuments, has been actively involved in all fields as a partner and collaborator of the East Azerbaijan Cultural Heritage, Handcrafts and Tourism Directorate. I am now happy that the international potentials of Tabriz have allowed us to host scholars of the Institute of Archeology of Germany—a country of good repute in Azerbaijan and Tabriz.

Increasing international cooperation after Iran's nuclear deal and benefiting from all economic, social and scientific-technical potentials of Iran, especially Tabriz, in the international arena have been some of the macro and strategic policies of President. Ruhani's administration. Germany, as one of the strategic partners of

Iran in international relations, therefore, enjoys a privileged status in Iran's foreign policy.

One of the most important strategic plans of East Azerbaijan ICHHTO concerns implementing the strategic plan of *Tabriz 2018* event in the best possible and organized manner. Thanks to its available infrastructure and diverse potentials, Tabriz has fortunately been chosen by the Organization of Islamic Cooperation as the Capital of Islamic Tourism in 2018. This has naturally charged us with the heavy responsibility at both local and national levels.

As a rule, systematic conserving, repairing and maintaining the historic texture and monuments in Tabriz and its surroundings and the World Heritage site of Tabriz Historic Bazaar Complex, the Blue Mosque, Arch of Alishah, Rabʿi Rashidi, Hasan Padishah Complex and the historic village of Kandowān could not be carried out just by the diligent staff of the East Azerbaijan ICCHTO. In addition to national determination and support from all supportive provincial and national authorities, it requires the intense involvement of international scholars and experts of the field. In his respect, apart from the Research Institute for the Conservation of Historic-Cultural Monuments & Quarters at Tabriz Islamic Art University and the tripartite international treaties signed during my tenure, the scholars from the Archeological Institute of Germany will doubtless have an important, unique, and strategic role in meeting the objectives President. Ruhani's administration has defined to realize the cultural prosperity of Azerbaijan and *Tabriz 2018.*

Now, as the director general of East Azerbaijan ICCHTO, I express my desire to extend cooperation with Iranian scholars and extend my warm welcome to the German scholars attending this conference, wishing them good luck for the strategic plans of Rabʿi Rashidi, Kandowān and the UNESCO's World Heritage Site of Tabriz Bazaar Complex.

Mortezā Ābdār Bakhshāyesh
Director General
Iranian Cultural Heritage, Handcrafts and
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Section I

Interdisciplinary Approaches in Archaeological Sciences

A Survey of Archaeometric Applications in Archaeology

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Abstract

Archaeometry bridges the branches of humanities and natural sciences in a very distinctive and impressive manner. Archaeometry is further emphasizing the interdisciplinary character of modern Archaeology that nowadays cannot be imagined without it. The contribution will give a survey of the history of Archaeometric approaches (in Archaeology) that are today commonly established in natural and humanities and are used in restoration and conservation. A long-lasting, still ongoing critical examination of the different applications for more than 75 years—since Libby developed the method of radiocarbon dating in 1946—lead to the establishment of Archaeometry as a practically self-contained science, representing a huge spectrum of distinctive methods and approaches. Beyond this, Archaeometry has also pushed Archaeological sciences to new perspectives for understanding and solving questions such as: How did ancient societies develop technologies on a minute scale? What did they eat or used? And, where did their resources came from? However, Archaeometry can be regarded as a primary science, with common standards of analytics, examination and investigation. It is thus necessary to discuss in a deliberately and cautious manner the possibilities for humanity sciences in general, and to determine standards of education, equipment and facilities for Archaeometric departments in universities.

Keywords: Archaeometry, Archaeology, Archaeological sciences, Scientific microanalyses, Absolute dating, Ancient technologies

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Dendrochronological Dating Of Old Houses in the Village of Shahkouh in Gorgan, Iran

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Abstract

Shahkouh is an old village in the Alborz Mountains with routes connecting it to Gorgan to the north and Shahroud and Damghan to the south. Located on an ancient south-north communication line across Alborz, it has an old history. The old houses have lavishly used juniper wood as construction material because the village lies next to the natural juniper forests. The durable wood of juniper would keep the building upright for a prolonged period of time. Since on the basis of its structure and the available evidence the village is believed to date bake over a millennium, a total of 28 discoid samples were taken from the columns and beams of the ruined or standing houses by a chainsaw. Having been prepared, the ring width was measured in all samples with 0.01 mm precision using LINTAN5 measuring machine and a binocular. Given the high frequency of missing rings in juniper trees, at least two sides of each specimen were measured. The ring-width time series of two sides were then analyzed by statistical tests such as correlation, GLK and student's t-test. Then the average time series obtained for each house were cross dated using (checked against) the reference curve that was established from the nearby juniper forests that span at least 500 years. Once the correlation between the two series was verified, the samples and, consequently, the houses were dated. The results suggested that the houses for the most part were constructed or rebuilt over the recent 100 years, though some dated to 200 to 250 years ago. And, a single house was found to be built some 350 years ago. The results showed that it would be possible to reconstruct the history of the village provided that all houses therein are going to be sampled.

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Keywords: Tree rings, crossdating, dendrochronological dating, juniper, old houses

Magnetometer Prospecting for Archaeologists: Methods and Selected Case Histories

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Abstract

Magnetic prospection was applied for the first time to Archaeology in 1956. Over the years since then, it has become one of the most important Archaeological methods for the detection and mapping of buried remains at large Archaeological sites. Magnetic detection methods are extremely sensitive in the characterization and analysis of iron oxides, much more so than any other form of chemical analysis. Therefore, given a full understanding of the nature of magnetic properties, many details of soil layers and buried Archaeological structures can be discovered, visualized, and interpreted only by the "magnetic eye". A complete Archaeological interpretation prior to excavation must consider all available Archaeological background information as well as surface findings; however, many more crucial details can be derived through a comprehensive soil magnetic analysis, and many new Archaeological questions arise from such geophysical prospecting results. For a long time, Archaeologists held the firm conviction that geophysical prospecting results on their own would be only of limited use in the resolution of Archaeological problems. Today, it has become commonplace that the initiation of a modern Archaeological excavation must be preceded by some kind of geophysical prospecting. The great success of magnetic prospection in general is due to the fact that almost all soils of the world show an enhancement of magnetic minerals such as magnetite or magnetite in the topsoil. Except for very rare situations, mostly on sites with dammed-up water and consistent soil wetness, there exist no limiting geological factors precluding the application of magnetic prospecting. Enrichment of these minerals in Archaeological soil layers—especially in fireplaces, but also in ditches,

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pits, or postholes—is caused by the formation of these minerals either by natural or anthropogenic fires, varied pedogenic processes, or magneto tactic soil bacteria. The use of fire, however, plays the major role in the enhancement of magnetic minerals in Archaeological soils, since this occurs on nearly all sites from the Paleolithic to modern times. Selected case histories from our latest research projects in southern Germany, the ancient world Mesopotamia and Eurasia will be shown to explain the methodical research on soil magnetism.
Keywords: Archaeological geophysics, Magnetometery, Soil magnetism, Site formation, Interpretation

A Geomatical Analysis of the Landscape of Death in the Iron Age Central Qaradagh, Azerbaijan, Iran

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Abstract

The paper concerns the Iron Age landscape of death in Central Qaradagh, East Azerbaijan. Characterized by a cold semi-arid climate and a steppe landscape, the mountainous region of Central Qaradagh consists of ravines, with extremely precipitous slopes. The area served as a natural main route connecting eastern Urmia Lake to the south Caucasia during the prehistory. In light of Archaeological surveys, the region is dominated by subsistence systems not dependent on permanent settlements, now represented simply by burials and some indications of temporary occupations. Even the few modern-day rural centers have been mainly abandoned due to the harsh regional climatic conditions and the frequent abrupt torrential currents. Ecological conditions and low fertility of arable lands have hindered development of any settlement systems. The surface survey of Central Qaradagh recorded 32 sites in Azghan and 46 sites in Uch Hacha; they include forts, enclosures and burials. The typology of sherds and graves date these sites to the Iron Age I-II, and burial sites dominate the list. Landscape of death is a concept in landscape studies and is concerned with the relationship between burial data and geographical landscape in terms of social/ideological factors. Landscapes of death would evolve deliberately and generally within pastoral nomadic subsistence systems to affirm honoring ancestors and remembering collective memories, to strengthen social bonds, and to mark routes leading to resources. The key point regarding the relation between ancient burials and the landscape is their intentional placement. In this regard, the GIS can be used to decipher the reasons behind the distribution of burials in the region and to interpret them socially and ideologically. Hence, environmental and cultural attributes of both the burials and enclosures that were identified in the area were studied. The Iron Age burials of Qaradagh could be classified in three main types and three subtypes, each showing distinct distribution

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patterns. The distribution patterns of the graves were geomatically analyzed in relation to the natural landscape features (altitude, streams, rivers and other water resources), the cultural features (permanent rural settlements), and the spatial interrelations between sites. The major data analysis technique was multi-buffering. Results have been discussed in three areas of spatial distribution of graves in relation to the features, g-forces of the graves of the same kind, and ultimately Central Qaradagh's landscape of death. The most important point regarding the distribution of graves in the regional landscape of death appears to be the fact that each distinct grave types mark a different ethnic-social group.

Keywords: Archaeological distribution, Central Qaradagh, Geomatical analysis, landscape of death, Iron Age

Using Dynamic Pulse Function for Semantic 3d Modeling of Historical Landmarks

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Abstract

The pulse function (PF) is a technique based on the procedural preprocessing system to generate a computerized virtual photo of the façade with a fixed square size. Dynamic Pulse Function (DPF) is an enhanced version of PF which can create the final photo proportional to real geometry. This can avoid distortion while projecting the computerized photo on the generated 3D model. The challenging issue that might be handled for having 3D model in LoD3 rather than LoD2 is the final goal that has been achieved in this paper. In the technique based on DPF, the geometries of windows and doors are saved in an XML file schema which does not have any connections to the 3D model in LoD2 and City GML format. In this research the parameters of Dynamic Pulse Functions are utilized via Ruby programming language in Sketch Up Trimble to generate windows and doors (with exact position and deepness) automatically in LoD3 based on the same concept of DPF. The advantage of this technique is automatic generation of huge number of similar geometries, e.g. windows, by utilizing parameters of DPF along with defining entities and window layers. In case of converting the SKP file to City GML via FME software or City GML plugins, the 3D model contains the semantic database about the entities and window layers which can connect the CityGML to MySQL. The concept behind DPF is to use logical operations to project the texture on the background image which is dynamically proportional to real geometry. The process of projection is based on two vertical and horizontal dynamic pulses starting from upper left corner of the background wall and ending in lower right based on image coordinate system. The logical values 1/0 on the intersections of two vertical

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and horizontal dynamic pulses will/will not project the texture on the background image. It is possible to define priority for each layer. For instance, the priority of the door layer over the window layer means that the window texture cannot be projected on the door layer. Orthogonal and rectified perpendicular symmetric photos of the 3D objects that are proportional to the real façade geometry must be utilized for the generation of the output frame for DPF. The DPF produces very high quality and small data size of output image files in quite smaller dimensions compared with the photorealistic texturing method. The disadvantage of DPF is its preprocessing method to generate output image file rather than online processing to generate the texture within the 3D environment such as CityGML. Furthermore the result of DPF can be utilized for 3D modeling in LoD2 rather than LoD3. In the present work the random textures of window layers are created based on parameters of DPF within Ruby console of SketchUp Trimble to generate the deeper geometries of the windows and their exact position on the façade automatically along with random textures to increase Level of Realism (LoR). As the output frame in DPF is proportional to real geometry (height and width of the façade) it is possible to query the XML database and convert them to units such as meter automatically. In this technique, the perpendicular terrestrial photo from the façade is rectified by employing projective transformation based on the frame which is in constrained proportion to real geometry. The rectified photos which are not suitable for texturing but necessary for measuring can be resized in constrained proportion to real geometry before measuring process. Height and width of windows, doors, horizontal and vertical distance of windows from upper left corner of the photo, and dimensions of doors and windows are parameters that should be measured to run the program as a plugin in SketchUp Trimble. The system can use these parameters and texture file names and file paths to create the façade semi-automatically. To avoid leaning geometry, the textures of windows, doors and etc., should be cropped and rectified from perpendicular photos, so that they can be used in the program to create the whole façade along with its geometries. Texture enhancement should be done in advance such as removing disturbing objects, exposure setting, left-right up-down transformation, and so on. In fact, the quality, small data size, scale and semantic database for each façade are the prominent advantages of this method.

Keywords: Dynamic pulse function, random textures, automatic 3D semantic modeling, historical landmarks

Iranian windmills and their millstones: An Interdisciplinary Approach

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Abstract

Persian windmills were frequently mentioned to be amongst the first machineries that used wind power for technical purpose. Unproven stories about the windmills were preserved in historical documents and narratives, whereas Archaeological evidences can partly clarify the history of this technology. Nowadays most of these mills are scattered on the border of Iran and Afghanistan but disappeared from their assumed motherland, Sistan, which is also divided between these two countries on the southern part of their common border. An Archaeological study on remains of windmills in eastern Iran, fortified by Archaeometrical research on their millstones as well as a systematic investigation on the relevant historical texts and ethnographical observations, shed a new light on various faces of this technology and its history. This study was conducted to shed light on the history of Persian windmills and manufacturing artificial millstones based on Archaeological and Archaeometrical investigations. The results show that various types of Persian windmills exist in Iran and Afghanistan. These windmills are generally similar but vary in technical details and in the use of raw materials. In the highlands of eastern Iran three clusters of windmills can be found that are distinguishable from each other concerning their construction, machinery and their millstones. Another group of windmills, which is categorized as Archaeological windmills, were built on the lowland of Sistan and possessed artificial millstones. These synthetic millstones where produced by a complicated high-temperature technology and represent the importance of windmills in ancient Sistan. Analytical studies on the mineralogical and crystallographic texture combined with experimental replica of their microstructure on these millstones unfold part of this ancient technology which achieved a high temperature of 1170° C that was kept for long time to produce these millstones. An interdisciplinary approach of this study provides a basic ground for further excavation of windmills either in Iran or Afghanistan.

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Keywords: Windmill, Iran, Sistan, chrystal structure, Mineralogical structure

Section II

Analytical Chemistry in Archaeometry

Application of SEM-EDX to Microstructural Analysis of Historic Organic and Mineral Remains

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Abstract

There are several systematic approaches today that permit non-destructive examination of finds to obtain the most information possible. The approaches are able to answer many questions with regard to the type of material, technological sophistication of different communities, and the region of origin of raw materials used in the production of ancient objects. EDX (also known as EDS and EDAX) is one of techniques that enable elemental analysis of a specimen or a fragment of it. EDX is not applied *per se*; rather it is associated with SEM or, more properly, is part of it. One of the research projects undertaken by our team concerned the examination of the Achaemenian leather fragments from the Chehrabad salt mine of Zanjan to decide on the presence of mineral tanning agents through SEM-EDS elemental analysis; the specimen proved to lack such agents. A second investigation aimed at identifying the mineral elements in a leather fragment sampled from a leather shoe excavated at Tepe Ashraf of Isfahan. The EDX results revealed high calcium content, evincing the potential use of lime in deharing process. A third work on the glaze of the incised pottery vessels of Amol Style employed EDX-SEM to detect the elements on the glaze surface, across the glaze, and the slip.

Keywords: Archaeometry, Applied chemistry, SEM-EDX, Leather, Pottery

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A Study of Archaeological Skeletons On The Basis Of Isotopic Analysis of Strontium and Trace Elements

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Abstract

Stable isotope analysis, commonly used in many research areas, has also been applied to Archaeology during the last three decades to address questions regarding the paleoclimatology and ancient diet, and mobility and migration. Despite the growing number of Archaeological studies adopting the technique, it has found only limited application in the Archaeology of Iran. This research aimed to study the human skeleton remains of Iron Age site of Masjed Kabud in Tabriz, using strontium stable isotope analysis. Therefore, tooth and bone samples from the skeletons were studied through strontium isotope ratios ($^{87}Sr/^{86}Sr$) and trace element analysis for Sr/Ca and Ba/Ca to ascertain whether or not they belonged to local people. Result of $^{87}Sr/^{86}Sr$ revealed that all samples could be considered as local with the exception of Burial 81-8, a female, whose obtained value was beyond the local range (local mean ± 2 s.d.). The trace element analysis for Sr/Ca and Ba/Ca were implemented statistically, suing an independent test sample. Results for both sample groups (Sr/Ca and Ba/Ca between teeth and bones) demonstrated that there is no significant difference between the two groups. Therefore, skeletons can be logically described as local. Beyond this, the research revealed that the method could be applied in similar research projects and the result of strontium isotope and trace element analysis could also be used in different fields, among them being Archaeology, geology and other interdisciplinary scientific areas.

Keywords: Stable isotope analysis, Strontium isotope ratio, Trace element analysis, Iron Age cemetery of Tabriz, Human skeletal remains

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Geochemical Data on Mudbrick: The Elemental Analysis on Chogha Zanbil Mudbricks

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Abstract

The Mud brick is the main construction materials found in Iranian Archaeological sites. However, this material is not studied so often in technical studies of Archaeological materials. The Chogha Zanbil is one the main Elamite Archaeological sites with a verity of earthen architecture structures. The study presented here is the preliminary results of elemental analysis using P-ED-XRF and ICP-MS spectroscopy in order identify the clustering of mud bricks regarding their geochemical data. more than 200 samples have been taken from all buildings and possible clay deposition on the site. Major, minor and trace elements were handled by different statistical methods to discriminant samples and identify the grouping patterns. The results show that there is a significant difference between three surrounding walls in compare to the single buildings. Even though the mud bricks are very similar to the in-situ soils, there is a significant difference with clay deposits just close to the site.

Keywords: Geochemical analysis, Mudbrick, Chogha Zanbil, P-ED-XRF, ICP-MS

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Science Matters: Analyzing Pigments and Paints from Pasargadae and Persepolis on the Sites and in the Museum

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Abstract

Already more than 160 years ago, early modern travelers visiting the site of Persepolis or Takht-e Jamshid employed scientific methods of materials analysis to understand the chemical components of the still visible colors covering the original surface of the monuments. Analysis on the site of Persepolis, but also at other monumental sites like Pasargadae and Susa as well as research in museum laboratories and with portable equipment has much advanced and improved our knowledge about the building façades in recent years. This paper will provide an overview of the old and new work on pigments, paints and other original surface decoration so far undertaken. It will introduce more recent collaborative efforts to understand the materials used and technologies employed in the Achaemenid period, and help identifying and understanding best practices in the field. How has Archaeometric research conducted on Achaemenid Persian monuments improved, and what are the great opportunities and challenges laboratories and institutions in Iran and worldwide can offer in the next decades? How can scientific methods help us to understand better the advanced state of knowledge achieved among craftsmen of the monumental buildings and façades on the site?
Keywords: Achaemenids, Persepolis, Archaeometry, Pigment analysis, Portable XRF

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Identification of Characteristics for fresh and Old Varnishes in "Kaman Oil" Coating Using FT-IR

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Abstract

The so-called "Kaman oil" coating is the most typical varnish used in Iranian art. It is cited in ancient textual evidence from at least as early as the 6th century AH, and the examined historical objects trace its use history back to at least the 8th century AH. The material was in common use since the Timurid period in the book arts and as coating on artistic works such as wooden artifacts, mirror frames, caskets and pen boxes. This oil-resin based varnish is produced through melting sandarac or copal resin in linseed oil in a controlled condition at higher temperatures, and the resulting product is used as varnish or binding agent for gold leaves in artworks, depending on the density of resin. The resin melted in oil goes through structural changes; the oil also experiences changes in its chemical structure. These changes lead to the modification or complete elimination of some characteristics of resin in varnish, hindering its tracing by infra-red spectrometry. Also, varnish undergoes still other changes as a result of time passage and aging process. Studies have indicated that the aging process is accompanied by increased absorbance at the O-H region, and that the absorbance is heightened at the fingerprint region due to the stretching C-O absorbance. In addition, the carbonyl absorption band becomes broadened. This denotes the domination of the aging process in the varnish by the oxidation process. These reactions occur mainly in diterpenoid resins through the hydration process of binary bonds. Escape of fugacious compounds and

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the products of destruction of terpenes with lower molecular mass and polymeric components of resins will occur in the form of changes at the C-H region. Though the changes attested during the analysis of resin may be the result of artificial aging, these factors will be partially missing in an old varnish. Transverse bonds result in reduced C-C and C-H indexes, which exist in the structure of polymeric resins such as copal and sandarac. Some markers of resin and oil will be present even after aging. Also, old varnishes contain a series of new markers which are not seen in modern varnishes, a fact that stems from the formation of novel bonds or destruction of some polymeric or semi-polymeric components in the course of aging. The present paper attempted to compare the infra-red spectrum properties of fresh "Kaman oil" varnish to those observed in old instances. Data collected through laboratorial analyses were correlated to the results from related previous studies and were finally presented adopting an analytic and interpretative approach.

Keywords: "Kaman oil" coating, Sandarac, Copal, Linseed Oil, Oxidation, FT-IR.

Section III

Geo-sciences in Archaeometry

Contributions of Geosciences to Archaeometry: Examples from Iran

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Abstract

Geomaterials and their related ancient processed materials are the substantial constituents of Archaeological finds, whose Archaeometric investigations would reveal fundamental knowledge about the characteristics, application, provenance, and cultural impacts and connections of such materials. This would, on the other hand, reveal some information over the early development of technologies and innovations as well as the usage of georesources. In this regard, geological, mineralogical, and geochemical investigations on the materials involved in the ancient production of metals, ceramics, building materials (e.g. bricks, terracotta, mortar and plaster, etc.), rocks, and lithic tools would be of great help for understanding of the ancient societies, their trade patterns, and their interactions. Nevertheless, the contribution of geoscience to Archaeometry is not confined to material characterization and provenance studies. Geochronological, sedimentological, tectonic, ecological, and environmental investigations make also considerable contributions to Archaeometry. Although Archaeometry is normally considered as an aid to Archaeology, it can the other way round, help the other disciplines of science using Archaeological tips. Examples of this could be prospecting and exploration for modern mines following the traces of ancient mining, study and better understanding of earthquakes following up the record of ancient earthquakes, investigations on paleomagnetism, and study of ancient ecology and climate, as well as getting some modern technological tips from ancient artifacts e.g. glazed and enameled ancient materials. All these can introduce Archaeometry not only as what it has so far been known for (i.e. an interdisciplinary science at the service of Archaeology), but also as a new branch of science in its own right. In this paper, following some introductory points over the geoscientific aspects of Archaeometry, some recent Archaeometric examples from Iran will be given which include the studies on the provenance of ancient tin-copper ore, study and provenance of ancient stone sculptures and soap stone materials, and investigations on geomaterials for production of lithic tools.

Keywords: Ancient geomaterials, Ancient georesources, Ancient tin-copper ore

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The Archaeometric Provenance Determination of the Obsidian Samples from Northern Qaradagh of Azerbaijan, NW Iran, Using XRF Analytical Method

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Abstract

Ascertaining the original resources of Archaeological obsidians stands among the basic issues in the prehistoric Archaeology of northwest Iran and Caucasia. Renfrew and his colleague's works in 1960s have suggested the upland areas around the Lake Van as well as the southwest Caucasia and the environs of Agri Dagh as the main resources wherefrom northwest Iran and Caucasia obtained their obsidian in antiquity. However, in recent decades mining areas within the Iranian plateau or in the Lake Urmia Basin have been proposed as the possible provenances by J. Rafifar, K. Niknami and A. Chaychi Amirkhiz. The Dec. 2008-Feb. 2009 excavations of Khodafarin region in the Araxes valley yielded obsidian pieces whose XRF elemental analyses evince the highlands in the northwestern Araxes valley as the region of origin. These Archaeometric observations of the related material from northern Qaradagh in Iranian Azerbaijan, by the method of XRF, have corroborated the former results obtained from Khodafarin samples by the method of PIXE.

Keywords: Azerbaijan, Archaeometric provenance determination, Northern Qaradagh, Obsidian, XRF

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Obsidian in Prehistoric Azerbaijan, NW Iran: The Geochemical Fingerprints and the Potential of Portable XRF

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Abstract

A number of research projects on obsidians found in prehistoric Azerbaijan, NW Iran sites have proved recently that they came from a wide range of geological sources in Anatolia and Transcaucasia during the different periods. Obsidian sources in NW Iran (Mount Sahand and Mount Sabalan volcanic regions) have also been discussed in this regard, but at the current state of research further socio-economic discussions and interpretations about their role in potential trade routes or exchange networks are limited, mainly because basic information on the Iranian sources is still pending. Although there have been several research projects on the topic, open questions remain, especially concerning the geochemical fingerprints of the purported NW Iranian obsidian sources and their potential for local prehistoric exploitation and use. Several particular objectives could provide further insight: extensive Geo-Archaeological field surveys, focusing both on raw material sampling at obsidian outcrops for geochemical analyses and on the identification of potential old mining sites and related infrastructure. These can serve as targets for future excavations. New finds can help establish a better understanding of the chronological evolution of the "chaîne opératoire" of obsidian production and its role in cultural interaction, and it also can optimize the workflow of Archaeometric analytics. Portable XRF has some downsides compared to traditional laboratory based geochemical analytics, mainly concerning the limit of detection of several trace elements, but the handheld device has considerable advantages too. The measurements can be made on the site, in the camp or in the museum. The time to spend for each measurement is comparably short, so a representative amount of finds can be analyzed and the costs are limited. The major fact is that portable XRF analysis is non-destructive, which is a vitally important concern for any responsible research in the cultural heritage realm. Nonetheless, using portable XRF is a complex matter that requires a profound geochemical training and experience in analytical methods. To

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avoid errors during analysis, data processing and interpretation, a certain methodological work sequence has to be established, which pays attention to the specific questions and requirements of geochemical obsidian studies in the region as we can learn by critically comparing and evaluating previous laboratory based analytical methods, the technical parameters, data processing, their editing and publication of results and further interpretations. The comparison of measurements of raw materials from known geological sources and multiple analyses of the same sample by different laboratories can help to determine the potential and the limits of portable XRF and to constantly adjust and calibrate the system so as to gain the maximum result. Especially, technical parameters can be optimized, such as e.g. the shortest justifiable measuring time, according to filter settings and economic data processing. Compatible databases including GIS-related mapping help assigning geochemical fingerprints to material groups and identifying new or problematic samples, which then can be analyzed in the laboratory. Portable XRF will by no means replace traditional laboratory based analytical methods in the future; it simply offers a wide spectrum of new approaches to support Archaeometry outside the lab.

Keywords: NW Iran, Prehistory, Obsidian, Geochemistry, Portable XRF

Archaeometric Determination of the Provenance of the Late Chalcolithic Obsidian Tools from Davagoz of Khoy through Elemental Analysis Using Portable XRF

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Abstract

The first season of excavation at the Archaeological site of Davagoz in Khoy brought in light deposits from the late Paleolithic/transitional Chalcolithic (sixth millennium BC) to late Chalcolithic 3 (ca. 3600 BC). Of the whole assemblage of obsidian tools discovered in this season, some 134 pieces from different periods were subjected to XRF analysis to determine their geological mines. The results suggested that a number of different obsidian resources were exploited by the Davagoz population. Of the specimens examined by portable XRF with identifiable chemical structure, a total of 44 instances dated to the Late Chalcolithic; their X-ray florescence analysis suggested the use of raw materials from the characteristic mines of Syunik (n = 1), Satankar (n = 2) and Sukar (n = 29), South Caucasia (n = 32), Gegasar and (n = 4) Gutanser (N = 1) also in South Caucasia, Meydan Dağ in eastern Anatolia in the Van Lake Basin (n = 3), and Arteni (n = 1). And, provenances of 3 pieces were impossible to ascertain. Thus, the closest resource represented in the Chalcolithic deposits at Davagoz was Syunik separated by almost 75 km from the site, and the farthest was Nemrut Dağ located about 300 km away. In order words, the main mining areas used by the people of Davagoz were those in the Sevan Lake Basin of Armenia and the Van Lake region in Turkey. The results shed light on a wide network of cross-regional trade in the prehistoric Northwest Iran.

Keywords: Davagoz of Khoy, Obsidian, Archaeometric provenance determination with XRF, South Caucasia, Anatolia

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Microstructural Analysis of Aliabad Style Potteries from Mokhtarabad, Shahdah, SE Iran

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Abstract

The present work deals with the examination of a sample of seven pieces of Aliabad style ceramics (fourth millennium BC) from the Archaeological site of Mokhtarabad in Shahda to study their structural and mineralogical comparisons and disparities, to identify their raw materials and finally to determine the provenance of their soil and their manufacturing technique. Petrographic thin-sections and X-ray diffraction approaches were employed. All specimens revealed an identical homogenous fine-crystalled clay petrofabric. As regards mineralogy, they are composed of grains akin to sharp-edged crushed quartz, plagioclase with polysynthetic crystal twins and feldspar, fine-grained muscovite, and carbonate and calcareous grains. Given the similarity of all instances that suggest a same source for their raw material, it could be argued that the shreds are local made.

Keywords: Microstructural analysis of pottery, Mokhtarabad, Aliabad culture, Shahdad, Chalcolithic Age

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Microstructural Analysis of the Bronze Age Marble Artifacts from Shahre Sukhteh Periods II and III

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Abstract

Structural analysis of materials is of vital importance in characterizing and detecting the interior and exterior differences and exploration of any cultural phenomenon. Marble is among the most common metaphoric rocks used in production of ancient decorative and utilitarian objects and monuments, among them being the marble vessels and objects that come from Shahre Sukhteh. The present work presents the results of analysis and study of 10 marble samples from Shahre Sukhteh II (2800-2500) and III (2500-2300). The prepared 30-mm-thick samples were subjected to thin-section analysis using TEM polarizing microscopy, and FT-IR to determine their structure and mineralogy. The results showed the rocks from both periods tend to feature yellow to brown strands, attesting to the conversion of magnetite oxide Fe_3O_4 to hematite oxide Fe_2O_3. Needle shaped oblique structures were attested in most pieces. Results of infrared spectrometry support the presence of a calcite phase in the entire specimens given the presence of distinct bands in 1429, 789, and 708 ranges (zones?) and their similarity in the entire sample. Finally, calcite $CaCO_3$ and aragonite were found to be the major elements in the pieces from both periods. Thus, one may surmise that the raw materials used to manufacture marble objects in the two periods at Shahre Sukhteh are identical as far as their structure is concerned.

Keywords: Shahre Sukhteh, marble, petrography, FT-IR, aragonite

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Archaeomineralogy of the Neolithic Pottery Style of Ahranjan and Qara Tepe, Azerbaijan, NW Iran

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Abstract

The Neolithic sites of Ahranjan and Qara Tepe lie in the Salmas plain (northwest Lake Urmia region) of N.W. Iran. The pottery assemblages from the two sites, separated by only 3 km, represent a tradition that outdates that of the Hajji Firuz Tepe. The tradition is characterized by handmade forms with a chaff-faced appearance, with a core suggesting of firing at lower temperatures judging by microscopic observations. A major question in the present work was to determine the manufacturing technology of the pottery: Did they represent coiling technique that involved pinching and beating together long threads of rolled clay? To what extent they were fired? And more importantly, what are the major reasons behind their chaff-faced appearance? Is the high chaff temper indicative of the poor nature of soil (lacking enough clay content), which forced potters to compensate it with adding chaff or it simply points to a distinct pottery style? In an attempt to provide answers for these questions, petrographic tests, XRD, SEM-EDX and STA techniques were applied to a sample of sherds from both sites to identify the crystalline phases in individual specimens and compare the results with the regional geological specifications, and also to determine the firing temperature by virtue of the correlation between the latter and the mineralogical changes. Results suggested that the specimens were produced using local raw materials that was obtained from a single source—i.e. the Salmas plain. The phase conversion of the quartz to tridimite in the Ahranjan assemblage indicates firing at temperatures above 700 C, which

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furnished with it a better quality that the later Qara Tepe forms. The main result, however, was that the available geological dataset on the region and the mineralogical data gained from the present study rule out the hypothesis of the poor soil of the plain; the high chaff content of the fabric instead appears to demonstrate the primitive state of pottery making at these sites. The local populations probably lacked a proper knowledge of pottery techniques, thus tempering the paste with excessive amount of chaff.

Keywords: Neolithic tradition of Ahranjan-Qara Tepe, Ceramic petrography, XRD, SEM-EDX, STA

Petrographic Analysis to Recognize the Provenance of the Iron Age Potteries from Southern Sheyvar Dagh, Central Qaradagh of Azerbaijan

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Abstract

In the present work, ceramics recovered from the sites in southern Sheyvar Dagh of north Ahar in the Qaradagh region were examined with microscopic and X-ray diffractometric techniques. The selected sample has a clay base composed of ilite and caolinite minerals and coarse feldspar potassium minerals, plagioclase, quartz, amphibole, magnetite, calcite, and biotite. They contain angular quartz and are heavily pitted, which shows the proximity of the clay source, and the heterogeneous fabric resulted in less stiff vessels. The specimens have a dark core and a brick red exterior. The numerous, elongated pores were induced by the presence of organic materials and the burning out of these materials intensified the pitting. The rocks forming the southern flank of Sheyvar Dagh and the Archaeological sites therein are of the same igneous type that constitutes the core of the mountain, with a monzonite to granodiorite composition and the Cretaceous calcareous-shale sediments. Presence of coarse feldspar, plagioclase and calcite in the microscopically analyzed thin-sections indicates the local production of the ceramics using the in situ (consolidated) soils formed in the foothills of Sheyvar Dagh.

Keywords: Petrography, Geochemistry, Pottery, Iron Age, Central Qaradagh

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Archaeometry of the Iron I-II (Pre-Urartian) Pottery Technology of Azghan Region of Qaradagh, Azerbaijan, NW Iran

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Abstract

While the Iron Age settlements in both the Azghan and Uch Hacha regions of Qara Dagh belong to a same chronological horizon, the pottery assemblage from Azghan differs from that of Uch Hacha in manufacturing technology and quality. The discrepancy may arise either from different cultural traditions or diverse regional climate and ecology. Also, the ceramics appear to be local products, and the reason for their varying qualities is the richer soil of the Azghan region and firing at adequate temperatures. Some 17 pottery pieces collected during the regional surveys from Azghan were subjected to Archaeomineralogical and ceramic chemistry analyses using XRD, IRS, polarizing microscopy, and simple magnifier. The results suggested that, given the regional geological map and the results of the petrographic characterizations, the pieces were locally produced at a temperature above 800°C, and that despite their technological similarity to the material from Uch Hacha, they were of higher quality thanks to the richer soil of the Azghan region with lower calcite and higher clay contents. Since Azghan lies at a lower altitude than Uch Hacha, these clay deposits were used in pottery production, and the deposits contain fragments of available raw material in the region that have led to stiffer fabric. Thus, they are stiffer and of a relatively higher quality when compared to the other forms where calcareous or evaporative (gypsum) materials were employed as filler (temper). Thus, the hypothesis that the soil in Azghan was richer and better than that of Uch Hacha proves true, the same fact that was responsible for the higher technology of Azghan material.

Keywords: Azghan, Qaradagh, Iron Age I-II, XRD, FT-IR, Petrography of pottery

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Section IV

Metallurgy in Archaeometry

Ancient Metallurgy at Arisman, Central Iran: A Reconsideration

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Abstract

The Arisman ancient metallurgical site in north central Iran hosts huge metallurgical remains from the Late Fourth to Early Third millennium BCE which attest to an extensive production of arsenical copper and silver at the same time. Despite some concrete scientific investigations performed on the site, some questions about the provenance of the ore, the technological procedures utilized and the possible connection between copper and silver production have remained open. In this paper, beside the reassessment of the previous analytical data, some of the metallurgical remains including ore and slag pieces as well as litharge fragments were reexamined and analyzed using different mineralogical and geochemical methods. The results show a clearer provenance for the ore as well as a sharper picture for the metallurgical processes. It seems that the ore has been provided from at least two polymetallic ore deposits in central Iran. The ore contained copper, arsenic, lead, and silver and was processed in two interconnected steps of smelting and cupellation producing arsenical copper and silver.
This research was performed in the frame of the first author's postdoctoral stay in Germany and was financially and technically supported by the Gerda-Henkel-Foundation and the Curt-Engelhorn-Zentrum-Archäometrie Mannheim.

Keywords: Archaeometallurgy, Arsenical copper, Cupellation, Mineralogy, Geochemistry, Lead isotope analyses

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A Study of Metal Objects from B5 Settlement at Darestan, Bam, SE Iran

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Abstract

Darestan is located to the east of Bam, near the western edge of the southern Lut Desert in Southeast Iran. The site designated as Settlement B5 is one of the over seventy prehistoric sites that were recorded in the course of several field surveys that covered the region during mid-2000s. Metal objects constitute a significant component in the assemblages from the region, particularly from Settlement $B_{5\text{-}86}$. Settlement B5 and its satellite sites are located about 24 km from the modern city of Bam, Kerman on the asphalt road which connects Bam to the village of Qal'eh Bala in Darestan. The settlement is part of a complex of mounds that lie along an east-west line and are related chronologically, spatially, and topographically. Lut, the second major desert basin in Iran, covers vast parts of southeast Iran and is divided into several different zones. The area is bounded by Hirmand basin to the east and the Kerman basin and Kavir Desert to the west. It is surrounded by the Kaputi volcanic mountains and Akhori and Jamali mountains to the north and south, respectively. Larestan is the last village in the southwestern part of Lut. The village lies on the main communication route that connects Bam to Loot Zangi Ahmad, Kesht, and Shahdad. Based on the excavations and sampling, B5 contains various finds ranging from (bichrome) pottery to metal openwork seals. Stratigraphic excavation at the site produced important information from the late Chalcolithic-early Bronze period. The metals objects were for the most part collected during surface surveys. Further five pieces were found during the stratigraphic excavation. From the Archaeological work in Darestan come in total 25 metal objects, which reveal high functional diversity. The present paper focused on the manufacturing technics of these pieces. Given the important role of the corrosion morphology in recording the potential structural data in corrosion layers, corrosion analysis was also undertaken.

Keywords: The prehistoric Settlement B5, Metal objects, Morphology of corrosion, Darestan, Bam

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Early Bronze Age Artefacts from the Royal Tombs of Ur

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Abstract

The Royal Tombs of Ur in Bronze Age Mesopotamia (Early Dynastic II/IIIA, 2600-2450 B.C.E.) were excavated from 1921 to 1934 by Sir Leonard Woolley. The graves bore countless metal artefacts such as jewellery, hair decoration, weapons, tools, vessels, figurines, seals, or containers, all made of gold, silver, calcite-alabaster, lapis lazuli, and carnelian. Besides there are many green, blue, red, black and white pigments spread into shell halves, which are commonly treated as being cosmetics. The surprisingly rich suite of materials is in contrary to the fact that Mesopotamia is void of mineral deposits. Analytical work has been carried out over the past three years on a wide spectrum of the objects in a joint research project funded by the German Science Foundation (DFG). Object observations and samples result from several visits of the Penn Museum in Philadelphia, PA, and the British Museum, London. Preceding this project, Begemann and Schmitt-Strecker presented analyses from copper and bronze metals from Ur. Two PhD theses within the present project care intensively about the gold and the copper and bronze artefacts (Moritz Jansen, Eveline Salzmann). One master thesis was finished last year and concentrated on the calcite-alabaster vessels (Hendrick Wick). In addition to the analytical work, technology studies predominantly on the gold objects are ongoing (Barbara Armbruster, Toulouse). Besides the numerous objects and particularly the samples that were gained from them, the project also look at the mineral pigments in shells, which are produced from various minerals mixed with identified binding components. The project aims to discover the mineral sources that were exploited for the smelting and production of metals and the stone and mineral-based objects. The identification of the geological sources by geochemical methods thus has a key position to decipher the interactions between Mesopotamia and its neighboring regions.

Keywords: The royal tomb of Ur, Early Bronze Age, geochemical analysis, copper objects, bronze objects

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The Archaeometallurgical Studies On the Arsenical Bronzes from "Lama Cemetery" (2nd Millennium Bc), Iran

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Abstract

The ancient cemetery of Lama is located in in Kohgiluyeh and Boyerahmad Province, some 25 km northwest of Yasuj. Archaeological work was carried out in this region to partially rescue the historical monuments that would be cut by the construction of the modern road connecting Isfahan to Yasuj. The painted decorative ceramics and the metal tools and objects suggest a date in the Middle Elamite II, III and neo Elamite I (1400-800 B.C) for the cemetery. The assemblage of finds contained 33 needles, 11 beads, 42 bracelets, 13 armlets, 18 arrowheads, 2 spearheads and 3 unidentified pieces. The majority of these are ornamental, though some may have been used as actual weapons. The objects were subjected to chemical and structural examinations using ICP-OES, OM and SEM-EDX. The results showed considerable variations in the Cu-Sn ratio in the metallic core of the objects, and arsenic was present in their surface as a main metallurgy-related compound. Presence of arsenic evinces the inverse segregation of the element during the manufacturing process, which is indicative of the presence of eutectics in the surface areas of these objects during melting at high temperature and rapid cooling. The metallurgy displayed by the Lama metals—i.e. the use of arsenical copper with tin bronze together—marks a transition from traditional accidental metallurgy to a planned one.

Keywords: Archaeometallurgy, Arsenical bronze, Prehistoric cemetery of Lama, OM, SEM, ICP-OES

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The Identification of the Technology, And the Pathology of Bronze Personal Ornaments from Kurgan No. 8, Jafar Abad, Khodafarin

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Abstract

Burial customs have always been influenced by the culture and religious beliefs of different communities. Analysis of the finds from systematic excavations can immensely help Archaeologists and conservators in understanding culture, religion, trade and art of ancient societies. As a burial tradition spanning the fourth millennium BC through the Iron Age, kurgans are a series of barrows used by the Eurasian warrior nomads to bury their dead and represent their sole architectural evidence. Studying kurgan culture and the relevant finds is still in its nascent state, hardly dating back a decade. The surveys in past few years have identified a large number of kurgans in northwest Iran, especially in East Azerbaijan, the most important of which are those of JafarAbad. The latter kurgans are about 1 km west of the modern village of Jafar Abad and about 1 km from the village of Tu'ali in. The kurgans were excavated in 2011, yielding metal, ceramic, and stone and bone objects of various types. The totals of 54 bronze objects discovered in the first season are majorly personal ornaments that come from Kurgan. The present study focused on the analysis of the technology and pathology of 3 instances of these bronze ornaments, including 2 bracelets and a button. The composition of the employed alloys and the technology involved in the manufacture were studied and the type and extent of corrosion that affected the pieces over time were appraised. Metallographic studies were supplemented by SEM-EDX, AAS, X-ray radiography, and XRD analyses. Results of elemental analysis showed that the pieces were all made of bronze. Metallographic microstructural analyses revealed hammering and annealing as the techniques used to shape the ornaments are. The application of hammering was verified by radiographic images, which also revealed some microstructural damages. In light of the XRD phase analysis, the corrosion products contained cuprite and malachite, and the chloride phase nantokite was present only in the bracelets. Drawing on the results of this analysis, the corrosion products formed on these pieces were of aerobic and underground or soil type.

Keywords: Archaeometallography, AAS, Bronze personal ornaments, Jafar Abad kurgans, SEM-EDX

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A Mineralogical and Geochemical Study Of Copper Smelter Slags from the Iron Ii Cemetery at Tepe Sagzabad, Qazvin Plain, Iran

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Abstract

Slags are a type of Archaeometallurgical data containing important information on the ways in ancient societies mined, smelted, roasted and extracted metals. Beyond this, they play a pivotal role in determining the original provenance of minerals and raw materials used in manufacturing metal artefacts. While slags form considerable parts of the assemblages of metallurgic finds from the Iranian plateau, they have often been overlooked due to their lack of displaying features in museums. Sagzabad in the Qazvin plain is a key metallurgical center in the Bronze and Iron Age central plateau of Iran. Thanks to its rich archeometallurgical assemblages and its location at the core of the plateau, it is of utmost significance in reconstructing the metalworking trends. Related evidence from the site includes various types of metal artefacts (copper, bronze and iron), crucibles, metal ores, and slags. The present study represents a step towards understanding and examining the copper extraction and smelting technology in Sagzabad through mineralogical and geochemical analysis of the slags that were recovered in its Iron II burials. SEM-EDX was utilized to identify the composition and microstructural analysis, and petrographic test and XRD were used to phase and mineralogical analyses of the sample. Results suggest extraction of copper from sulfide minerals, and presence of metallic phases evinces melting in a reducing atmosphere. Also, compositional analysis of slags identified high contents of copper, silicon, iron and sulfur. The observed ratios of these elements and the presence of different phases in their compositions can be related to the uncontrolled temperature and melting process.

Keywords: Tepe Sagzabad, Iron II cemetery, slag, geochemistry, copper processing, material microstructural analysis

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Archaeometallurgy of Slag Discovered At the Village Of Angirt in Central Qaradagh, Azerbaijan, NW Iran

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Abstract

Determining the geological resource and constituent elements of alloys used in Archaeological objects has always been a major issue in the prehistoric Archaeology of Iran. Northwestern Iran and Azerbaijan has been one of the major regional centers for development of metallurgy since the fifth millennium BC (the Chalcolithic period). Copper and arsenic were the primary alloys exploited at the time, and understanding the involved mining technology and pinpointing the resources of copper and its alloying process as a practical metal have been subject of continuous scholarly debates. Surveys of 2009 in the highland Central Qaradagh have recorded remains from metallurgical activities including slags resulting from smelting processes at the village of Angirt in Ahar County. Also attested were remains of crucible walls. Regardless of their chronology, the mere existence of these pieces is indicative of local metallurgy-related processes in the area. On the other hand, the Qaradagh Mountains are rich sources of copper (particularly in Sungun), iron and gold, a fact that would have acted as a determining factor in the widespread metallurgical activities in the region. Therefore, determining the metal elements of the attested slags serves as the main question of the present work. It was attempted to be answered through quantitative analyses of the specimens, which were subjected to polarizing microscopy. Also, XRF was used in elemental and phase analyses to obtain information on the chemical composition of the slags and the qualitative content of major and minor elements in the specimens in order to identify their original provenance and the phases present in them. Judging from the observations made, the original ore came probably from the local mines, a fact that evince metallurgical processes and smelting copper and iron were carried out in the region.

Keywords: Archaeometallurgy, Metal slag, Azerbaijan, Central Qaradagh, XRF

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Understanding Production and Trade through the Elemental and Lead Isotope Analysis of Dirhams

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Abstract

In this paper, a short overview of the research history on the material science analysis of Early Islamic dirhams will be outlined and recent elemental and lead isotope analyses of 9th and 10th century dirhams will be presented. The main aim of this research is the characterization of minted silver in order to locate potential silver mining areas and to see the relative importance of the different silver sources and their distribution and chronology. The end goal is a better understanding of the history of industrial development and economic relationships. The use of laser ablation inductively coupled plasma mass spectrometry has greatly enhanced our ability to identify silver types and/or sources and see the movement and mixing of silver. Case studies of Samanid dirhams and slag from silver production sites will be presented showing successful results, but also problematic results will be discussed to highlight areas that are in need of future research.

Keywords: Archaeometry, Isotopic analyses, Lead, Silver, Samanid dirhams

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Microstructural Analysis of the Alloy Used In a Seljuk Lamp Stand Assigned To Qala Zahhak in Azerbaijan, Iran

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Abstract

The Seljuk period is among the brilliant epochs in the history of Iranian industry and art, during which metalworking flourished and exquisite contemporary pieces today enrich museum collections. Manufacturing brass and bronze lamps, candlesticks and chandeliers, occasionally embellished with gold or silver inlays, was one of the branches of fine arts of the time. The available body of evidence on Seljuk metalworking is indeed mainly restricted to Archaeological investigations, and little archaoemetric work has done in this regard in particular as regards the structural analysis of the objects. The focus of the present study is a metal lamp stand, which was allegedly recovered according to available Archaeological reports in the 1996 excavations of Qala Zahhak of Adjabshir and is currently kept at Azerbaijan Museum in Tabriz. The study concentrated on identifying the alloy and the involved manufacturing technology building on the results of quantitative and qualitative analyses. In addition, the paper provides data on the metal structure of the object and the respective quantities of major elements. Results of the examinations, including metallography, SEM-EDX, and AAS, suggested that the alloyed was composed of copper and tin with a high lead content, and the stand was made using molding technique.

Keywords: Seljuk period, Archaeometallurgy, Qala Zahhah of Azerbaijan, AAS, SEM-EDX.

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