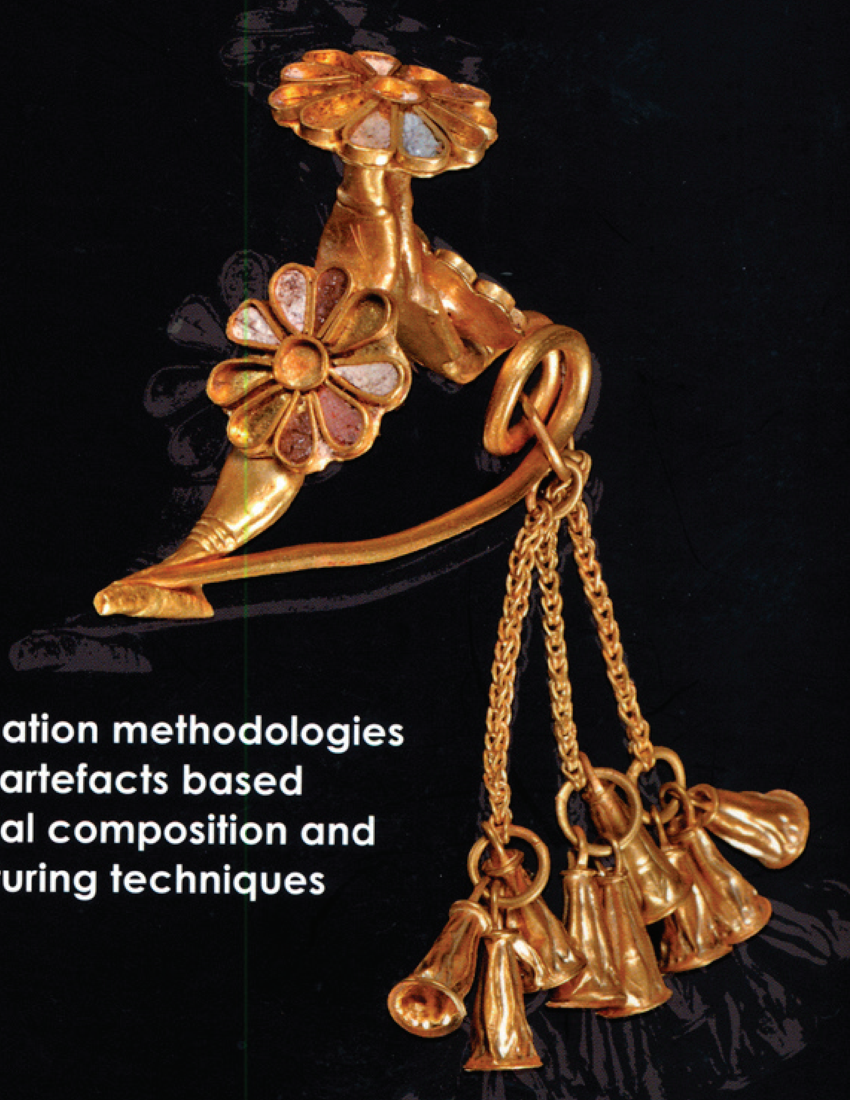
Maria Luisa Vitobello
Thilo Rehren

A quest for Authenticity



Authentication methodologies for metal artefacts based on material composition and manufacturing techniques

A quest for Authenticity

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Monica Roncaglia

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Kitione Fibula, National Museum of Archaeology of Nicosia, Cyprus, ΜΛΑ 1742.
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Maria Luisa Vitobello
AUTHENTICO Project coordinator

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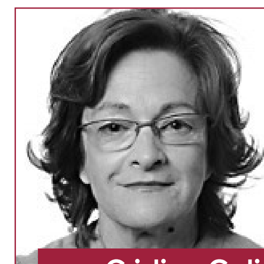
Foreword

Cristina Gutiérrez-Cortines

Research into themes related to the arts is often viewed as a "soft" science, linked to humanities, and for that reason of less soundness and importance. It is ignored that technical and scientific discoveries have on numerous occasions opened doors to artistic creativity. It is forgotten that a qualitative jump in scientific and technical knowledge could be the instrument with which artistic innovation is created.



Cristina Gutiérrez

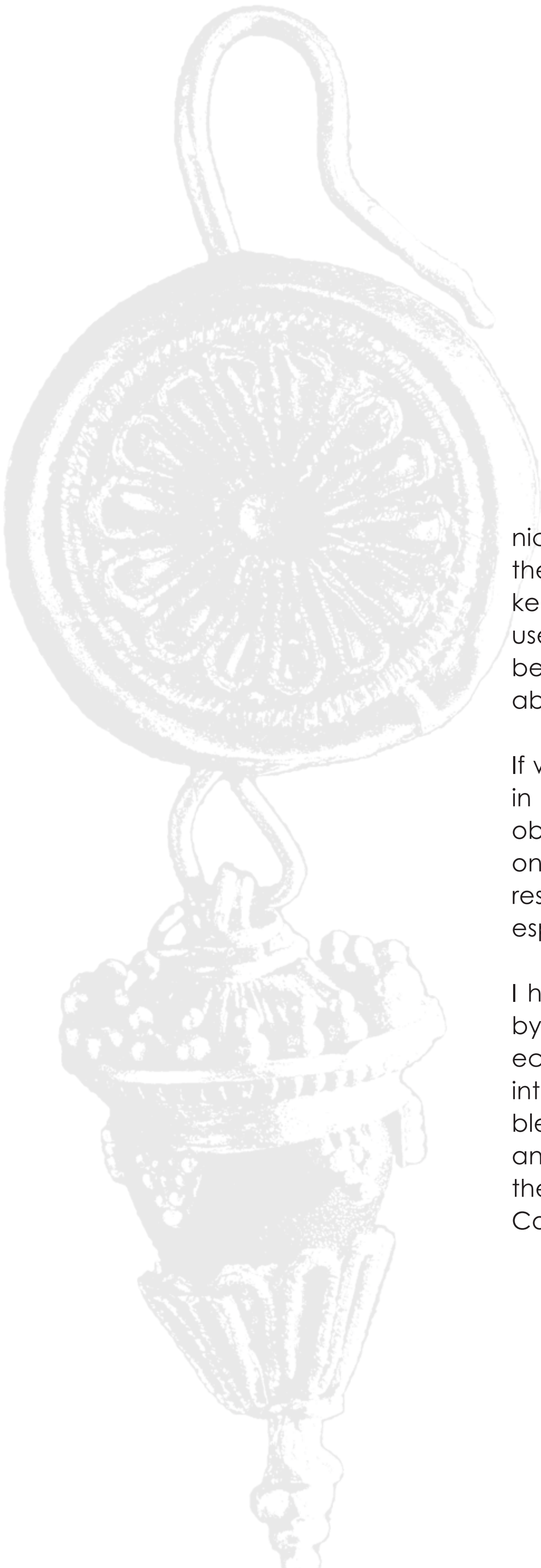
Professor of Art History,
University of Murcia, Spain
Member of the European
Parliament.

We have studied the History of Art in detail, but we still have much to discover about the history of the technique on which this history is based. In the case of visual arts, sculpture and other types of material objects, we do not always know all the aspects of the techniques that have been used in the execution and in the external treatment of the materials. For this reason, we must welcome any research that can contribute to identifying materials, processes or forgotten techniques and which help us to understand the age of these artefacts.

I say this because the project published here today is not only useful so as to identify the authenticity of the object; it is also an essential instrument for art historians worldwide. The history of technology can contribute in a decisive way to the stability and the security of the antiquities market, including jewels and archaeological objects.

The History of Art in its diverse branches has been built on the basis of two axes: the authorship of the piece of work and the chronology of these works. The day the technology discovered here is implemented, many theories will be consolidated, ancient methods will be discovered, creators will be confirmed and it will be proven that many works are contemporary imitations or even fakes.

From now on, it will be possible to complement the interpretation of professionals, connoisseurs and experts, adding a tech-



nical diagnosis, and in this way providing more guarantees of the knowledge about the artists, their schools and for the market. On the other hand, the understanding that comes from the use of these methods will also provide information that should be brought together to create a common fount of knowledge about the techniques and the materials involved.

If we add to this the important application of these techniques in order to verify the authenticity of jewels and other precious objects, work I believe we should support, but we must also insist on the necessity to extend and commercialise the results of this research in order to be used in a systematic and rigorous way, especially in museums and, of course, in the antiquities market.

I hope that the initiative and the technology developed here by Maria Luisa Vitobello and her team will be welcomed on the economic stage and that the Institutions integrate this research into their management systems. Authenticity is an indispensable and necessary condition for History and for the valuation of ancient objects. For that, I would like to congratulate the team, the institutions, the Italian Public organisations and the European Commission for the support they have given this project.

European Commission

Europea Commision

Andrea Tilche

Cultural heritage is a non-renewable resource and the need for a policy of sustainability in this area is more pressing than ever. Much of our cultural heritage is under attack – from environmental degradation and climate change, from socio-economic pressures and the accelerating pace of urbanisation, from forgery or trade in stolen artworks.
Research has been supported by DG RTD since 1986 through its Environment Directorate with the aim of reinforcing the scientific and technical basis for preserving, protecting and rehabilitating the tangible European cultural heritage. The growing success of cultural heritage tourism in Europe, attracting millions of visitors to European cities and regions, also provides a strong economic rationale for cultural heritage research. The safeguarding of cultural heritage is an important goal in helping to safeguard jobs, quality of life and ensure successful implementation of the EU sustainable development strategy.

Supported under the "Scientific Support to Policies" (SSP) Programme of FP6, the AUTHENTICO project links environment and security research issues helping to combat cross-border crime, as the methods and technologies that have been developed help to verify the authenticity and traceability of cultural artefacts, in particular in cases of theft, and more generally to combat fraud and illegal trafficking of works of art. The project provides a basis for scientific evidence to be used in court when the proof of authenticity and provenance is needed. The worldwide problem of illicit trade in antique artefacts and fraudulent dealing of counterfeits has continued to boom over the past decade and has in effect further fuelled the demand for forgeries, which amplifies the difficulties connected to their authentication.

The AUTHENTICO project addresses this problem of global importance in tackling authentication of metal artefacts since gold work such as jewellery and coins are among those that suffer significantly from this illicit trade.

Andrea Tilche

Dr Andrea Tilche, Head of Unit "Environmental Technologies" European Commission, Directorate General Research.

The project has successfully led to an innovative, shared and international protocol for a set of non-invasive authentication techniques and procedures on movable metal artefacts and developed portable instruments to carry out analyses in situ (LIPS, e-Nose, 3D micro-topographer). The identification between genuine and fake artefacts is now possible and prototypes of the innovative portable instruments have been developed, demonstrated and are under refinement. Moreover, the technologies that have been developed show great promise to be also used as non-invasive tools for diagnosing the state of deterioration and to help guide restorers on how to better protect and maintain cultural heritage objects.

The truly multidisciplinary nature of research within the AUTHENTICO project was only made possible due to the complementary, reputable and highly motivated consortium together with the strong cooperation of stakeholders - public and private owners, scientific researchers, national and international police services.

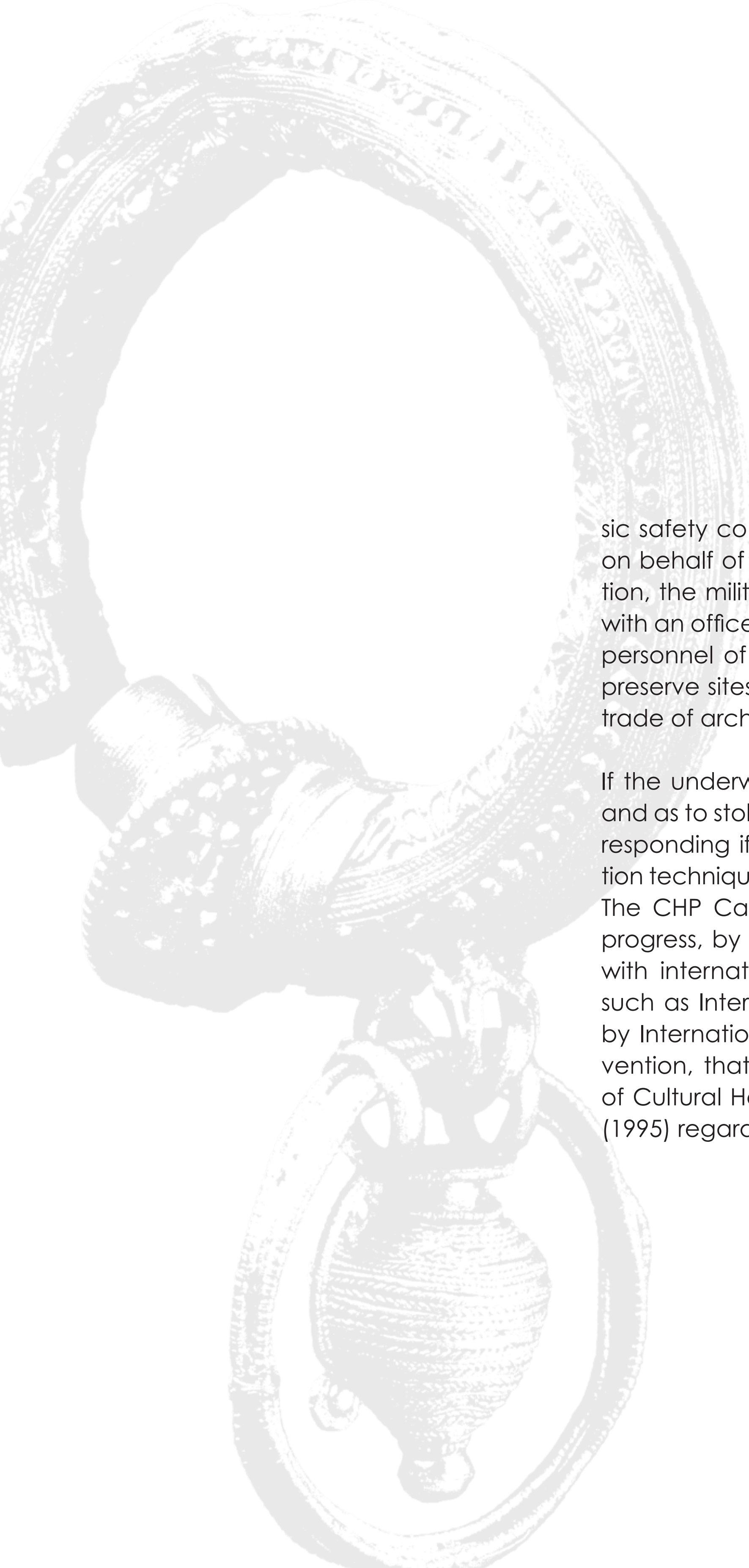
I am convinced this publication will serve as both interesting and useful for all stakeholders, as well as for the ultimate beneficiaries of this research – the general public.

Carabinieri Command for Cultural Heritage Preservation

Ministero Beni e Attività Culturali, Italia

The AUTHENTICO research project results are extremely useful for the work of the most valuable allies of Superintendencies in the field of the Italian and international archaelogical and historical heritage protection, i.e. the Carabinieri of the Artistic Heritage Preservation Task Force. During the Sixties the Italian Ministry of Public Education, which was managing Superintendencies at that time, concerned about the widespread phenomenon of artwork thefts, proposed to the Carabinieri Force High Command to create a dedicated military Task Force, focused on the preservation of the immense cultural heritage of our country. So, on May 3, 1969, the "Comando Carabinieri Ministero della Pubblica Istruzione - Nucleo Tutela Patrimonio Artistico" (Carabinieri Command Ministry for Public Education – Artistic Heritage Task Force) was constituted, and on February 10, 1975, it was shifted under the direction of the newly created Ministry for Cultural and Environmental Heritage. In 1980, the illicitly obtained artworks data base was set up which is considered today a benchmark and a model for police forces worldwide. This database is about to be replaced by a more updated version, improved, more flexible and versatile, that will hopefully be compatible with those used by Superintendencies and Custom Offices. On March 5, 1992, a specifically devised Ministerial Decree established the specific and univocal functional settlement of the Task Force under the portfolio's activities.

The present definition "Comando Carabinieri di Tutela Patrimonio Culturale" (Carabinieri Command for Cultural Heritage Preservation) was adopted on January 12, 2001. Today this Command coordinates a central operative unit, eleven "Nuclei" (squads) for Cultural Heritage Preservation deployed over national territory, generally responsible for inter-regional areas, and the SED (Sezione Elaborazione Dati, Data Processing Department), specialized in the search of stolen artworks through I&C technologies. The CH Preservation Command was also assigned protection tasks concerning international CH in situations of total deterioration of ba-



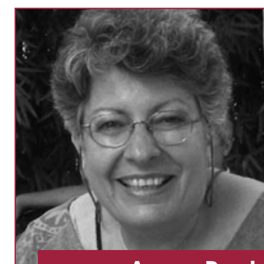
sic safety conditions, such as in Afghanistan and Iraq. Recently, on behalf of UNESCO, further to a request of the Italian delegation, the military officers of the CHP Command, in collaboration with an officer of the Ministry, were in Amman to train and instruct personnel of a special Jordan police unit, expressly created to preserve sites, prevent and repress specific crimes and fight illicit trade of archaeological artefacts.

If the underworld has alas evolved both in its criminal methods and as to stolen goods trade channels, on the other hand an corresponding if not superior refinement of police forces' investigation techniques and of crime-fighting instruments has taken place. The CHP Carabinieri actively contributed to this technological progress, by dynamically interacting with other Police Units and with international coordination bodies between police forces, such as Interpol and Europol; their activity has been supported by International Conventions, including the 1970 UNESCO Convention, that prohibits any illegal import, export and alienation of Cultural Heritage and the more recent UNIDROIT Convention (1995) regarding restitution of stolen or illegally traded CH.

New technologies in service of archaeological heritage preservation

New technologies in service of archaeological heritage preservation

Anna Rastrelli



Anna Rastrelli

Director,
Florence Museum
of Archaeology, Italy.

The intensification of the production and trade of forgeries, benefiting from the use of modern technologies, is damaging for cultural environments as well: counterfeit artworks, more accurate than ever, to the point of being indistinguishable from originals after a brief visual examination, are spreading through the market with harmful consequences.

In addition to this situation producing major damages to the private antique market, difficulty in distinguishing counterfeits is disreputable for official heritage preservation authorities as well. As an example, among the many pieces that circulate through custom offices, in charge of preventing the export of cultural heritage artefacts, one can easily find forgeries; it has also happened that custom service officers released an export authorization for an object believed to be a fake, while in fact it was an original that should have never crossed the Italian border.

Consequently, government bodies responsible for the protection of cultural heritage share the hope that the progress of research will lead to the production of increasingly more sophisticated technology, on one hand, as well as to the development of portable equipment, on the other (as moving the artefacts in order to perform analyses is not always possible), which would allow obtaining more certain evidence for the identification of counterfeits. In the case of artefacts made with organic materials, such as wood, radiocarbon dating is quite a valuable instrument, while for ceramics, techniques relying on thermoluminescence analyses represent the most successful dating methods for determining the production period of an object available to date. The situation of metal artefacts is more complex, despite the fact that technology has advanced significantly in this direction as well.

Authors

Maria Filomena Guerra

Maria Filomena Guerra holds a Portuguese doctoral degree in Nuclear Physics and a French doctoral degree in Material Sciences. A Senior Lecturer at the New University of Lisbon from 1981 to 1990 and Professor of Physics from 1990 to 1993, she also held a research grant from the Calouste Gulbenkian Foundation. In 1993 she joined the French National Centre for Scientific Research (CNRS) and since 2001 is affiliated to the Centre of Research and Restoration of the Museums of France (C2RMF), where she is now Director of Research in Chemistry at the CNRS research unity 171. An expert in science-base study of gold cultural heritage objects – manufacturing techniques of jewellery and coins, and provenance and circulation of gold – she gave about 170 conference presentations and published about 150 papers in the field.

Jadwiga Łukaszewicz

Jadwiga Łukaszewicz, assoc. prof. She received in 1987 her Ph.D. in Humanities in the field of Art Sciences (conservation and restoration of historic objects). In 2002 completed habilitation at Nicholas Copernicus University in the field of conservation and restoration. Currently employed at the Fine Art Department of Nicholas Copernicus University as an associated professor and head of the Department for Conservation and Restoration of Architectonic Elements and Details. She runs lectures and laboratories for students on conservation and restoration. Her scientific profile covers several areas: investigations on reasons and mechanism of historic objects corrosion, development of new methods for conservation and restoration of buildings, architecture details and sculptures made of natural and artificial stone, conservation and restoration of art objects made of glass, metals and amber. Membership of Polish National ICOMOS Committee, Historic Monument Protection Council at the Minister of Culture and Cultural Heritage (Poland), Permanent Scientific Committee for Stone Conservation (since 2004) and an appointed expert of the Minister of Culture and Cultural Heritage (Poland).

Salvatore Siano

Graduated in Physics from the university of Florence. Researcher at the Istituto di Fisica Applicata "Nello Carrara" of the Italian National Council of Research since 1994. He has participated in and has been responsible for various national and international projects mostly dedicated to the study and conservation of cultural heritage. His activity focuses on the development of optical, laser, and neutron diffraction techniques for material characterisation and conservation purposes. He is strongly involved in archaeometallurgical research. Among the most relevant contributions to this field are the interpretation of the execution techniques of the David by Verrocchio, the Attis by Donatello, the Decollazione del Battista by Vincenzo Danti, the Minerva from Arezzo, the David by Donatello and other artworks. The results of his research activities are reported in about one hundred and fifty publications in scientific journals, books, and congress proceedings.

Andrej Ŝumbera

Andrej Ŝumbera has been restoring precious heritage artefacts, in particular the Treasury of the Prague Castle and the Reliquary of St. Moor. In 2003, he has restored and documented the Bohemian crown jewels. He is an expert in restoration and conservation, and lectures on historical goldsmith technologies and metal restoration at universities and academies around the world. He is specialised in the photographic documentation of cultural heritage and has published several interactive CD-ROMs. Most recently, he published a book and CD-ROM on the Bohemian Crown Jewels.

Thilo Rehren

Professor Thilo Rehren has studied mineralogy, obtaining a first degree in economic geology (Technical University Clausthal) and a doctorate in vulcanology (University of Freiburg). In 1997, he received a higher doctorate ('Habilitation') in archaeometallurgy from the Faculty of Materials Sciences at the Technical University Freiberg. From 1990 to 1999 he has worked as a research scientist at the Deutsches Bergbau-Museum in Bochum, Germany. In 1999 he was appointed Chair for Archaeological Materials and Technologies at the UCL Institute of Archaeology in London, UK.

Professor Rehren is Co-Director of the Institute for Archaeo-Metallurgical Studies (IAMS), Executive Director of the International Centre for Chinese Heritage and Archaeology (ICCHA) at UCL and Peking University, and joint Chairman of the Standing Committee of the Conference on the Beginnings of the Use of Metals and Alloys (BUMA), together with Professor Jianjun Mei from the University of Science and Technology Beijing. He is one of the editors of the Journal of Archaeological Science, and has published widely on aspects of ancient metallurgy, technical ceramics, and glass.

Maria Luisa Vitobello

Chairperson of the European Jewellery Technology Network, EJTN GEIE, Belgium, incorporated in 1998. In this capacity she has coordinated several EU-funded research projects in the field of jewellery technologies, precious metals, socio-economic and cultural heritage aspects of the jewellery industry and crafts, as well as other areas of interest related to cultural heritage, in particular traditional water technologies and authentication methodologies for metal artefacts. She majored in English and Russian languages, and holds a Master's Degree in Jewellery Design. A master goldsmith and jewellery designer, she has attended professional jewellery courses in Paris (France) and at the Kulicke-Stark Jewellery Academy in New York, USA, and has won international design awards from the World Gold Council, De Beers, and the Platinum Guild. She is a UNDP expert for Technology Transfer, EUROPAID Technical Consultant, Evaluator, European Commission, DG Research, Consultant to the Milan Chamber of Commerce Promotion Body and lecturer, History of Jewellery Technologies at Milano Bicocca University, Italy.

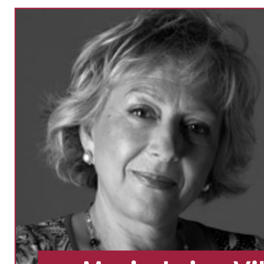
introduction

A quest for authenticity

A quest for authenticity

Maria Luisa Vitobello

Why do we need to authenticate an artefact and what for?



Maria Luisa Vitobello

President, EJTN GEIE

Since man overcame his primary needs, he found the need to express his feelings in a form that would convey them, as art is an expression of the soul.

An artefact (from Latin ars, and facere) is indeed an object that bears its creator's identity. The technical capability of the maker transforms a piece of clay into a jug, with a defined shape: through his creativity and feelings, scenes of daily life, rituals, mythological representations are added to decorate the surface, in a manifestation of his interpretation.

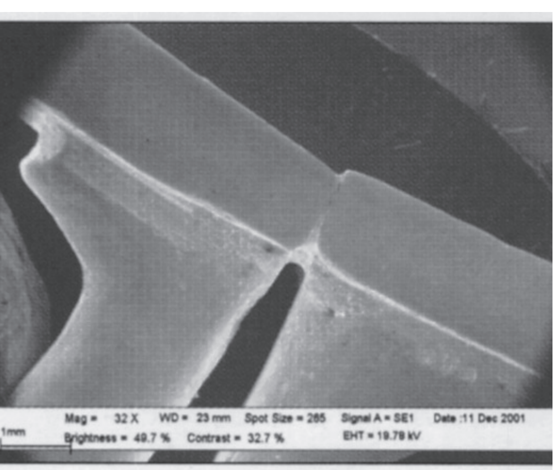
The small bronze statuette cast thousands of years ago transfers the spirituality and harmony achieved by the culture it is a witness of. A gold artefact crafted in antiquity has a much higher value than the metal it is made of: it proves the ancient goldsmith's skills but it can also symbolize high religious significance. Philosophical concepts can be unveiled through the most advanced scientific technologies, as it happened a few years ago with a small Phoenician amulet found in Malta archaeological excavation.

On such occasion, there were doubts, not so much on the authenticity of the amulet, but rather whether it was a Renaissance pastiche: were the two idols crafted separately and then joined or else? Was this technical solution intentional or else? Through SEM (Electron Scanning Microscope) it was possible to identify that both the statuettes of Horus and Anubis were crafted by the same artisan, by analysing the rhythm of the chisel marks which highlighted the contours of their eyes: there was a reason for the two gods to be facing opposite directions: it was representing the duality of life, the relationship between the observer and the observed.

Horus and Anubis amulet

The Ghain Klieb Double Amulet with Horus and Anubis; gold. Phoenician (6th century BC). National Museum of Archaeology, Valletta, Malta.

Ghain Klieb Double Amulet: the soldering joint linking the two bases on which the figurines are standing (SEM image; magnification 32X).



Objects that belong to our common heritage should be protected, cared for, conserved, restored, and identified as authentic heritage. Far too many artefacts are subject to looting, illicitly traded, their origin, identity and their cultural surroundings unknown.

The authenticity of some objects that surface on the market, with unknown provenance and doubtful provenience, should be proven.

Usually, objects whose provenance is certain, i.e. artefacts found in excavations, do not pose doubts on their authenticity. Such artefacts belong to the national heritage of the country where they are excavated, such as in the case of the Phoenician fibula shown on the cover page of this book.

In other cases, hoards or single objects are offered to Museums, or purchased, or donated. And how can a Museum be confident that the objects are authentic? What about their provenience, their traceability?

Unfortunately, a large majority of artefacts are of uncertain and unknown provenance, many of them are illegally traded on the global market: such objects could be authentic, but how do we know?

Let's not forget that the illegal trade in artefacts is third in the global black market, after arms and drugs. Just a few years ago it was fourth, with traffic of human beings in the third position. Such an immense turnover, tax free, obviously justifies fakes (Source: NTPC, Italian Carabinieri, UN Blue Berets). It even happens that some objects are intentionally placed inside tombs by rogue merchants who fool incautious private buyers, brought on location during the night, pretending to offer authentic objects. It can also occur that an authentic object is offered as part of a hoard, while the rest is fakes, while the incautious buyer believes having acquired a treasure.

With respect to authenticity, the major problem with metal artefacts is that science cannot use the well-known thermoluminescence tests, where dating can be rather accurate for fired ceramic objects and confirm the period of the last firing.

Dealing with metal objects is more complicated. How can science deliver to the authorities, the Law Enforcement Agencies, the Museums, the Superintendences objective evaluation of a metal artefact, providing sufficient information that can justify acquisition, or custody, offering the citizens at large an authentic testimonial of our common heritage?

Neither should we underestimate the investment needed for research and studies of the objects, the human and financial resources devoted to cultural heritage in general, and in particular to the authenticity issue.

As an example, the Phoenician fibula has already, even as a small object, called for the contribution of archaeologists, conservators, scientists, researchers, and yet it has neither been officially displayed at the Cyprus Archaeological Museum, nor has travelled abroad in international exhibitions: the first official publication of this unique and precious artefact is being released here.

Luckily, in our case, the artefact is an authentic testimony of a culture, a people, the Phoenicians. What if such an object would have proven not to be authentic? Such a tiny jewel is a Pandora's box full of information, on the cultural, spiritual, social, aesthetic, artistic, technological context in which it was created, witness of the international – obviously of the reference period – relations and trade that occurred in the Levant, proof of the spiritual Egyptian influence in the area.

When we admire an artefact in a museum or in a gallery, we are amazed at the harmony and perfection of form, technical skills that jointly generate the object. And we ask ourselves: how could they do it? How could they achieve such excellence and elegance, with hardly any tools, when compared to modern technological solutions, how could they create such immortal pieces of art? How do we know that such an object is really a witness of our past? How do we prove its authenticity, in order to understand, respect and love the heritage left by our forefathers? Of course, the archaeologist will provide its competent knowledge and compare, identify the period, the socio-cultural and historical background, the iconography, the epigraphy. It happens though, that learned fakers can transfer such characteristics to a piece of jewellery that they intend to market.

Technologists can describe and confirm the manufacturing process to be the same as the one adopted thousands of years ago, although such processes can also be reproduced.

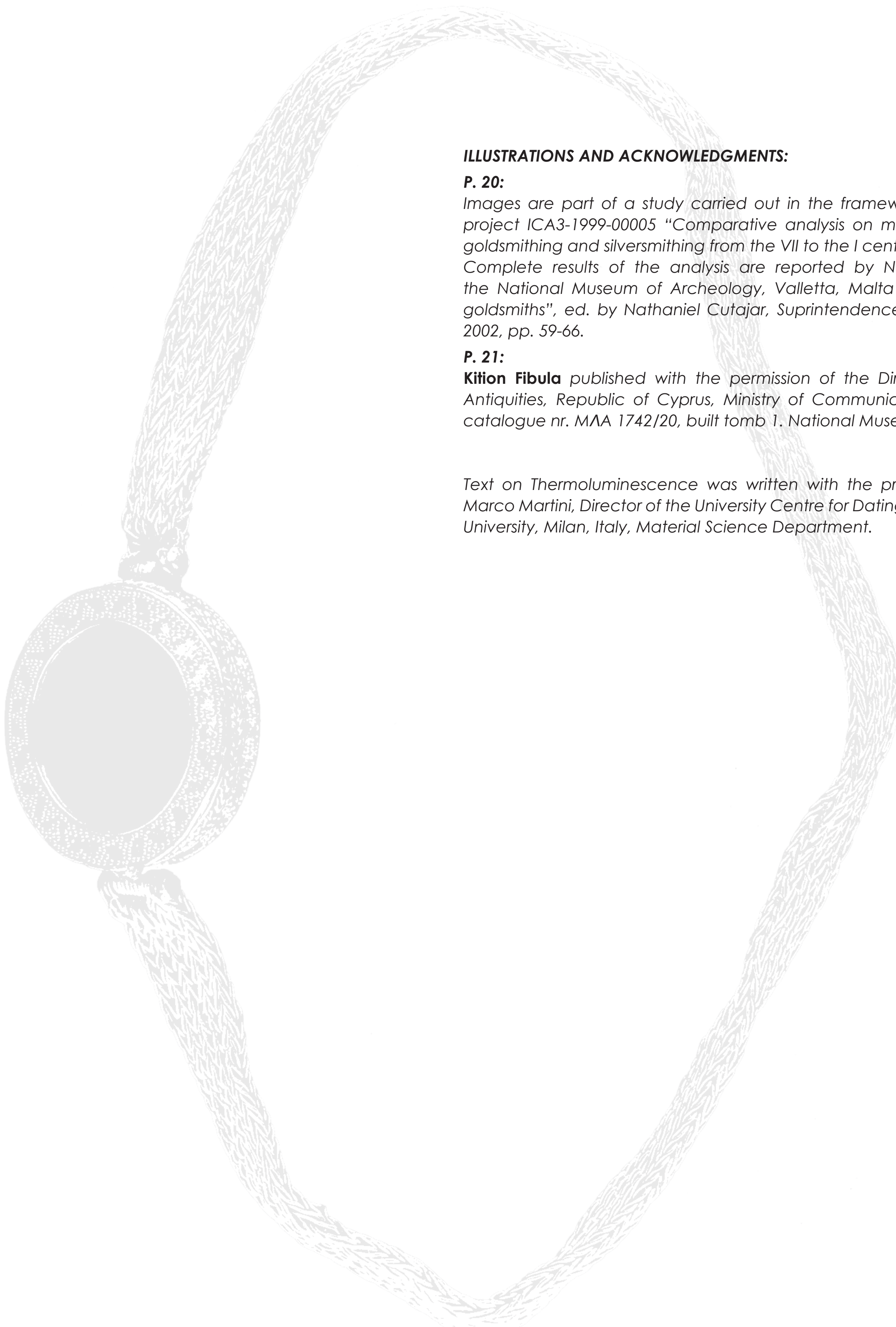
Then, how can we know, how do we find out? Here comes the help from science coupling with the above mentioned competences: the latest equipment and the highest know-how come into play, bringing information that ten or twenty years ago were not yet known, applied, put into practice. And then, through interaction and multi-disciplinarity the puzzle starts to take shape, giving glimpses that create little by little a profile that will identify the object as an authentic or a fake.

Kition fibula

Detail of the Kition Fibula, Late Cypriot III (800-750 BC). Excavated in Kition (modern Larnaka), Cyprus National Museum of Archaeology.

THERMOLUMINESCENCE

Thermoluminescence authentication techniques, specifically developed for ceramic artefacts, can be, under certain assumptions, successfully applied to the ceramic cores of bronze objects. Such material, usually including sand, calcite and mineral inclusions, has been heated when the metallic object was made, becoming a suitable material for TL analysis. It is then possible to evaluate the amount of energy absorbed since its firing to verify if it is compatible with that expected value considering the supposed age of the object.
It should be pointed out that the results obtained on a ceramic core are an indirect evaluation: it is assumed that the ceramic core followed the same archaeological history as the metal object. This is mostly true, but not always: contaminations are always possible.
It must be remembered also that any TL dating refers to the last heating at high temperature experienced by the item to date: in case of restoration or repair performed by heating, this last event will be dated instead of the initial firing (or fusion in case of bronzes). This means that a new heating makes the object appear "younger".
The possibility of dating ceramic cores is furthermore precluded if the object has been intensively radiographed before sampling the core material.



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P. 20:

Images are part of a study carried out in the framework of Jewelmed EU funded project ICA3-1999-00005 "Comparative analysis on manufacturing technologies in goldsmithing and silversmithing from the VII to the I century BC".
Complete results of the analysis are reported by Nathaniel Cutajar, Curator of the National Museum of Archeology, Valletta, Malta in: "Lost arts of the ancient goldsmiths", ed. by Nathaniel Cutajar, Suprintendence of Cultural Heritage, Malta, 2002, pp. 59-66.

P. 21:

Kition Fibula *published with the permission of the Director of the Department of Antiquities, Republic of Cyprus, Ministry of Communication and Works. Reference catalogue nr. ΜΛΑ 1742/20, built tomb 1. National Museum of Archaeology.*

Text on Thermoluminescence was written with the precious collaboration of Prof. Marco Martini, Director of the University Centre for Dating (CUDaM) of Milano Bicocca University, Milan, Italy, Material Science Department.

AUTHENTICO Project: an answer

Maria Luisa Vitobello

In 2003, after the looting of the Baghdad Archaeological Museum, with more than a hundred people attending a Conference in Jordan on Science and Cultural Heritage, we all had tears in our eyes, seeing the looting documented by photographs, brought over by a Professor from Baghdad University.

The trade in antique artefacts – whether legally obtained or looted – is booming, driven by demand by wealthy Western and Eastern collectors seeking to decorate their SoHo lofts and Shanghai penthouses with everything from ancient Buddha heads to Khmer sculptures. (TIME Magazine, November 3, 2003).

Modern production

MAIN: rosette earring, provenance unknown. Private collection.
INSET: X-ray radiography.

Jewels from FNMA

BELOW: 'baule' earring, Florence National Museum of Archaeology, Italy, ref. cat. 7746.
Earring with pendant, Florence National Museum of Archaeology, Italy, ref. cat. 15747.

Antiques smuggling networks arrange transfer of artefacts, organized in international trade. Photographs are circulated, prices agreed on, arrangements for the statues to be stolen and sent to buyers are made. Only a tiny percentage of stolen art is ever reported.

The global appetite for antiquities and relics has sparked a lawless ring that allegedly stripped hundred of sites, temples and monuments of sculptures, objects and frescoes, then sent them on to be sold to collectors in the U.S. and Europe. It is then obvious how and why authenticity is a fundamental aspect in this scenario.

The basis for a research project was there, emerging from the context described above: a proposal to the European Commission, to provide authentication methodologies and guidelines for metal artefacts was approved and funded and the project officially started in 2007. Without the support of the European Commission, this project would not have been possible: unfortunately, there is not sufficient funding assigned to Cultural Heritage research and it was a tight race. Other excellent projects were submitted, but alas, there was funding only for one: should we call ourselves lucky or rather we identified an issue of paramount importance?

The Consortium has accomplished the proposed work-programme on schedule and final results presented in a last Conference, at the Bibliotheca Alexandrina, Alexandria, Egypt in November 2009.

The location is symbolic for AUTHENTICO project's involvement in the authentication issue: the ancient Alexandria Library was a beacon of knowledge for the whole world of that time: we hope today to have constructively contributed to improve and support the interests in authenticity of the public at large and of the Cultural Heritage stakeholders.

Some information on the project

The forgery of original works of art and fraudulent dealing of counterfeits have been a problem ever since ancient times; a global challenge at level with trafficking of weapons, drugs, human beings. AUTHENTICO project n. 044480, financed by the European Commission, DG Research, under the 6th Framework Programme, proposes multidisciplinary research to face this problem and provide a cost-effective science, technology and culture based strategy for the authentication of movable cultural patrimony, in particular of metal artefacts (precious and non-precious).

The Consortium consists of ten partners from eight countries: Belgium (EJTN GEIE), the Czech Republic (EDU-ART), Egypt (CULTNAT), France (C2RMF), Italy (CNR-IFAC, CSP, CR-SBAT), Poland (UMK), Tajikistan (SODESCO) and the United Kingdom (UCL IoA), involving research centres, academia, museums, conservation services, superintendencies, and SMEs. Direct support and interaction from Law Enforcement Agencies – the Italian Comando Carabinieri Tutela Patrimonio Culturale – and from Civil Protection representatives expand and increase the validity, applicability and usefulness of the project.

The project started in June 2007, for a total duration of 30 months, specifically aiming to:

- assess an innovative, shared and international protocol, for a set of non-invasive and non destructive authentication techniques and procedures on movable metal artefacts, integrating different approaches: experienced evaluation of the artefacts on the historical and morphological sides, description of manufacturing techniques and analysis of material composition with state-of-the-art diagnostic technologies, commonly used for the study of modern technological materials and practically never used for the study of ancient materials;
- develop portable instruments, integrating micro-topography performed with portable optical instruments, elemental analysis based on Laser induced breakdown spectroscopy and electronic-nose technology for the detection of selective molecular markers, for a simplified and non-invasive set of analyses and diagnostics to be carried out in situ, changing the perspective of authentication procedures for valuable objects, masterpieces, and large museum collections.

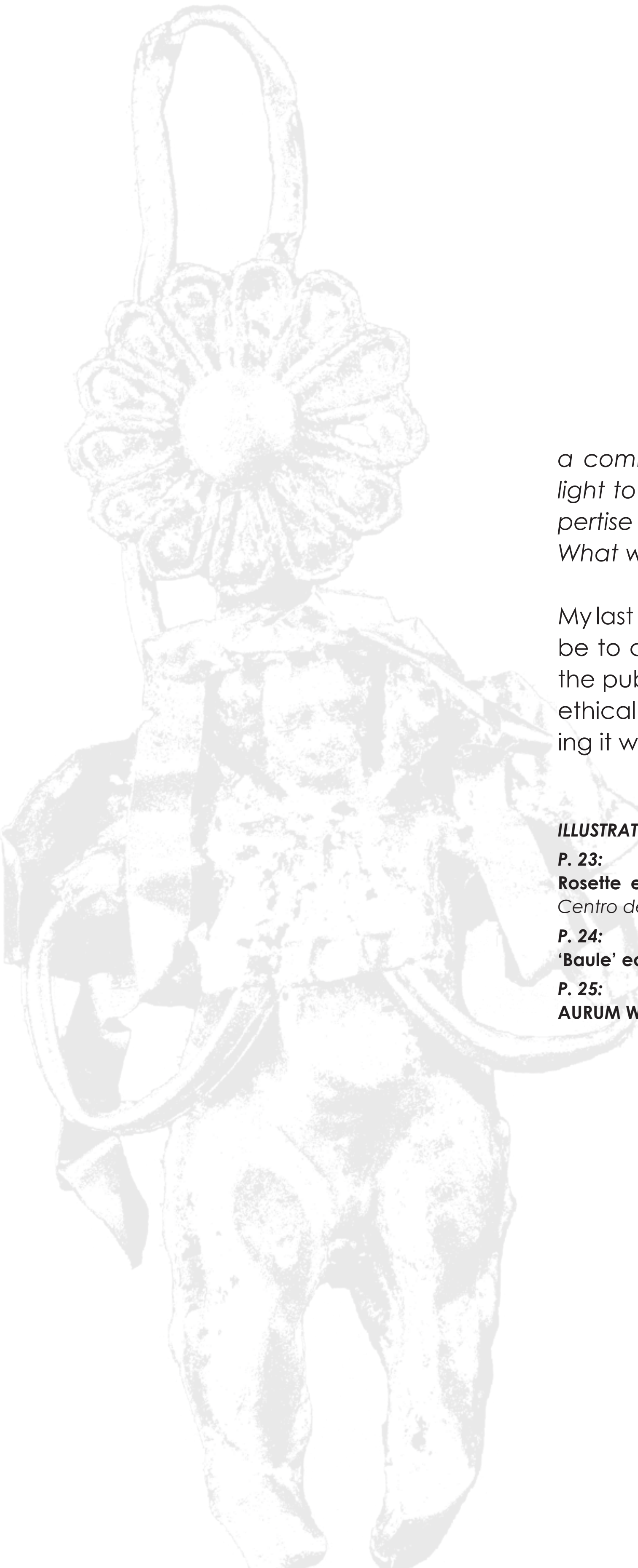
AURUM WORKSHOP

Participants of the international workshop AURUM at the C2RMF, May 11-13, 2009.

During the project, at the C2RMF-CNRS Research Laboratories, Louvre Palace, Porte des Lions, a 3 day workshop was held on the application of scientific techniques to the study and authentication of ancient gold work: "AURUM: authentication and analysis of gold work".

Over 120 participants from 28 countries worldwide attended the workshop; on May 13, 2009, a round table was organized, with invited speakers from the most prestigeous Museums worldwide – from North and South America and Europe – art historians, Cultural heritage experts, curators, scientists and Law Enforcement representatives. The audience also participated sharing opinions and comment.

In particular, I do care to recall the words from two top representatives of European Law Enforcement Agencies, Commander Dominique Lambert from the French OCBC (Office Central de lutte contre le trafic des biens culturels) and Lieutenant Colonel Alberto De Regibus, from the Italian Nucleo Tutela Patrimonio Culturale: "*Authentication is the key issue. Whether an object is authentic or fake determines the difference in the type of crime. What can science and research bring? There is a strong need for*



a combination of proof to bring objectivity. Science can bring light to support magistrates, it can provide a more objective expertise with respect to those based on human sciences alone. What we expect from science is to unveil the truth."

My last and humble suggestion to the European Commission would be to create a European Authentication Authority, serving both the public and the private sector, bringing forward the European ethical approach, which pertains to our culture already, spreading it worldwide as a European Authenticity Certificate.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

P. 23:
Rosette earring. *Main photograph: AUTHENTICO project. X-ray by Luisa Carvalho, Centro de Física Atómica de Universidade de Lisboa, Portugal.*

P. 24:
'Baule' earring and earring with pendant. *Photographs by Andrej Ŝumbera.*

P. 25:
AURUM WORKSHOP. *Photograph by Elsa Lambert, C2RMF.*

The Kition Fibula

Maria Luisa Vitobello

Kition fibula

MAIN: Kition Fibula National Museum of Archaeology of Nicosia, Cyprus. Photo: NMA, Cyprus. Reference catalogue nr. ΜΛΑ 1742/20, built tomb 1. INSETS FROM ABOVE: Scarab pectoral of Tutankhamun; detail of the Kition fibula.

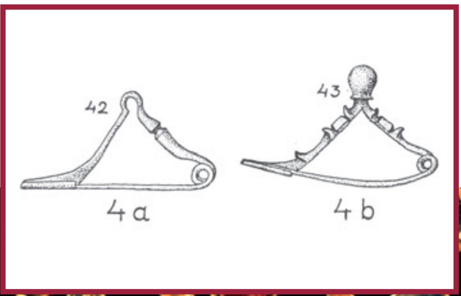
Historical and artistic context

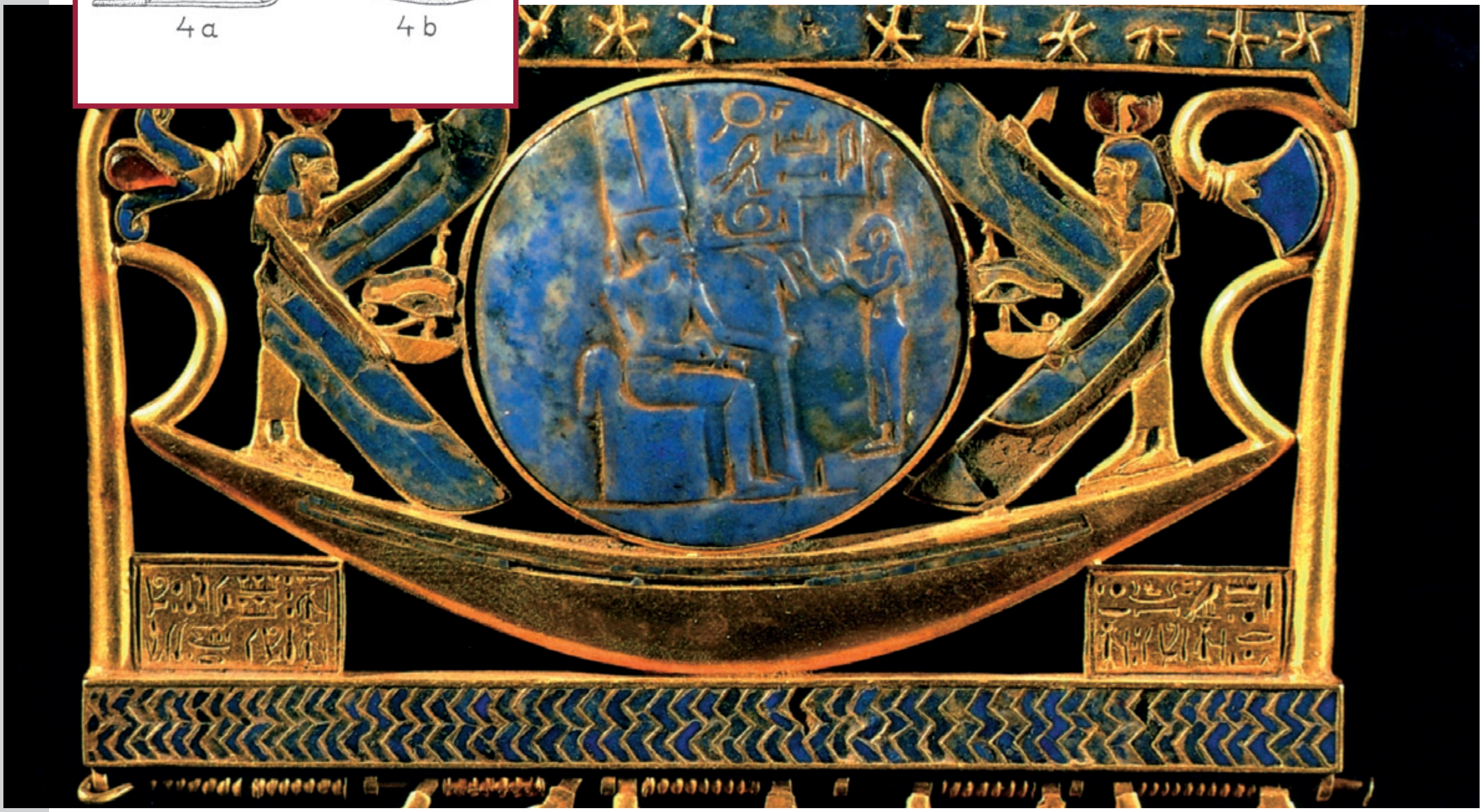
The fibula reproduced in the cover page and further illustrated in the text (see gold studies section) was found in a tomb located in a private residential courtyard near modern Larnaka in 1998. Preliminary to a final publication which will reconstruct the excavation's context and methodology, some introductory content is here provided, aiming to position the artefact within its historical and archaeological context. The fibula's main body, of irregular triangular shape, can easily be referred to Type 4b (see image in the inset) of the Cypriot fibulae, according to the criteria previously presented by the Swedish Cyprus Expedition (Gjerstad 1948) and further confirmed by the typological analysis of D. Stronach (1959); it represents an original Cypriot typology. The chronological horizon appears to be clearly established around the 8th-7th century BC (Cypro-Geometric period). This typology is common in the Syro-Palestinian area, and in the Anatolian and Aegean environments, especially Rhodos and Aegina.

Characteristic features of the Kition fibula are the addition of three chains and lotus bud pendants, and above all the exceptional enrichment of three cloisonné rosettes to the main body, enhanced by polychrome enamel cloisons, which are placed two at the centre of each of the fibula's arms, and one at the top of the fibula's apex, respectively. With their curved shape, both of the fibula's arms appear to recall the Egyptian solar boat: this appears evident in the bows' shapes, which meet towards the apex with an elegant decorative effect, while the two rosettes, topping both arms, are placed in the area where the cabin is usually located.

Egypt

MAIN: pectoral of the King Sheshong II, 21st Dynasty. INSETS FROM ABOVE: the solar boat; examples of Cypriot fibulae.





Such a tendency to use Egyptian or Egyptianizing elements or symbolism in such an eclectic and audacious way is a typical and founding aspect of Phoenician art, of which the Kition fibula is certainly one of the most original and uncommon examples (Ciafaloni 1995). Not only in jewellery, but also in glyptic arts (i.e. on a chalcedony scarab at the Louvre Museum: Tallon 1995: n. 205, p. 102) and in ivories (Herrmann 1986: nn. 989-994, Pls. 2255-57), the solar boat symbolism is widely asserted, and represented in numerous and ingenuous variations with respect to the classical Egyptian interpretation.

Phoenician sumptuous objects had a widespread diffusion with all Mediterranean élites, in this particular instance in its oriental area, in the chronological span already identified, and in particular in Cyprus, as shown by the example of the so-called Cypro-Phoenician bowls (Markoe 1985), which constitute the most evident manifestation of such an eclectic trend. Within the Levantine and Cypriot environments, Phoenician craft is permeated with Mesopotamian and Near-Eastern influences; in fact, it can be probably inferred that it shares an ample aesthetic and technical Koiné only partially known.

Notwithstanding this aspect, the extraordinary recent discovery of the Nimrud Queens' Tombs (Damerji 1999) has added an impressive quantity of artefacts to the meagre evidence related to Mesopotamian jewellery from the 1st millennium BC. As an example, cloisonné and champlevé techniques are widely exemplified by the application of enamels and semi-precious stone inlays on sumptuous bracelets (Damerji 1999: Abb. 27-30), known until now only from relief reproductions of neo-Assyrian palaces.

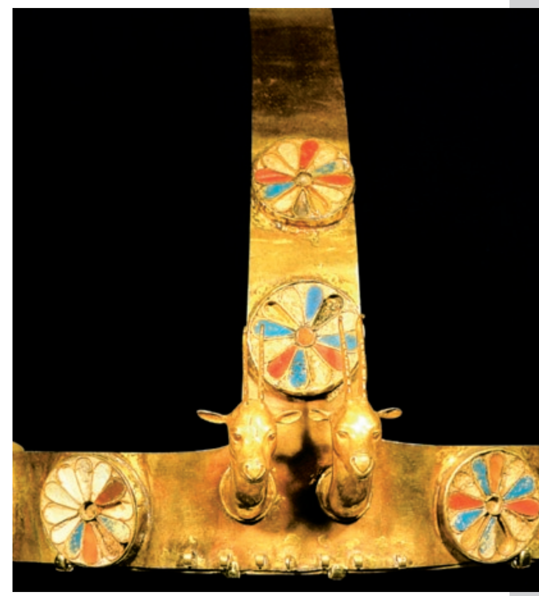
It then appears that not only Egypt should be taken into consideration as a source of the decorative technique applied on the rosettes, even if, since the New Kingdom period, there are undoubtedly copious testimonials of floral elements characterized by these techniques in Egypt (see the headdress of Tutmosis III's wife from Thebes, now at the Metropolitan Museum of Art, New York), as well as in Mycenaean setting (Vaphiò's ring at the Athens National Archaeological Museum: Demakopoulou 1988).

To sum up, it could be concluded that, in the Kition fibula, the corpus of Egyptianizing elements generally recalling the religious world steers towards an eschatological and symbolic interpretation of the artefact, possibly destined, since its creation, to a real use in everyday life, to be worn by a prince or a member of the Kition aristocracy, as well as for funerary use.

Furthermore, the rosette motive in the Mesopotamian area appears linked to the major oriental female goddess Ishtar/Astarte,

Egypt

Diadem with two gazelles' heads,
Egyptian 18th Dynasty;
gold headdress of a lady
of the court of Tuthmosis III.



i.e. in neo-Assyrian setting, chronologically parallel (8th century BC) to the Kition fibula: cloisonné rosettes appear on a bracelet from the above mentioned Nimrud Queens' Tombs (Damerji 1999: Abb. 30), where the same goddess is represented in the bracelet's centre-plate. Taking into account the eclectic and syncretic orientation of the Phoenician culture already identified above, it is possible to assume that both sources, the Egyptian and Mesopotamian, efficiently merge into a clearly unique artefact.

Wall painting

Sennufer with the 'gold of honour'.
Wall painting in the tomb
of Sennufer, Egypt, 18th Dynasty.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

P. 27

Kition fibula. *Photo: NMA, Cyprus. Reference catalogue nr. ΜΛΑ 1742/20, built tomb 1. Published with the permission of the Director of the Department of Antiquities, Republic of Cyprus, Ministry of Communication and Works.*

Scarab pectoral. *Photo: Müller, H.W., Thiem, E., The Royal Gold of Ancient Egypt, (1999) Tauris & Co. Ltd. UK, p. 189.*

P. 28

Pectoral. *Cairo, Egyptian Museum JE72171 in Müller, H.W., Thiem, E., The Royal Gold of Ancient Egypt, 1999, Tauris & Co. Ltd. UK, p. 225.*

Solar boat. *Solar boat Museum, Giza, Egypt.*

Fibulae. *Arts & Crafts. Bronze, Vol. IV, Part. II (1948), p. 145*

P. 29

Diadem. *New York, Metropolitan Museum of Art 26.8.99. Photo: Müller, H.W., Thiem, E., The Royal Gold of Ancient Egypt, 1999, Tauris & Co. Ltd. UK, p. 161.*

Gold headdress. *Photo: Heininger, E. and J., The great book of jewewllery, 1974, Edita S.A., Switzerland, p. 114.*

P. 30

Wall painting. *Photo: Müller, H.W., Thiem, E., The Royal Gold of Ancient Egypt, 1999, Tauris & Co. Ltd. UK, p. 146.*

With thanks to Prof. Davide Ciafaloni, Università di Milano Bicocca, Italy, for his collaboration and contribution with respect to the humanistic aspects of the research on the Kition fibula.

BIBLIOGRAPHY

Ciafaloni, D. *1995. Iconographie et Iconologie, in V. Krings (ed.), La civilisation phénicienne et punique. Manuel de recherche, pp. 535-49, Leiden: Brill.*

Damerji, M.S.B. *1999. Gräber assyrischer Königinnen aus Nimrud, Mainz: Verlag des Römisch-Germanischen Zentralmuseums.*

Demakopoulou, K. (ed.) *1988. The Mycenaean world: five centuries of early Greek culture, 1600-1100 B.C., Athens: Ministry of Culture, National Hellenic Committee (ICOM).*

Gjerstad, E. *1948. The Cypro-Geometric, Cypro-Archaic and Cypro-Classical Periods. The Swedish Cyprus Expedition, Vol. IV, part II, Arts & Crafts. Bronze, p. 145, Fig. 26, Bronze, 4a and 4b, Stockholm: The Swedish Cyprus Expedition.*

Herrmann, G. *1986. Ivories from Room SW37 Fort Shalmanesher, nn. 989-994, Pls. 2255-57, London: British School of Archaeology in Iraq.*

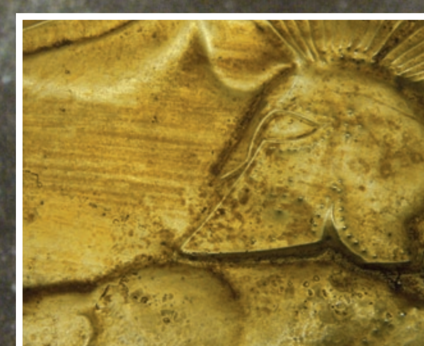
Markoe, G. *1985. Phoenician Bronze and Silver Bowls from Cyprus and the Mediterranean, Berkeley, CA: University of California Press.*

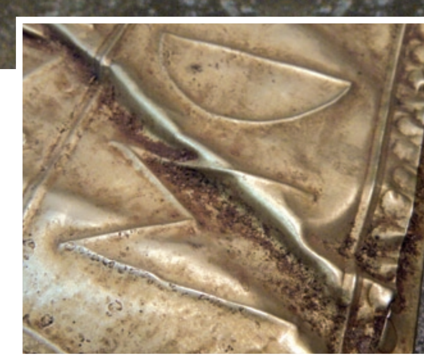
Stronach, D. *1959. The Development of the Fibula in the Near East, Iraq 21, pp.180-206.*

Tallon, F. *1995. Les pierres précieuses de l'Orient ancient des Sumériens aux Sassanides, n. 205, p. 102, Paris: Musée du Louvre.*

Ars sine scientia nihil: a continuous dialogue

Ars sine scientia nihil: a continuous dialogue





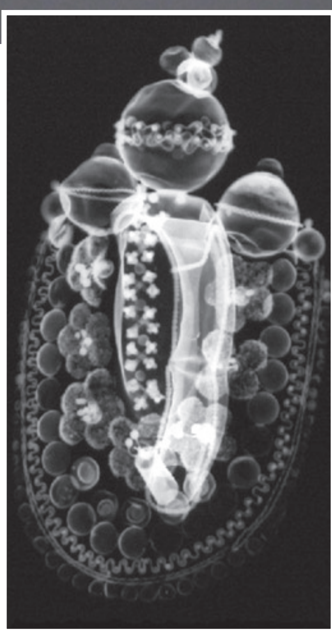
Salvatore Siano and Thilo Rehren

Scientific research and authenticity

The authentication of un-provenanced artefacts is fundamental for our knowledge of the objects, as well as essential to their possible acquisition by museums and governmental agencies, or their assessment in the court of law. As has been shown in this book, authentication is not just a hunt for fakes or a quick dating method, but rather a holistic search for the identity of the object, its social, aesthetic, cultural, artistic content, its historical background and, last but not least, its correct economic value.

Quest for authenticity

MAIN: gold bracelet, unknown provenance. Private collection. INSETS FROM ABOVE: details of a booklet, unknown provenance. Private collection.



Cluster earrings

One of a pair of cluster earrings, Florence National Museum of Archaeology, Italy, inv. 85036; X-ray radiography.

To unveil this identity, a multidisciplinary approach is necessary and required. Until recently, the authentication of such artefacts has been mostly based on stylistic criteria and technological examinations carried out by restorers and/or art foundry experts, which involved the material aspects only at a qualitative level. As a result of this, a first report is produced, identifying the object, the period, and, where possible, the excavation or wider region where the object was found. An integral part of this report is the identification of comparable material from public or private collections, auction catalogues, and excavation reports, leading to an evaluation of the object's possible provenance and possibly of the various steps concerning its manufacture.

Following this report, the technologist will analyse the object and provide a detailed and in-depth description of the material and its condition, addressing separately surface and core areas where cracks or joints allow seeing inside the artefact, identifying different components in composite objects, characterising any corrosion phenomena and previous conservation treatments, and reconstructing the likely manufacturing technologies applied in the fabrication of the object, to unveil the life of the object and its changes through time.
The recent development and refinement of quantitative discrimination criteria based on material characterisations, along with the introduction of non-destructive and micro-analytical techniques, is gradually favouring a novel approach to the authentication of metal artefacts, which is characterised by a growing involvement of natural sciences. Hence, authentication now includes three possible methodologies based on different criteria: archaeological, historical, and stylistic; technological; compositional and microstructural (metallographic).

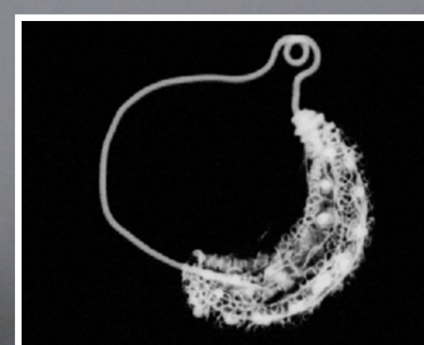
There is a general awareness regarding the need to combine these approaches in a global integrated authentication methodology, and to replace chemical and metallographic analyses based on material sampling with non-invasive techniques. Nevertheless, in common practice the three approaches mentioned above are still often applied independently, according to the significant methodological differences among the disciplinary and professional fields involved. Furthermore, compositional analyses are usually carried out on samples taken from the artefact. This type of procedure is invasive and provides only local information, which is potentially not representative of the whole artefact or fragment under investigation.

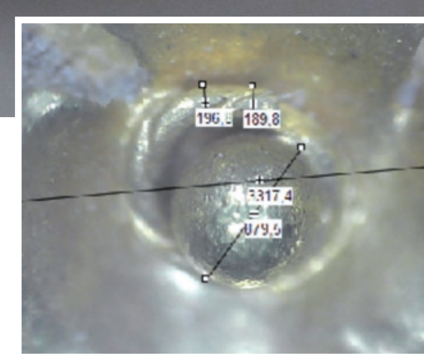
One of the main methodological goals of the AUTHENTICO project has been the formulation of integrated authentication methodologies (IAMs) for each category of metal objects, starting from the following general multidisciplinary investigation scheme:

1. Collection of archival information and archaeological attribution (formulation of the authentication problem).
2. Interpretation of manufacturing procedures by optical and radiographic examinations.
3. Non-invasive analysis of corrosion layers and metal bulk.
4. Comparative evaluation of the data and multidisciplinary conclusion.

Leech earring

MAIN: Etruscan leech earring decorated by rosettes, end of the 7th - beginning of the 6th cent. BC. Florence National Museum of Archaeology, Italy, inv. 15721. INSETS: X-ray radiography shows the fineness of the work; the small flowers are obtained by cutting a gold foil. The dimensions of each elements are visible on the micrograph.





In combination, these studies document how, across centuries and millennia, time and human interventions have shaped and modified the original artefact, how the meaning and materiality of the object changed and transformed it, until it became what it is today. The stylistic and technological examination will also expose areas that cannot be clearly interpreted, due to the absence of comparable finds, the blurring effects of corrosion and patination, to ambiguous joining processes or unusual compositions of the alloys used, or damaged surfaces, and so on. Examples of such integrated work, driven by art historical and conservation assessment and carried out within the remit of the AUTHENTICO project, are presented below in the section on baroque silver objects.

Earring

MAIN: earring, Florence National Museum of Archaeology, Italy, inv. 15701.
INSET: X-ray radiography.

The life of the object and how it changes through time

It is at this point that it is necessary to go further and merge and integrate the humanistic and artisanal competences with a scientific approach, resulting in an objective evaluation of the artefact; "*what we expect from science is to unveil the truth*" as stated during the AURUM workshop by a representative of the

Law Enforcement. The following text gives a brief introduction into the scientific methods applied.

To see the invisible: chemical analysis of metal artefacts

Numerous instrumental methods, such as radiography, LIPS, XRF, PIXE and other materials characterization techniques, allow penetrating into the object, seeing beyond its surface, detecting its manufacturing secrets and material composition in greater detail. It is possible to support the humanistic and technological study by analysing technological characteristics of the material the artefact is made of, acquiring and interpreting data relevant for the reconstruction of manufacturing techniques applied in crafting the object, providing exact information on the conservation status of the artefact to allow its appropriate preservation and restoration, and even identifying its chemical and isotopic association with other objects, possibly determining the geological origin of the metal it was made of. Non-destructive analytical techniques performed with fixed or portable instrumentation can be used for numerous applications, including:

- Material characterisation
- Analysis (microanalysis) of trace elements
- Identification of the causes of materials defects
- (Fast) measurements of mechanical properties
- Digital imaging

As a general rule, only non-destructive analyses are preferably taken into consideration for cultural heritage objects, to allow quantitative evaluation of one or more chemical-physical qualities without causing any alteration to the integrity of the find. When compared to fixed facilities installed at research laboratories, portable instrumentation has the advantage of avoiding the removal of the artefacts from their customary locations (i.e. museums), and of being able to analyse as many artefacts as needed with minimum logistical effort.

How do these methods work?

The most important non-destructive methods for determining the chemical composition of an object currently available are all based on the measurement of characteristic X-rays emitted by the constituents of a sample. These X-rays are emitted when an electron drops from a higher shell to a lower shell in any of the various atoms that make up the artefact to be analysed. In order to enable an electron to drop to a lower shell, a vacancy has first to be created in a lower shell by removing a low-energy electron.

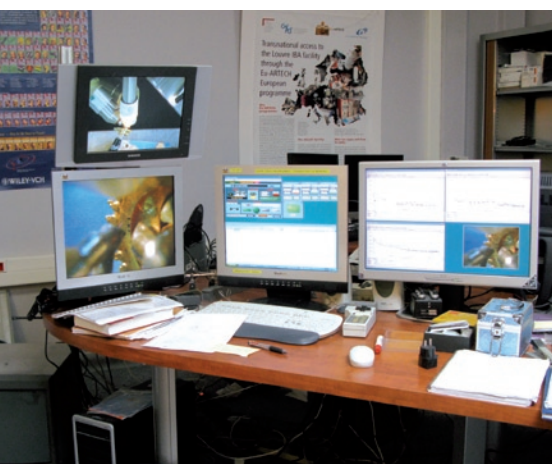
The energy or wavelength of the X-rays emitted during the de-excitation by the electron dropping down are very specific for

Photography

Photo lab, C2RMF.

AGLAE PIXE

One of the earrings from the National Museum of Antiquity of Tajikistan analysed at the AGLAE accelerator, C2RMF.



each electron drop, and differ from element to element. Hence, they are called ‘characteristic X-rays’. Their energy or wavelength identify the element in question, while their intensity indicates the quantity of that element present in the sample.
Two different types of sensors are available for recording characteristic X-rays: energy-dispersive spectrometers (EDS) and wavelength dispersive spectrometers (WDS). Energy-dispersive spectrometers are faster, more convenient and less expensive; however, they are also less sensitive and less discriminating than wavelength dispersive spectrometers. Their greatest advantage, however, lies in their enormous flexibility concerning the surface shape and size of the artefact to be analysed; energy-dispersive spectrometry does not require any sample preparation, making it an ideal non-destructive method. The excitation of the atoms in a sample can be carried out in several ways. In a vacuum or low-pressure environment, an electron beam can be scanned over the surface of an artefact, creating both a highly-magnified image and characteristic X-rays, which can be recorded using an energy-dispersive spectrometer. This is the principle of the analytical scanning electron microscope (SEM-EDS). Since the electrons of the SEM are relatively weak, they are best suited for imaging, while the analytical capability is restricted to elements present in concentrations above approximately half a percent by weight.

A more powerful possibility for the excitation of atoms in the sample entails the use of X-rays, typically generated by a cathode tube. These primary X-rays penetrate deeper into the artefact than the electrons of the SEM and create the characteristic or secondary X-rays by fluorescence (XRF analysis). The most powerful method, however, involves using charged particles to excite the sample material, resulting in particle-induced X-ray emission, or PIXE. The three methods available for producing characteristic X-rays are fundamentally very similar, but differ in terms of energy, and therefore penetration depth and analytical power of the excitation method. Thus, PIXE has the ability to look relatively deep into an object, even through a corroded surface, and to detect trace elements at rather low concentrations.
For practical reasons, XRF analysis is the most common method for non-destructive analysis of cultural heritage artefacts. SEM-EDS analysis only works in very low pressure or vacuum conditions, so that typically only relatively small objects can be analysed. Also, scanning electron microscopes are not readily portable, so an object has to be brought to the SEM to be analysed.
Similarly, PIXE requires an accelerator to generate the charged particle beam necessary to excite the sample, making it a stationary method. While PIXE analysis can be performed in an open-air configuration, and hence can analyse objects of any size and shape, the accelerator is not portable. On the other hand, cathode tubes used to generate primary X-rays for XRF analysis can be

easily integrated in small hand-held and battery-powered devices, making these ideally suited for rapid analysis of objects, even in remote collections or at an ongoing excavation site.

In all cases mentioned above, the excitation takes the form of inner-shell ionisation, i.e. the removal of an electron from an inner shell of an atom. The resulting vacancy in this shell is immediately filled by an electron from a shell further away from the nucleus of the atom; often, this higher electron in turn creates a vacancy in its original shell, leading to a further electron moving inwards. Electrons in inner or lower shells have less energy than those in the outer shells, and each drop of an electron to a lower shell results in the emission of a specific amount of energy, in the form of an X-ray photon. As a result, an entire cascade of characteristic X-rays is emitted and recorded for each element present in the sample, and also recorded as a spectrum characterising that particular sample. Finally, fully quantitative trace element analyses and microanalyses of metal artefacts are best performed in qualified laboratories using specialised facilities, and less so with portable equipment. Analyses with such specialised devices are carried out particularly when quantitative evaluations of trace elements of geochemical interest are required, or microanalyses of some square micrometers areas are required for the study of metallographic structures. In this project, we used such large-scale facilities to evaluate the performance of the newly-developed portable equipment, as well as for the direct analyses of selected important artefacts. Some of the results are reported in the section on the analysis of gold objects.

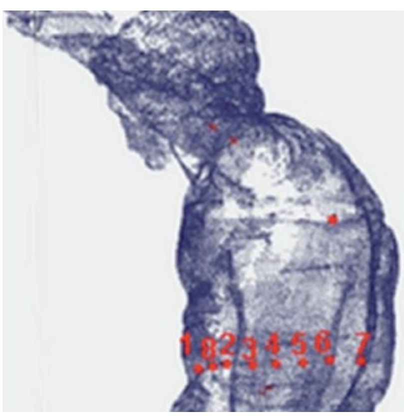
X-ray

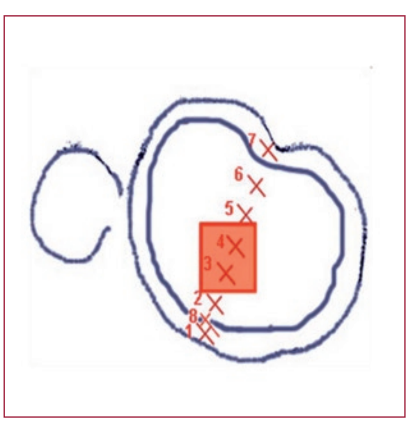
Radiography lab, C2RMF.

Thus, in summary, it is the elements themselves present in the artefact that react in one form or another to various stimuli provided by an input of some type of energy. These reactions take place all at the same time, and it is only a matter of selecting the most suitable detectors to register the most relevant signals emitted during the analysis. The combination of different stimuli with various detectors is reflected in the range of analytical instruments available; fundamentally though, they all work according to very similar principles. This is not very different from the analysis of the ball in a game of tennis. The player can record the incoming ball using any of three different sensors or detectors: the eye, looking at the light reflected from the surface of the ball; the ear, hearing the sound waves emitted when the ball travels through air or hits a surface; and the nerves of the hand holding the racket, registering the ballistic energy of the ball upon impact. All three sensors provide different aspects of the same event; only used together, do they provide a full picture of what is happening. Similarly, we need to combine different approaches in the analysis of metal artefacts in order to obtain as complete a picture of its past and present as possible.

Bronze

ABOVE: working with LIPS, C2RMF.
BELOW: young man seated on a trunk, Florence National Museum of Archeology, inv. 2282: adiographic details (negative view) and neutron diffractions scanning performed on ENGIN-X.





Novel approaches to bronze authentication

As part of the AUTHENTICO project, we have demonstrated that for copper alloy artefacts the most effective non-invasive techniques for authentication are laser induced plasma spectroscopy trials (LIPS) and time of flight neutron diffraction (TOF-ND).
LIPS is a micro-analytical elemental technique based on the spectral analysis of a laser induced plasma. The laser beam is tightly focused on the surface to be analysed, producing a micro-ablation and then a subsequent ionisation and plasma generation. The typical diameter of the laser spots used ranges between 10 and 100 microns. The associated surface damage is usually negligible for copper alloy artefacts, which allows considering this micro-destructive technique as non-invasive. Significantly, the progressing ablation allows monitoring depths profiles through the corrosion layer, providing extremely powerful criteria for interpreting the history of the formation of corrosion, and hence the history of the object and its most likely age. Further in this book we demonstrate the methodology presented above by investigating the authenticity of four copper alloy statuettes of ancient styles belonging to the antiquarian collections of the Florence National Museum of Archaeology (FNMA). From the multidisciplinary methodological standpoint, the results achieved demonstrate the effectiveness and reliability of the approach and, for the first time, the possibility to perform objective authentication of copper alloy artefacts using portable instrumentation.
Similarly to X-ray diffraction, TOF-ND provides information on metal and mineral phase contents and microstructure. Its advantages with respect to the former method derive from the deep penetration of thermal neutrons, which allows analysing thick metal walls up to some centimetres in depth. All the parts of a metal object can be thoroughly investigated in a completely non-destructive and non-invasive manner. Neutron diffraction is carried out in a few large-scale facilities, such as, in particular, the neutron spallation source ISIS at the Rutherford Appleton Laboratory, UK. This makes the technique not easily accessible and does not allow foreseeing its wide application in routine authentication. However, TOF-ND was very successfully used in the framework of the AUTHENTICO project for supporting the validation of authentication approaches based on portable devices such as LIPS.

ILLUSTRATIONS:

***P. 31* Gold bracelet and patera.** *Photo by G. Demortier, C2RMF.*

***P. 32* Cluster earring.** *Photo by Andrej Ŝumbera. X-ray by M. Miccio, CR-SBAT.*

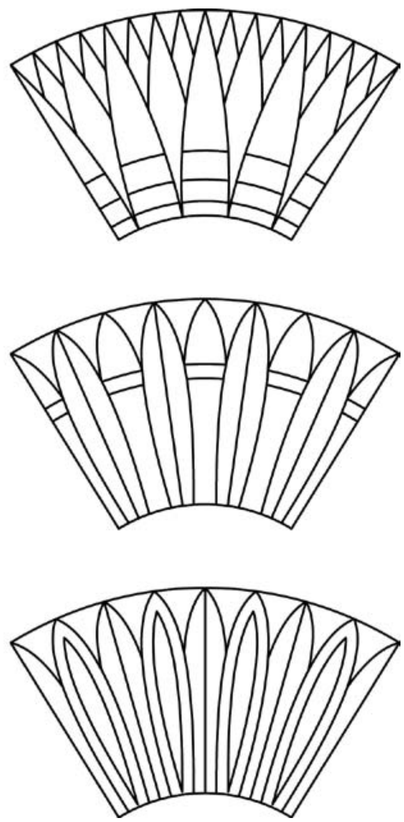
***P. 33* Leech earring**. *Photo by Andrej Ŝumbera. X-ray by M. Miccio, CR-SBAT. Stereomicroscope image by M.F. Guerra, C2RMF.*

***P. 34* Earring.** *Photo by Andrej Ŝumbera. X-ray by M. Miccio, CR-SBAT.*

Pp. 35, 36, 37, 38. *Photo provided by AUTHENTICO partners.*

Following the rhythm: from mind to hand

Following the rhythm: from mind to hand.



Maria Filomena Guerra and Maria Luisa Vitobello

Combining techniques, such as in the study performed within the project, of the lotus flowers produced by three different goldsmiths during the workshop organized in the French Restauration Laboratories, can bring unexpected results, which are enlightening for the understanding and identification of the variations in the "beat" peculiar to one craftsman or another.

The lotus lowers, whose design was inspired by the decoration of the Phoenician Fibula reproduced on this books cover page, were analysed by microtopography and SEM at C2RMF by Dr. Maria Filomena Guerra, leader of the Case Studies on Gold Jewellery. Optical techniques give surface measurements from roughness to the digitalisation of surface micro-topography of small details

Work steps

FROM THE LEFT CLOCKWISE: the original Kition fibula lotus buds; a lotus bud reproduced with the same chasing technique; design variations; individual goldsmith's interpretation; transferring the design onto precious metal plate.

with no previous preparation of the surface and, in the case of ancient jewellery, the use of non-contact analysis is crucial.
By scanning the surface with the appropriate optical sensor, an image in colourimetric scale or in synthesis can be obtained. The software allows the representation of a set of profiles as a 3D image corresponding to the volume of the tool mark.

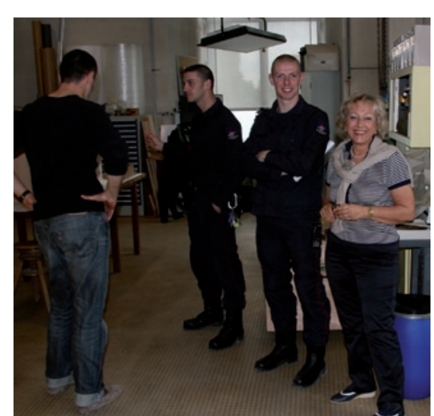
An extracted profile in a selected line presents a depth and a penetration volume, which are characteristic of the employed technique and tool as well as of the effect required by the goldsmith. The shapes of the valleys of the extracted profile correspond to the pattern expected for chasing, characterised by their regular surface valleys and no peaks on the borders. With respect to conclusion in this particular study, the work of the goldsmith who produced the very large size lotus flower is very different from the work observed for the other items. The motif of this very large size flower is deeply applied, certainly with a chisel. The chisel might have been used to obtain certain parts of the motif by a single hammer-touch like for stamping.

In the same register, the work the goldsmith who produced the small-size lotus flower is very different from the work observed for the other items. The very smooth motif of the flowers seems to indicate the use of repoussé. The motif is afterwards revealed by "scratching" – a kind of not deep engraving - around the large forms.
At last, the large and medium size lotus flowers have motifs which are not very deep but using different techniques. As if the goldsmith wished to give the same aspect to the same type of objects but "forced" himself to use different techniques. The large-size lotus flower is basically produced by chasing, while the medium-size lotus flower is produced by a kind of low engraving ("scratching"), which produces very smooth motifs.

Photos by A. Ŝumbera.

Work steps

FROM THE TOP COUNTER-CLOCKWISE: work in progress: comparing the initial design to results obtained; details of results considered satisfactorily close to the original; a lotus bud completed for scientific characterization; C2RMF, Pavillon de Flore, Rastauration Laboratories, Louvre Palace. Goldsmiths at work; firemen monitoring pitch fumes during chasing technique.



Authenticating gold objects – a flow chart

All archaeological and historical metal objects are unique in their production, origin, and individual history. Similarly, any approach to authentication has to be tailored to fit the individual object and its circumstances, and cannot follow a rigid routine. However, some fundamental considerations do apply to the majority of cases, and these are developed here on the example of gold objects: a category of objects very often counterfeited, due to the huge profit that can be extracted from the art market.

When is an expertise necessary?

From the point of view of a museum laboratory (governmental institution), an expertise of gold objects is required in 3 cases:

- Objects from ancient museum collections with an incongruent element and without a 'pedigree': expertise required by the museum owning the object.
- Objects offered by private galleries and private collections for acquisition or donation: expertise required by the museum considering the acquisition of the objects.
- Requests from Cultural Heritage police and other law enforcement agencies in connection to national or international trade (genuine objects and fakes).

In the first case, the expertise is typically part of a research programme connected to an exhibition, to a better understanding of the artefact, or to a scientific publication on a specific subject (civilisation, goldsmithing techniques, circulation of gold, etc.). The results of such an expertise are diffused in catalogues, scientific publications and conferences, and so on.

In the second case, the expertise remains confidential if the object is not acquired or received as a donation. On the contrary, if the object is acquired or received by the museum, the expertise falls under the same conditions valid for the previous case (museum collection).

In the last case, the expertise remains mainly confidential. The report becomes official when the case goes to court, and the expert may be called for a deposition. In a few cases, objects stolen from museum collections may represent the subject of an exhibition, and, in this case, the work of the expert may become a part of the exhibition.

The first stage of authentication

When a gold object (jewellery, coin, statuette, etc.) requires authentication, the first question that must be answered is: 'how far

Earring with pendant

Earring with pendant in form of an amphora, Florence National Museum of Archaeology, Italy, inv. 15743/4; detail: at the edges of the hoop two bands of thin wires form the linking element of the clasp.

is the object credible?'. There are two main steps necessary to answer that question when we consider the fact that usually gold work shows no patina, and base alloys consist of different combinations (according to required colour, mechanical properties, etc.) of copper, silver and gold.

3D Microtopographer

3D Microtopographer prototypedeveloped wthin Authentico Project

- Identification of the geochronology of the object (where and when it was produced) by comparison with the iconography of other known genuine objects with a 'pedigree' (from certified excavations). This step requires (when files are not confidential) the help of the curator/art historian/archaeologist specialised in the gold work produced by the assumed civilisation.
- Observation of the object under different lights and radiations in order to verify the extent to which the goldsmithing techniques are reliable (for example: is the gold plaque obtained by hammering or lamination? Is the motif obtained by simple casting or by casting and engraving?).

Second stage of authentication

Even when the object is consistent with the expected iconography and is produced with the expected manufacturing techniques, it can nevertheless be a fake. It is in the second stage of the authentication process that scientific analysis plays its major role. Examinations and analytical techniques bring together supplementary information on the different construction stages of a gold object.

At this point we must briefly explain how a gold object is produced. We can propose to include all the aspects related to its production in two main stages:

- The *chaîne opératoire* of the metal: it consists of all the metallurgical processes carried out from the extraction of the metal to the production of the alloy.
- The *chaîne opératoire* of the object: it consists of all the stages involving the transformation of the foil or cast form into the final object. In general, these steps are the following:
  1. *Mise en forme*: production of the base elements of the object by hammering, casting, lamination, etc.
  2. Decoration:
     - With addition of elements: for example, by addition of granules and filigrees when an exclusive gold aspect is desired, or by inclusion of other materials, such as gems, ivory, glass, etc., when the goldsmith wishes to obtain a polychrome result.
     - Without addition of other elements: for example, by engraving, chiselling, punching, etc.
  3. Mounting: assembling the different elements of an object by joining and/or mechanically.
  4. Finishing: by gilding, polishing, burnishing, pickling, etc.

The studies connected to the chaîne opératoire of the metal require elemental and isotopic analyses, which provide information on the composition of the alloys, on the origin of the metal (primary or secondary gold), and on the provenance of the metal (localisation of the exploited mines).

The studies connected to the chaîne opératoire of the object require examination and analysis. Generally, a low magnification examination under white light offers information on the surface morphology of the object that must in many cases be complemented by high magnification examinations under the SEM. These two examination techniques provide information on all the stages of the production process. X-ray radiography offers further information on the mise en forme and mounting processes, and surface characterisation supplies further information on decoration techniques. Finally, elemental analysis provides information on the alloys used to fabricate the different parts of the object, as well as additional information on the joining and finishing techniques.

Third stage of authentication

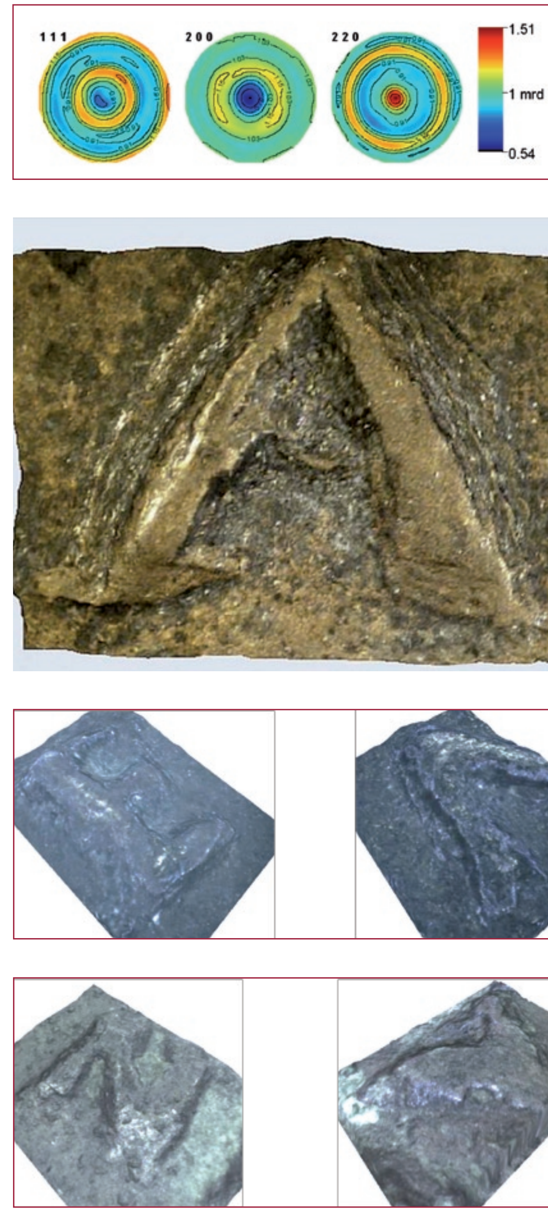
After the two previous stages of authentication, some doubts regarding the genuine character of the object can still remain. In this situation there are two main steps that can still be carried out:

- Reproduction of a part of the object (or of the entire object) based on the hypotheses formulated during the first and second stages of authentication and comparison of the object and its reproduction using the same scientific techniques.
- Study of identical genuine objects using the same scientific techniques in order to compare the results with those obtained for the object to be authenticated.

Non-destructive analysis

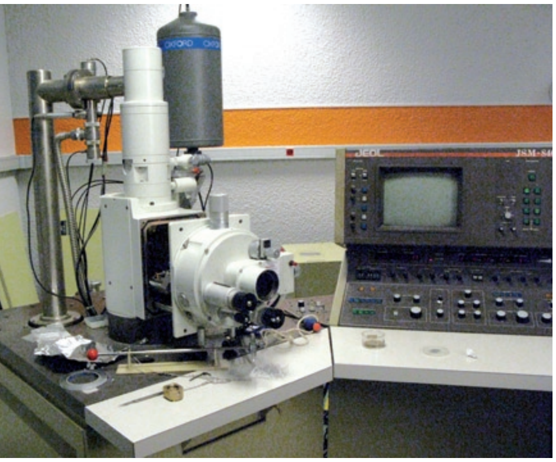
As mentioned above, for cultural heritage objects, completely non-invasive examination techniques are usually preferred. However, only a few analytical techniques can be used in these circumstances. In the case of gold work, analytical techniques can be divided into three types: elemental, isotopic and metallographic. The last two types of techniques require the extraction of a sample. If the sample used for metallographic analysis can be kept after etching in order to be analysed by other techniques, the sample used for isotopic analysis is usually lost during analysis by dissolution or evaporation. Only elemental analysis can in some particular cases be entirely non-invasive and non-destructive.

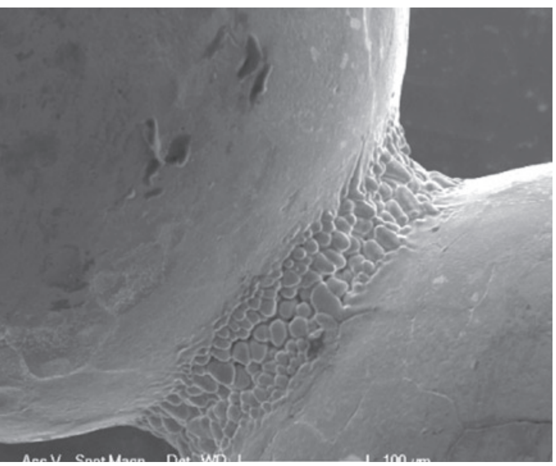
Elemental analysis of gold objects is at present performed by a small number of non-invasive techniques. These techniques range from portable XRF and LIPS (the latter using micro-sampling) to



3D - Microtopograph

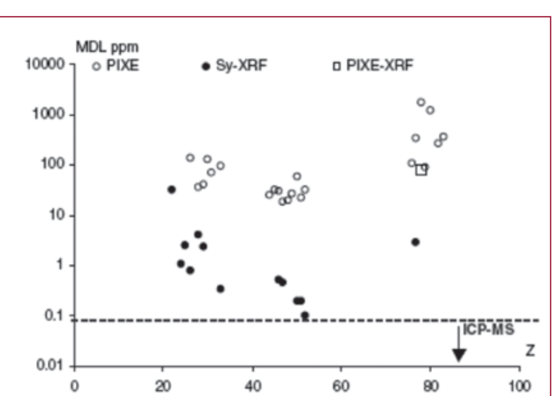
Coins: reconstructed pole figures showing a typical preferred orientation produced by striking process; 3D -MT details providing evidence of the striking process.





Gold analysis

ABOVE: SEM, C2RMF; joining region of two granules produced by EJTN GEIE observed under the SEM at C2RMF.
BELOW: detection limits obtained for gold standard RM 8058 and a set of three ancient coins measured by filtered PIXE, PIXE-XRF and Sy-XRF and compared to the detection limits of ICP-MS for the same samples.



techniques using heavy instruments, such as ion beam analysis (IBA, mostly PIXE-PIGE and sometimes PIXE-XRF), based on particle accelerators, and Sy-XRF, at high and low incident energies, based on synchrotrons. We must also bear in mind that when a sample of some mgs is available, ICP-AES or ICP-MS analyses can be carried out. We prefer the use of the latter because, when associated to laser ablation (LA), sampling is of the same size as for LIPS and detection limits are at the ultra-trace level.

Access to large facilities is difficult. If access to small accelerators such as those used for IBA became easier a few years ago, access to large equipment, such as synchrotrons, requires setting up a complicated project about one year before the analysis. The advantage of Sy-XRF, allowing elemental mapping and micro-beams similarly to IBA techniques, resides in the very good detection limits that are obtained in a non-destructive way. When we compare the Method Detection Limit (MDL) of Sy-XRF with those obtained for gold samples and standards with routine filtered PIXE and PIXE-XRF, we observe in the figure below a gain factor of about 100. ICP-MS, with MDL under the ppm level for almost all the elements of the periodic table, remains the best technique available for the measurement of ultra-trace elements, but requires sampling and, without LA, a long chemical dissolution of the sample. However, we must also note some of the limitations of LA: the small volume of the ablation cell, the impossibility to perform elemental mappings and quantifications for elements with low melting points.

It is also important to point out that portable techniques, providing information only on the concentrations of major elements, might not supply sufficient information on the object in a few cases. For those cases, the measurement of trace elements may be of paramount importance. Finally, we can consider that SEM-EDX, linking imaging and analysis, is certainly at present the most important technique for investigating gold jewellery, due to the often small size of the objects, and the outstanding quality of the image obtainable, highlighting minute manufacturing details. Unfortunately, SEM is a fixed system. In the case of in situ museum analyses, it can be roughly replaced in some cases by low magnification microscopy, if an approximately x200 magnitude can be attained and micro-XRF can be performed.

Assessment

To conclude, we must take into consideration the entire range of objects that can be traded, from entirely genuine to complete fakes. In general, traded objects can be grouped under six categories from the point of view of their authenticity:
• Totally genuine
• Slightly restored: addition of filigree and granules to complete

the object. In this case, disparities in terms of diameters, joining techniques, compositions of alloys, etc. must be investigated.

- Heavily restored: addition of missing parts, either of modern or ancient production. An example of this would be the construction of a pair of 'completed' earrings, mounted by using parts of two or three pairs of ancient incomplete earrings. In this case, we must look for disparities in terms of dimensions, motifs and mountings.
- Pastiches: invented objects obtained by assembling ancient and modern parts. Ancient parts may correspond to heteroclite periods. In this case, disparities in terms of decoration and mounting techniques, as well as in the compositions of alloys must be analysed.
- Copies: exact reproductions of genuine objects. In this case, we must first examine the mise en forme and decoration techniques. Thus, sometimes the object is cast instead of hammered and decorated, the foil is laminated instead of hammered, the motif is punched instead of engraved and chiselled, and so on.
- Fakes: entirely modern objects that could have been made by a certain past civilisation, but were produced with more or less ability by modern goldsmithing. In this case, and according to the ability of the goldsmith, part or all of the steps presented above might be necessary.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

P. 41:

Earring with pendant. *Photo by A.Ŝumbera. Stereomicroscope image by M.F. Guerra, C2RMF.*

P. 42:

E - nose. *CSP.*

P. 43:

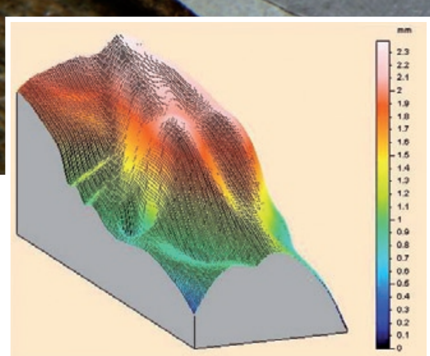
3D-Microtopograph. *CNR IFAC.*

P. 44:

SEM. *Photo by C2RMF.*

Table. *By M.F. Guerra, C2RMF.*

Understanding manufacturing techniques



Lotus bud

MAIN: one of the lotus buds reproduced applying the same chasing techniques. INSETS: SEM image of a decoration detail; 3D representation of the microtopography data in colorimetric scale obtained for a detail of the decoration, which illustrates the depth of the incisions. Maria Filomena Guerra, C2RMF.

Maria Luisa Vitobello

A talk between Emmanuel Plé, in charge of Atelier de restauration metal, Filière Arts décoratifs Departement Restauration, C2RMF, UMR171, Palais du Louvre, and Maria Luisa Vitobello, Project Coordinator and ancient jewellery technologies expert and goldsmith.

Upon request of Dr. Maria Filomena Guerra, chief scientist and researcher at C2RMF-CNRS Labs at the Louvre Palace, both people have worked, together with Andrej Ŝumbera, project partner and restorer of the Prague Castle Royal Treasure, with the aim to measure and document the individual qualities of each “artisan”, applying a set of crafting techniques using the same tools and different tools.

The talk concerns the experimental work performed at the Restoration Workshop premises, in early May 2009, the scope of which is the understanding of the manufacturing techniques with the support of the most advanced scientific diagnostics by experimental reproduction of the technological process of the ancient goldsmithing craft, traditional and archaic. Understanding and knowing traditional manufacturing techniques is fundamental for the identification of the fabrication and processing steps.

"The tool, whichever kind, whether made of metal, wood, organic or inorganic material (agate, iron, steel, copper, wood) can be assimilated to the BAR-CODE of the object. The beat, the hand, the defects of the object and its marks, the size, the thickness, as well as the depth of the beat, all these details provide the evidence to the investigation methodology for the object's authentication, provenance, the place where it was made: maybe from the same workshop and the same artisan, or maybe by another craftsman.

The experiments performed, what was achieved, are then functional to the study of ancient jewels, authentic artefacts: at the same time these information can also support the understanding of fakes; as an example, from the 19th century onward, all the identifying marks and defects of the "contemporary" making can be used to detect fakes.

The aim is univocal: all experiments and analyses are significant but if the knowledge of the technologist and the researcher are not merged and integrated, the result is neither complete nor fulfilled.

In our time we want our objects to be faultless: this peculiarity can also be applied as a trace and track question: nowadays, craftsmen want their tools to be in perfect shape: in antiquity this was not as important.
Today, we like that everything is perfect in terms of technological precision, achieved through industrial design solutions. In antiquity, the object was perfect although of a higher and harmonious perfection because the tool, the hand were driven by the soul.

In ancient times, the relationship between man and its higher self, the divine, unveils itself in the artefact: each object is unique, as the hand of the craftsman is driven

Talking with

Maria Filomena Guerra, C2RMF.
Emanuel Plé, C2RMF, and
Maria Luisa Vitobello, EJTN GEIE.

by its mind and soul. Today, it is driven by numeric control machines and mass produced. Even defects are computer generated.

This is to confirm that an authentic object, meaning a cultural heritage artefact, has its own identity: detectable, traceable, understandable, with knowledge, competence and passion.

What we did, what we experimented, the phenomenon of cooperation between scientists, researchers and technicians, is overwhelming. The researcher calls on the technician; first reaction at visual inspection: beautiful, but what is moving, beyond what is visible, is when you observe the object in depth, in all its details, you reach out to the person who made it, you feel the moment when it happened, how it was made, the mistakes, the changes, the creative path that brought the artefact into life, the mind of the creator into the finished expression of a craft.

It's a matter of soul: if there is no soul, it is an object, simply an object, with no heart; if the soul is there, then the object becomes an artefact, an immortal statement, beyond time and space, rejoining with those who can interpret it, and is forever alive, as the soul."

Photos by A. Ŝumbera, M.F. Guerra.

manufacturing technologies

Maria Luisa Vitobello

To understand how a particular piece of jewellery was made, and the tools and materials that were involved in its making requires understanding still other aspects of the ancient manufacturing technologies. To the trained eye the craftsmanship in those pieces is superb; but the vast ingenuity that lies behind this craftsmanship is even more impressive. Only the simplest of implements were available, but they were good enough to produce jewellery so fine and so complex that to reproduce it today, with all the resources of the third millennium, would require an enormously time-consuming investment and therefore a difficult return on the same investment in terms of costs.

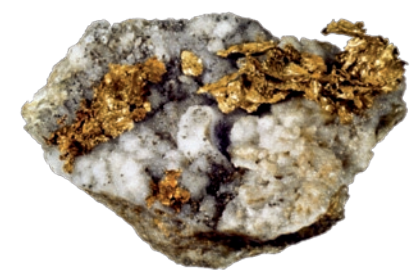
This is the major deterrent for today's falsifiers: it takes too much time and with the latest advancement in diagnostic it becomes more and more difficult to produce authentic fakes.

The information on ancient technologies comes from three sources: from literature, both ancient and modern; from laboratory analyses of archaeological material; and finally from empirical workbench experiments attempting to duplicate ancient fabrication plasticity and effects. The literature on this subject has often piled confusions or misconceptions.

Terminology has been inexact and at times, almost a matter of personal whim; the systems of measurements have often approached the arbitrary. Accordingly it has become necessary to set up a standard terminology and to rely on a technical notation that is consistent. To this effect, we are providing at the end of this publication, a glossary from the EU funded project JewelMed ICA3 – 1999-00005.

Gold recovery

Among the major deposits from which the ancient world obtained gold, were those in Nubia, Arabia, Bactria and Asia Minor. The meager deposits in Greece had, by Hellenistic times, already been exhausted. Although there was still gold to be found in the Cyclades, Macedonia, and Thrace, the fruitfulness of the two latter sites is debatable. Perhaps it is not coincidence that the swathe of Alexander's conquests in Asia Minor and Iran included all of their rich gold deposits: his empire engulfed Egypt with her



The myth of gold

One among the many forms in which gold is found in nature: auriferous quartz, Gold Museum, Brad, Romania.

Jason bringing Pelias the Golden Fleece; a winged victory prepares to crown him with a wreath. Side A from an Apulian red-figure calyx crater, 340 BC–330 BC. Collection of Joseph-François Tochon d'Annecy; purchase, 1818.

TOOLS

Tools were made of wood and stone, copper, bronze and iron.
The working tools consisted mainly of stone moulds, bronze models and various bronze punches, tongs, awls, tracers and chisels.

Other ancient tools such as saws and rasps have been unearthed but they were never used to work gold, for they were too coarse to work efficiently on the thin and flexible sheet gold of which so much of the jewellery was made. Their coarseness would have irreparably scarred the precious material.
The tools, which are now preserved in the museums, tell us little about early techniques. On the other hand, careful studies of the gold-work itself reveals a great deal. We know, for instance, that saws, files and wire cutters were not used on ancient jewellery because their marks are absent, even in areas where they could not have been easily erased by abrasive. However, we often see a mark of a chisel, a tool, which is even better than a jeweller's saw for cutting thin sheet gold.
Although drills were known and used by stone cutters, their marks do not appear on gold sheet work. Holes were pierced with awls or with small chisels. Other tool marks are those of punches, gouges and burnishers.
Many toolmarks are hidden under decorative wires and granulation, as many tools simply leave no marks.

Nubian sources as well. No elaborate methods were needed to recover and prepare gold for use in the ancient world. The ancient miners could gather gold with relative ease from the pockets of river beds.
These alluvial deposits were formed in prehistoric times, when streams cut through gold-bearing rocks, freeing the heavy metal and carrying it to pools and reefs where it settled with the sand. In some areas, gold was also plentiful in dry alluvial sands, which had been deposited by flooding or shifting rivers.

Not all the gold lay loosely in desert sands or riverbeds. Much of it was still imbedded in quartz lodes on the surface of the land. The gold from the surface rocks was mined first, and the veins were then followed underground. Once the quartz ore had been brought to the surface, it was not difficult to crush the rocks and release the gold.

Composition of gold

Repeated meltings of native gold in an oxidizing atmosphere may cause base metals to be slagged off, but the silver remains. Silver must be separated from gold by parting, a complicated process, which is not normally part of the workshop routine. Because goldsmithing techniques and designs are affected, indeed determined, by the composition of the alloys, it is important to know what alloys were used in ancient times.

Since gold combines chemically with neither oxygen nor sulfur, it occurs abundantly in nature in the metallic state. Oddly enough it never occurs in a pure state, such as some fake objects which are made with 24 Kt gold. It is always alloyed with silver in proportions that vary from less than 10% to as much as 50%. These natural alloys are called native gold. Alloys of 20% or more of silver – their colour is light and faintly greenish – are called electrum.

Native gold may also contain small amounts of copper and traces of other metals. "One may suspect that deliberate alloying was involved in making pieces that contain more base metal than would normally be found in native gold. Likewise, a gold alloy with only a trace of silver or no silver at all indicates that it has been deliberately refined".

The next problem, in this procedure and in the other methods of mining, was to sort out the gold particles from the pulverized rock or sand. One method was to wash the gold-bearing ore over carpets of fleece. The heavy gold sank and was caught in the wooly hide while the lighter material was washed away. After the gold-filled fleeces were dried along riverbanks, the gold particles were shaken out, melted together and cast into ingots.

At work

Weighing the metal (and noting the weight) and knotting a bead collar with falcon-head terminals, from a relief in the tomb of Mereruka.

Work on a deep choker with a bib pendant and the inscription 'Get on with your work, slowcoach'.

Knotting a necklace with the inscription 'It is very beautiful, friend'.

Through experimentation with materials known to have been available to the ancient craftsman, and by copying the details visible under magnification, we have learned much about methods of gold construction in those times.

Sheet metal works

By far the greatest part of ancient jewellery is made from sheets of very thin gold. In ancient times, the long-handled hammer had been invented and must have been the goldsmith's principal implement. Whether the hammer was made of hardwood, stone or bronze, it must have been convex.

Gold wreath

Detail of a Hellenistic gold wreath of oak leaves and flowers. The oak was the sacred tree of Zeus at the foremost centre of his worship. Dodoni in Epiros. Benaki Museum, Athens.

Stamping

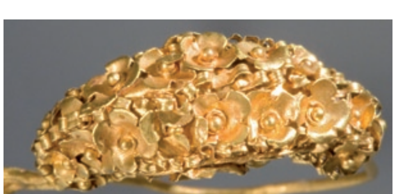
Rosettes appliques. Late Helladic II-III A: 15th-14th century BC. Gold foil, repoussé. Thebes, diam. 5.8 cm. Benaki Museum, Athens, inv. nr. 2063 - 2067.

Striking

Khubishki. Gold coins, 2nd century AD. From Tajikistan National Museum of Antiquities, Dushanbe.

Repoussé

Etruscan leech earring decorated by rosettes, end of the 7th - beginning of the 6th century BC. Florence National Museum of Archaeology, inv. nr. 15721.



Goldbeaters had learned much earlier that a rounded tool beats out gold more effectively than a flat-face one. They beat the chunks or ingots of gold into sheets, annealing it periodically to restore its ductility. Then, with chisels, they cut the jewellery blanks from the sheet and worked the gold in various ways to produce whatever shape or effect was called for in the design.

Plasticity: shapes, volume, forms

There are five methods of working sheet gold into relief or into a figure in the round:

- stamping
- striking
- repoussé and chasing
- working into a die
- working over a model

Stamping

The design is stamped into the metal. The stamp consists of a punch with one entire unit of design in relief on its faces. The metal may be placed over a negative impression of the design, cut or cast into a firm material such as wood, stone or bronze. Alternatively the metal may be supported on a bed of resilient material such as pitch or beeswax. The depth of the impression must be calculated to correspond to the material's thickness and tolerance to stretching.

This technique is not practical for very deep impression, nor can the design have any undercuts.

Striking

The design is struck like a coin. In this technique, the gold, which must be thick, is placed on a hard support such as a smooth metal anvil or a polished rock. The tool is a rod with the intaglio design cut into the end. The goldsmith positions the rod on the ingot and strikes it with a heavy hammer. This blow compresses the background and leaves the design in relief. The back of the blank remains flat. The design can have no undercuts. Because of the required thickness of the metal, this technique is seldom used on jewellery.

It is not always easy, especially on small pieces from which the edges have been trimmed, to tell whether the piece was cast or struck. Because of their diminutive size and the smooth surface textures, we think that certain parts of Early Mediterranean jewellery may have been struck. It is possible to determine whether a gold object has been cast or struck by exposing it to X-rays and observing the pattern in which the X-rays are diffracted.

Repoussé and Chasing

The metal is worked freehand from the back into a semi-resistant material such as a pitch. This is a familiar technique referred to as repoussé. It is almost always combined with chasing – essentially the same but done from the front with more delicate tools in order to add details to the repoussé design. In repoussé the craftsman places the gold face down in a warm pitch. Then he develops the larger areas of the relief by tapping the punch with a light hammer while moving it continuously over the surface to avoid a lumpy effect. When the relief has reached the desired height and shape, he turns the piece right side up in the pitch and chases the details into the simple bulged form.

Repoussé differs from stamping. In the latter the goldsmith lifts and repositions the punch after each blow of the hammer, whereas in the repoussé technique, he slides the punch smoothly over the gold without lifting it between each tap. As a result, repoussé punches usually have plain, smooth faces; stamping punches are shaped into a definite motif.

Raising the relief in repoussé is a slow process during which the goldsmith must often remove the gold from the pitch to anneal it. If the form is complicated, the work must alternate many times from the front to the back, that is, between the chasing and the repoussé. However by this technique the gold can be worked into very high relief, even more than half round.

Working into a Die

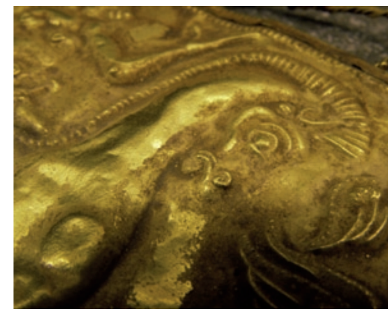
Very thin native gold is rubbed, tapped or pressed into a die. The die must be sturdy enough to withstand the pressure of working the gold into it. It can be made of wood, stone or clay. The pattern is carved into a die. Designs may have large or delicate motifs but they can have no undercuts.

The Macedonian helmet models found at Memphis and datable to the third century BC were made of stone with intricate border designs carved into them, that is to say, in intaglio.

The models were used for the purpose of forming wax impression of the border designs, from which metal borders were cast. These stone models may have been used as a core over which the goldsmiths shaped thin funerary helmets.

Experiments show that thin gold, being extremely malleable, can be curved with ease in the opposite direction after the design has been worked into it, without damage or distortion. This thin gold shell was either left unsupported, if it was a funerary piece, or it was mounted on a metal backing of either bronze or gold.

The same technique may have been used to produce certain low relief designs in thin gold such as the pediment diadems.



Chasing

ABOVE FROM THE TOP: one of a pair of sphinxes (detail). Archaic, 6th to 5th century BC. Gold with filigree and granulation on base, provenance unknown. Benaki Museum, Athens. Nr. 3756: h. 5 cm; l. 3.1 cm; th. of the base 0,7 cm. Nr. 3757: h 4,5 cm; l. 2 cm; th. of the base: 1 cm. Inv. Nos 3756, 3757. UNDER: patera with ring-pendants, provenance unknown, modern production. Private collection.

Over a model

ABOVE FROM THE TOP: medallion with bust of Athena. Hellenistic, 2nd century BC.
Gold sheet embossed and chased with filigree and granulation, garnet, blue enamel. Thessaly.
Benaki Museum, Athens, diam. 11.1 cm. Inv. nr. 1556.
UNDER: torque with linx-head finials. Hellenistic, 2nd century BC.
Gold sheet chased, with filigree and granulation, garnet, traces of green enamel. Thessaly.
Benaki Museum, Athens, diam. of torque: 12 cm; diam. of tube: 1.75 cm. Inv. nr. 1555.

Working over a model

The technique of working over a model is the fifth technique for forming sheet gold. Most of the early pieces of jewellery with animal and human heads are not one of a kind: a pair of goat earrings requires two goat-heads; the animal-headed bracelets terminate at both ends with identical heads. Sometimes, there are, on a single ornament, not only duplicates but also multiples of similar heads. Heads were made in two halves. The seams, which were obliterated by burnishing, cannot usually be seen except under magnification. Lion heads were made in left and right halves, and human heads in either left and right or front and back halves. Thus, the manufacture of matching heads was complemented by the difficulty of making each head of two perfectly fitting halves.

The repoussé, which is a freehand technique, could not produce two symmetrical parts which fit precisely together. It should be pointed out that the smaller the object, the less tolerance there is for ill-fitted parts. Undoubtedly the exactness with which the heads were duplicated speaks for the fact that they were made in or on a form. For ancient goldsmiths, the procedure of working over a pre-formed core would have developed naturally from the earlier practice of overlaying or encasing objects of wood, faience and bronze with sheets of gold. Even in ancient times it was common to make gold animal-head bracelets with bronze cores. It is then only one short technical step to remove the gold casing from the model altogether, and then use the model for further identical overlays.

Thus, the rough contours of two half-shells of each head were probably formed over a model; the half-shells were then joined, the seams burnished and the details added. Repoussé and chasing techniques were used to sharpen the contours and adjust the fit. On the simplest heads, all features were modeled as a part of the rough form. On more complicated heads, it was necessary to add details made from separate pieces of gold.

Because of their shapes and positions in relation to the heads, features such as antelope horns and bulls' ears among others could not be made as a part of the rough form. Antelope horns were usually made of notched or beaded wire; bulls'ears were made of sheet gold wrapped into the shape of a funnel. These ears and horns were usually inserted into the heads through punched holes, a convenient way to hold them steady while they were being permanently fastened to the head. The uneven perimeters of the holes were then often masked with a ring of filigree wire, which also added strength to the joint.

After the craftsman had finished the hollow tubes, he probably filled them with clay or plaster which, when dry, served two purposes. First, it kept the tube from being crushed during handling, and second, it prevented it from expanding or exploding during subsequent procedures which required heat. If hollow loops with closed ends were heated, the air within would expand and cause the seams to open. Or, if the seams had already been fastened, the expanding air would stretch the gold so that if it did not explode upon heating, it would be crushed by atmospheric pressure upon cooling. This problem is familiar to any goldsmith working with hollow, closed forms. The problem is solved either by a vent hole, or by filling the void with any solid which does not burn up and which has a low coefficient of expansion. Clay neatly serves the purpose.

Casting

In early times, casting was a more difficult technique than it is today. Early Mediterranean goldsmiths were acquainted with two methods of casting: mould casting and lost wax casting.
Mould casting requires a mould which is made of two or more parts of some firm material and from which the metal cast is removed without damage to the mould. The mould may likewise be divided into those into which the negative form is made by pressing a model into a soft material, such as sand, clay or plaster, and cuttlebone, and those into which the negative form is cut, such as stone or cuttlebone. Mould casting may also be subdivided into two categories, namely flat casting and casting in the round.

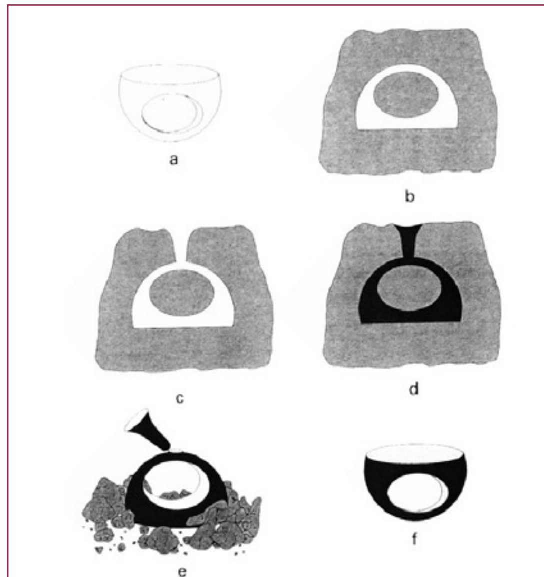
A flat cast is one in which one side of the cast is shaped and the other flat. A flat-casting mould may have two parts, one with the design cut into it and the other flat, or it may be an open mould made in one piece into which the molten metal is poured like aspic into a tin form. Mould casting in the round is more difficult for it requires a mould made by two or more parts, into each of which a portion of the shape has been cut or pressed.

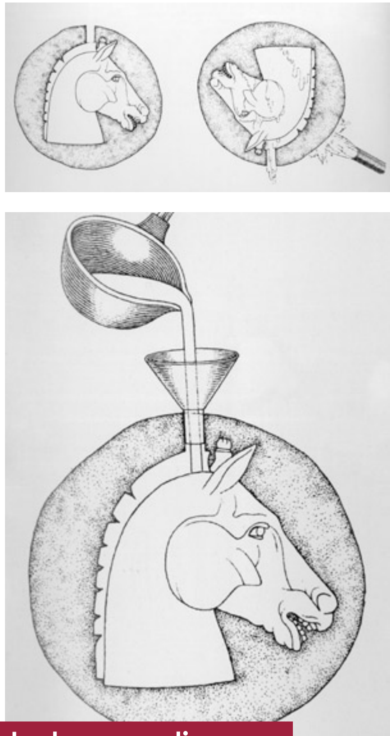
The mould parts must fit together so that the impressions are perfectly aligned: this is accomplished by using interlocking projectives, or at least register marks on the edges of the mould parts. Carving such a mould from stone is a most formidable task.

In ancient times as well as today, moulds, whether of plaster, clay or cuttlebone, were formed around prototypes of wood or cast bronze; wood grain has been identified on certain cast bronze tools, and it is believed that many of the bronzes found at Galjub were prototypes for moulds.

In the lost wax method of casting, the craftsman makes a wax prototype of the figure fastened to a conical wax base called the

Stone casting mould, Archaeological Museum of Ancona, Italy.
Mould casting procedure.
(JewelMed EU project).





Lost wax casting

sprue. Next he encases the wax figure and sprue in wet plaster-like material called the 'investment', in which he has cut several small channels running from the figure to the edge to act as air vents.

When the thick-walled investment has dried completely, the craftsman heats it until the wax melts and burns away, leaving a void. Finally the goldsmith melts the gold and pours it through the funnel-shaped hole left by the sprue into the space left by the burned out wax. The cast is then complete. In order to remove it from the mould the mould must be destroyed. Thus, each lost wax cast object is unique.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

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Auriferous quartz. *Bachmann, H.G., Mythos Gold, Hirmer Verlag GmbH, München 2006, p. 21.*

Golden Fleece. *Marie-Lan Nguyen/Wikimedia Commons.*

P. 50-51

Reliefs *in the tomb of Mereruka at Saqqara, 6th Dynasty. Mueller, H.W., Thiem, E., The Royal Gold of Ancient Egypt, I.B. Tauris & Co. Ltd., London, 1999, pp. 76-77.*

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Gold wreath. *Fotoupolos, D., Delivorrias, A., Greece at the Benaki Museum, Benaki Museum, Athens, 1997, p. 116.*

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Rosettes. *Benaki Museum, Greek Jewellery, Adam Editions, Athens, 1999, p. 53.*

Coins. *Photo by Andrej Ŝumbera.*

Gold earring. *Photo by Andrej Ŝumbera.*

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Gold sphinx. *Benaki Museum, Greek Jewellery, Adam Editions, Athens, 1999, p. 136.*

Patera. *Photo by Andrej Ŝumbera.*

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Medallion. *Benaki Museum, Greek Jewellery, Adam Editions, Athens, 1999, p. 207.*

Torque. *Benaki Museum, Greek Jewellery, Adam Editions, Athens, 1999, p. 211.*

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Images *from EU funded project JewelMed ICA3-1999-00005.*

Lost wax casting. *Black, A., Histoire des bijoux, Grange Batelières, Paris, 1974, p. 30-31.*

Excerpts and adaptations from Hoffman, H., Davidson, P., 1965, Greek Gold: Jewellery from the age of Alexander, The Brooklyn Institute of Arts and Science, USA.

Chasing

Chasing is used to define or sharpen the details of any design in relief, and to add texture to a surface by using a variety of tracers, punches, liners and matting tools, as, for example, in making a serpent's scales or a rams' wool. Usually the goldsmith holds one end of the chasing tool against the gold while he taps on the other end with a light hammer. If, however, the gold is very thin, as, for example, when making the leaves of the golden wreath, he can use the chaser as a stylus to draw the design into the gold.
Chasing tools may be made of hard wood or stone as well as metal. A number of bronze chasers have been excavated; those of wood or stone may not have survived, or if they did survive, they may not have been recognized by the excavators as tools.

Chasing

MAIN: basket earring (pastiche): detail of the pendant in form of ram head, Etruscan, 5th cent. BC, FNMA inv. nr. 15698.
INSET: Vaphio's cup. One of a pair of gold cups of Minoan workmanship, probably dating from 1500-1400 BC. H.: 8.9 cm. National Museum of Athens.

Intaglio

Ring with intaglio bezel. Hellenistic, 2nd century BC or later. Gold intaglio. Thessaly. Benaki Museum, Athens. Height: 2.2 cm, inv. nr. 1612.

Inlaying

Pectoral with Nut, goddess of the heavens, her wings protectively outspread. Gold. 18th Dynasty. Cairo, Egyptian Museum JE 61944.

Stone setting

Volterra disc brooch, Florence National Museum of Archaeology, inv. nr. 70799.

Engraving

The technique of engraving was not commonly practiced in antiquity. The technique involves cutting away a strip of metal from the object. An engraved line deep enough to be clear would cut though the thin gold commonly used in ancient jewellery.

Engraving tools of obsidian, copper or iron may have been used in antiquity and earlier times. However, with any of these the artisans could merely make shallow scratches. Scratching, which does not remove metal, and engraving, which does, are distinctly different techniques. Any sharp material harder than gold will scratch it. But, in order to engrave an object, the craftsman requires a tool which he may push, like a plow, into the gold. Iron and copper points cannot be adequately sharpened, and in any case, would bend. Obsidian and flint tips simply break. The technique of incising metal was certainly known early on, but fine engraving was not possible until the invention of tempered steel at a later date.

Inlaying

The technique of inlaying one metal into another to achieve polychrome effects had been popular in Cyprus and the near East before Hellenistic times and early Mediterranean craftsmen continued to use it for decorating vessels. However the technique was apparently not fashionable in the making of early jewellery. Nevertheless, other means of achieving variety and contrast in colour were employed in decorating early jewellery. Semi-precious stones and glass were handled in various ways, although there is disagreement about the extent to which they were used. Almost all the little filigree bordered petals, discs and scrolls were once inlaid with enamel.

Glass framed by filigree wires was sometimes fused in place, and this is to be considered cloisonné enameling. Glass was sometimes used to imitate precious stones; it was cut, fitted and pasted in place or held in bezels. Glass was often used to indicate the eyes of animal finials, a case in which it was not always contained within a bezel, but fused to the background gold.

Stone setting

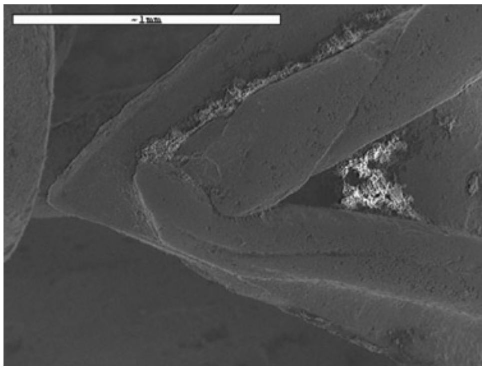
Gold settings for gemstones were simple. Either the stones were drilled and strung onto wire, or they were circled by a thin sheet gold wall affixed to the mounting and bent in around the top edge, holding the stone in place. This type of setting is called bezel. Prong settings were unknown in the Early Mediterranean era, perhaps because prongs made of the extremely malleable native gold would have been too easily bent and therefore impractical. A compromise between bezels and prongs is represented by serrated bezels such as those often used on the Herakles knots set with garnets. These we call 'dog-tooth' bezels.

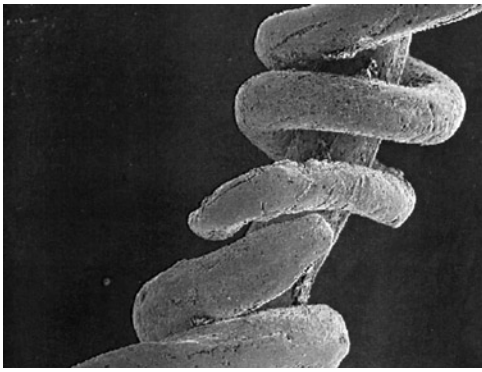
Twisted wires

Stereomicroscope image. Detail of an amphora earring. Found at Parkhar cemetery (Southern Tajikistan). Kushan period, 1st to 2nd century AD, Tajikistan Museum of Archaeology, Dushanbe, ref. cat. nr. 271.

The SEM image of a detail of the cup gives an estimation of the dimensions of the decoration wires.

SEM image. Detail of a strip-twisted wire. Pendant earring, turquoise, garnet. Found at Ksirov cemetery III in Dangara district of Khatlon region (Southern Tajikistan). Kushan period, from 1st century BC to 2nd century AD. Tajikistan Museum of Archaeology, Dushanbe, ref. cat. nr. 286.





It is almost inconceivable that the seemingly infinite amount of wire used in the ancient goldsmiths era was not mass-produced. By rough calculations it has been determined that a single strap and stone pendant necklace can contain nine meters of wire.

Today, in the craftsman's shop, wires of various cross sections and of all sizes are made by drawing a thick strip of gold through a series of graduated holes in a steel plate, each hole smaller than the preceding one. Simple round wires were either made by twisting a ribbon of gold foil in the way that soda straws are made, or by hammering and rolling a strip of thick gold sheet until it was round. Wires made by the first method are henceforth referred to as 'strip twisted', and those made by the second method as 'rolled'.

Strip twisted wire can be made smaller only by twisting it more tightly. Rolled wire can be made smaller and longer only by drawing or by re-forging and re-rolling.

Beaded and spooled wires appear more frequently than any other type of decorative wire, adorning unimportant pieces of mediocre workmanship as well as the finest examples. Beaded wire is that which looks like a row of small round beads fastened together. More likely, beaded wire was made of a row of granules fastened together and rolled.

Experiments reveal it to be much easier to fasten together a row of granules in order to make a beaded wire, than to fasten individual granules in an accurate row to the base sheet of gold, particularly when the area to be decorated is a narrow edge or rim. When beaded wire is made by joining a row of grains it is at first crooked and uneven. However, rolling the wire with a serrated tool similar to an old-fashioned butterball paddle evens it out without flattening the beading. The idea of fastening a row of granules together and applying them to jewellery in wire form was perhaps an ingenious, time-saving way to create the illusion of rows of granulation such as those visible on the seventh century BC jewellery of Rhodos or on early Italian examples. Certain spool wires are more elaborate than others; the wires were turned on a lathe, and that the 'seam' marks were actually left there by the chisel during the process of turning the spools. A similar example of spool wire bordering a diadem fragment in the Museum of Fine Arts, Boston is not a solid wire but, rather, an empty sleeve of sheet gold.

Joining

Bracelet

MAIN: bracelet, with an agate in box setting. Box setting - height: 4.6 mm, diameter: 18 mm; ribbon bracelet - length: 181 mm. Wire diameter: 3/10 mm. Weight: 14.7 gr.s. INSET: the strap consists of a ribbon made of four parallel double loop in loop chains, pierced through by supporting loops that create the flat ribbon by adding connecting loops to the desired length. Jewel by M.L.Vitobello.

Almost every piece of ancient jewellery is composed of many parts. Sometimes the parts are held together mechanically, that is to say, hinged, pinned or wired. Usually, however, they are joined permanently.

The procedures for making these permanent joints in ancient times have long been debated by craftsmen and historians alike, for on the ancient joints none of the scars which mark the joints of modern hand-wrought jewellery are present.
Soft soldering, hard soldering, welding, autogenous soldering, fusing and colloid hard soldering are only a few of the expressions which have been used to this purpose, sometimes carelessly and sometimes interchangeably.

There are three methods by which two pieces of metal can be permanently fastened together: soldering, brazing and welding.

Soft Soldering

Soft Soldering is carried out at temperatures below c. 400 °C. In this procedure, an alloy, namely solder, the melting point of which is well below 400 °C and also below the melting point of the metals to be joined, is added to the joint. When it is heated to the melting point, the solder flows between the two surfaces of the joint, filling all the surface irregularities. When it cools and solidifies, the two pieces are locked together.

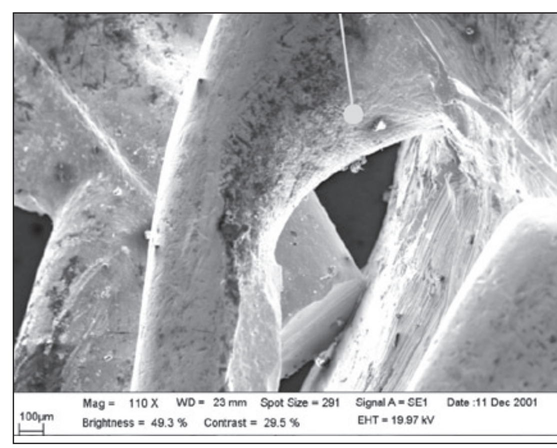
We do not know exactly when soft soldering was invented but it was relatively late. One of the earliest examples cited by Lucas is a Hellenistic flute found at Bucheum (Egypt Exploration Society, 1934) on which an alloy of lead and tin was used as soft solder. Lucas also describes an earring, datable to the third century BC, on which there are traces of tin solder. Pliny tells us that an alloy consisting of two parts lead and one part tin (approximately the same proportion as in a modern solder) was used at this time; although soft soldering may well have been known to Bronze Age craftsmen it was never used on gold jewellery, perhaps because of its whitish colour.

Hard Soldering

The terms ‘brazing’ and ‘hard soldering’ are used here synonymous, and both procedures are carried out at temperature well above 400 °C. Although the term brazing is commonly used in reference to the process of making joints in copper, bronze and brass, we adopt that terminology in this context to describe the process of using high melting alloys (hard solders) to make permanent joints whether in precious or base metals.

A hard solder differs from soft solder in the following ways: first of all, hard solders form molecular bonds with the two joint surfaces, whereas a solder only locks into the surface interstices and irregularities. Brazed joints are therefore stronger than soft soldered joints. Finally, hard solder can be manufactured to closely match the colour of the metal which is being soldered; soft solders are all whitish. Most modern jewellery is brazed. It seems reasonable to assume that ancient gold was also brazed. The first requirement for any gold brazer, of course, is that it melts at a temperature below the melting point of the object being brazed. The ancient goldsmiths simply used a native alloy with a lower melting point, however the rather high melting point of native golds would have made it difficult to use it for a brazers. Furthermore, on any piece which has many joints, several grades of brazers must be used seriatim in order to avoid undoing previously fastened joints while brazing later ones. Testing the alloys to determine the range of

BELOW: stereomicroscope image. Rod forged as a hook applied on the back side of the earring. Pendant earring, turquoise, garnet. Found at Ksirov cemetery III in Dangara district of Khatlon region (Southern Tajikistan). Kushan period, from 1st century BC to 2nd century AD. Tajikistan Museum of Archaeology, Dushanbe, ref. cat. nr. 286.
UNDER: Phoenician amulet, National Museum of Archaeology, Malta. SEM images show traces of removal of filler material.



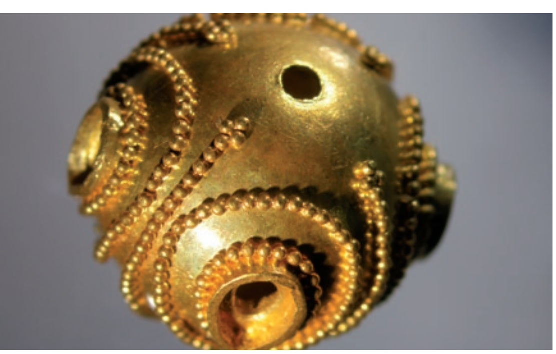
melting temperature and finding enough grades within the narrow range of native alloy melting temperatures would also have presented the ancient craftsman with a practical impossibility.

Fusion welding, autogenous welding and granulation

An additional problem is that of colour. Native gold alloys containing enough silver to be used for brazing are distinctly lighter in colour. Due to the lack of a difference in colour the joints of ancient metal, one can think they were made by a method referred to as 'autogenous soldering'. In this method the solder was a piece of metal of the same alloy as the pieces being joined. This technique, 'fusion welding or autogenous welding', consists of melting the surface to be joined and possibly adding molten metal of the same alloy to strengthen the joints. This is substantially the same technique described earlier; the distinction is that while in 'surface-welding' the surfaces are melted until they become 'tacky', in fusion welding the surfaces become molten. The difference is a matter of additional heat, and in reality the techniques are not distinguishable. Thus, we have five compound terms all meaning, in a practical sense, the same thing and none of which is practical for working on gold jewellery.

Granulation

Granulation technique.
Modern object, M.L.Vitobello.
Detail of Rosette earring,
provenance unknown.
Private collection.



The ancient craftsman, with his charcoal fire and blow pipe or bellows, was surely unable to control either the amount or direction of the heat as accurately as his modern counterpart can with his fine torch flames. On ancient Mediterranean jewellery there are no signs of stray brazer, no pock marks, no file or abrasive marks which result from cleaning up imperfect joints, no differences in colour at the joints. In fact, there is no evidence of brazing at all, and this is so because they used no metallic brazers. We are, therefore, led to believe that the joints were welded. Welding is the process of joining two pieces of metal without the use of either a solder or a brazer.

Some writers have suggested that seams were pressure-welded or simply burnished together. It is true that if two absolutely flat and smooth surfaces of gold are put face to face, there will be, in time, a migration of molecules between them so that the two pieces will eventually become one. This 'technique' should be disregarded in trying to account for ancient solderless joints.

The gold was fused together by heat alone. This theory may be based on the fact that as pure gold approaches the melting point, the surface becomes liquid a moment before the entire piece melts. If two pieces are heated to this point and instantly brought into contact, they will be welded together. This is the technique referred to as 'surface welding' and 'fusion welding'. The technique is impractical even with modern devices for the temperature control must be extraordinarily precise. The slightest error leads to the destruction of the piece. Students of ancient technology have tended to look with skepticism on the accuracy of ancient literature whose authors are dismissed as being naively superstitious, alchemistic or cryptic at best. The expression ‘gold-solder’ has been interpreted as referring to malachite, a basic copper carbonate well known to ancient Mediterranean craftsmen. Verdigris, an acetate of copper produced by the action of acetic acid on metallic copper, was especially used by goldsmiths to join gold to gold.

In the Early Mediterranean era, the art of granulation involved no special techniques - the grains were fastened to the sheet metal by the same method by which all joints were fastened. Granules, which may have been made by melting bits of gold suspended in powdered charcoal, were picked up one at a time or in clusters with a brush which had been moistened in a gum solution.
The granules were then placed directly on the gold where easily spared out or pushed into patterns. Sometimes, on ancient examples of granulated work, the grains seem to be immersed in or flooded by gold. One might suppose that this excess metal is solder but the same effects is sometimes created if the pieces is overheated in the ‘welding’ process. Thus, one should not dismiss an object as a fake on the grounds of flooded granulation.

ILLUSTRATIONS AND ACKNOWLEDGMENTS:

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Basket earring. *Florence National Museum of Archaeology. Photograph by Andrej Ŝumbera.*

Vaphio cup. *Bachmann G. H., Mythos Gold, Hirmer Verlag GmbH, München 2006, p. 70.*

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Ring. *Benaki Museum, Greek Jewellery, Adam Editions, Athens, 1999, p. 216.*

Pectoral. *Mueller, H.W., Thiem, E., The Royal Gold of Ancient Egypt, I.B. Tauris & Co. Ltd., London, 1999, p. 182.*

Volterra disc brooch. *Photograph by Andrej Ŝumbera.*

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Amphora earring.

a) Stereomicroscope image by Dominique Bagault, C2RMF.

b) SEM image by Maria Filomena Guerra, C2RMF.

Pendant earring. *SEM SE image by Maria Filomena Guerra, C2RMF. Pendant earring, turquoise, garnet. Found at Ksirov cemetery III in Dangara district of Khatlon region (Southern Tajikistan). Kushan period, from 1st century BC to 2nd century AD. Tajikistan Museum of Archaeology. Reference catalogue nr. 286.*

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Bracelet. *Photo: NMA, Cyprus. Published with the permission of the Director of the Department of Antiquities, Republic of Cyprus, Ministry of Communication and Works.* The item was found in a built tomb excavated in 1998, in the courtyard of a private house, in the southern outskirts of the ancient town of Kition, modern Larnaka. Materials: high carat gold, agate. National Museum of Archaeology, Cyprus. Reference catalogue nr. MΛA 1742/18, built tomb 1.

Strap. Goldsmith's contemporary production, Maria Luisa Vitobello. Photograph by Dominique Bagault.

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Pendant earring

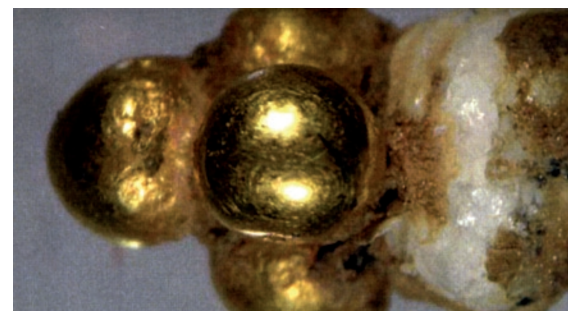
Stereoscopic image by Maria Filomena Guerra C2RMF.

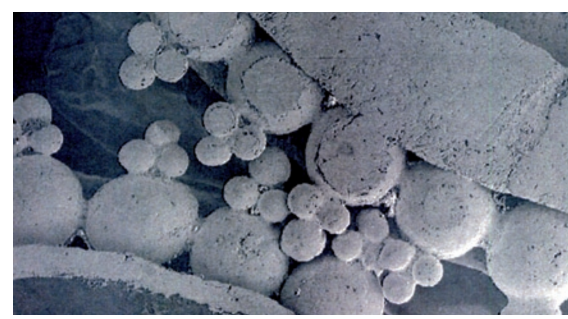
Amulet. *SEM image: Safeguard of Cultural Heritage Project, CNR (National Research*

Granulation

Stereomicroscope image. Detail of an amphora earring: granules at the end of the rod. Amphora earring (one of a pair), gold, pearls, bronze and glass paste. Found at Beshkent cemetery (Southern Tajikistan), Kushan period. From 1st to 2nd century AD. Length: 23 mm; width: 14 mm; weight: 1.65 gr. Tajikistan Museum of Archaeology, Dushanbe, ref. cat. nr. 274.

SEM image. Detail of a Fibula: junction of a disc. Gold, turquoise, glass paste. Found at Beshkent cemetery (Southern Tajikistan), Kushan period. From 1st to 2nd century AD. Length: 30 mm, width: 19 mm; weight: 3,760 gr. Tajikistan Museum of Archaeology, Dushanbe, ref. cat. nr. 267.





FINISHING AND POLISHING

Complex pieces of jewellery, covered for example with filigree, could not be finished with a high polish without wearing down the filigree wires and grains or without distorting the construction. As he worked alone, the goldsmith removed scratches and dents from each part with mild abrasives, such as powdered cuttlebone, and by burnishing. However subsequent heatings and cleansings gave jewellery the soft satin-like finishing which it retained. Some of the jewellery has been cleaned in recent years but much of it looks the same as it did when it was made 2,200 years ago.

FORTY TOOLS FOR A FIBULA

Maurizio Donati

Many of the jewellery collections assembled in the 19th century are composed of original pieces, as well as of modern pastiches. Inspired by these archaeological jewels and pastiches, goldsmiths such as Fortunato Pio Castellani in Italy brought into fashion a typically new jewellery style. In the case of jewellery items, the identification of a pastiche depends on the quality of the work, but also on the rarity of the object. For less known goldwork, scientific analysis provides access to complementary information on the manufacturing techniques. (Maria Filomena Guerra, 2005 in: Trèsor Antiques, Musée du Louvre Editions).

The Castellani gold brooch, the so-called 'Fibula putto e fiori' is here presented. The fibula (on the top), inspired by an Etruscan artefact excavated in Tuscany[1], was already listed in the Castellani records in 1854[2], and was shown at the London International Exhibition in 1862[3]. The fact that the fibula was crafted with a specific single stamping technique has been analysed, motif by motif, as these were implemented with the aid of a remarkable number of tools. It was calculated that the tools (some still available after the recovery, restoration and inventory of the original Castellani tools performed by the author[4]) amount to approximately 40 pieces. It should also be taken into account that, in order to be stamped, each element, including doubles, required four steel tools.

Council), Italy.

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Modern little sphere. *Photograph by Dominique Bagault, C2RMF.*
Rosette earring. Photograph: AUTHENTICO project.

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Amphora earring. *Stereoscopic image by Dominique Bagault, C2RMF.*
Fibula. *SEM image by Maria Filomena Guerra, C2RMF.*

Exerpts and adaptations from Hoffman, H., Davidson, P., 1965, Greek Gold: Jewellery from the age of Alexander, The Brooklyn Institute of Arts and Science, USA.

Text 'Forty tools for a fibula' was written with the precious collaboration of Dr. Maurizio Donati curator of the Castellani Legacy to the Museo Artistico Industriale (M.A.I.), Roma.
Gold fibula. *Villa Giulia National Etruscan Museum, Rome. Augusto Castellani modern collection. Inv. 85209. Authorized publication.*
Blanking-dies. *Steel. Alfredo Castellani legacy to M.A.I., Rome.*
M/F: 746,747,749,751,754,755,756 (Unpublished. Restoration by M.Donati).

1,2,3. Specimens of Greek, Etruscan, Roman, Medieval and Cinquecento Jewels, from existing originals.
4. Part of the Alfredo Castellani legacy, located at the Industrial Artistic High School in Rome in the 1930s, largely lost, recovered by the author in 1978; 1327 pieces in number, together with a set of drawings and pictures, at present conserved at the Istituto Statale d'Arte di Roma 1. See: Donati M., contributi vari: Del Mai, Storia del Museo Artistico Industriale di Roma (Borghini G., a cura di), pp. 228-231.

Maria Luisa Vitobello - Thilo Rehren

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