Science for Conservation of the Cultural Heritage

Elding, Lars Ivar

Published in:
Proc. COST Strategic Workshop - Safeguard of the Cultural Heritage, M. Fioravanti and S. Mecca (Eds.), Florence University, July 11-13, 2011

2011

Report

Session 2: Science for conservation of Cultural Heritage

Reporter: Lars I. Elding, Lund university, Sweden

Session 2 was subdivided into the following interrelated subsessions:

- **Subsession 2.1**: Conservation methods and materials science
- **Subsession 2.2**: Archaeometry: methods and geomaterials
- **Subsession 2.3**: Climatology and outdoor/indoor alteration of monuments/artefacts
- **Subsession 2.4**: Novel non-destructive techniques for diagnostics

1. Summary of contributions

Subsession 2.1: Conservation methods and materials science

Lars Ivar Elding (*Univ. of Lund, Sweden, and the Vasa Museum*) stressed the rapid scientific development of methods for characterization of properties of heritage materials during the last decade, exemplified by the research on the Vasa warship. *Light- and electron microscopy, X-ray diffraction, -scattering and -fluorescence, synchrotron-based methods such as EXAFS, XANES and X-ray microscopy, solution and solid state NMR spectroscopy, mass spectroscopy (GC and MALDI-TOF),* as well as chemical analysis by *size exclusion chromatography, lignin analysis, carbon-14 radioactive analysis* and analysis by use of *microbiological and molecular biological methods* have given significant new information. Novel methods for determination of *mechanical properties* of archaeological wood have been developed, as well as computer simulations involving finite element methods, enabling extrapolation of physical data for single construction elements to complex macroscopic structures. This rapid technical development will continue and accelerate. New technologies such as *time-resolved laser spectroscopy, ultrasound studies, neutron diffraction and micro-calorimetry* might be useful. Quantitative determination of the chemical and physical conditions of materials must be carried out before conservation. To predict the expected life-time of wooden artefacts, the key parameters controlling the nature, absolute rates and relative contributions of the various possible degradation reactions must be known. In addition to oxygen consumption measurements and accelerated ageing experiments (inherently difficult to interpret), *novel methods for determination of degradation reaction rates of heritage artefacts as a function of external conditions* have to be developed. Another important field for future research is the development of *novel conservation and stabilization agents*. Novel methods are usually developed at university laboratories or other research institutions. A successful knowledge transfer to those responsible for the cultural heritage will most certainly necessitate future increased recruitment of scientifically trained museum staff.

Matja Strlic (*UCL, London, UK*) emphasized the use of non-destructive methods for material characterisation, in particular *near infrared (NIR) spectroscopy with multivariate data analysis (MVA)*, applied to the study of materials such as paper, ink, parchment, textiles, canvas, and photographs. Applications range from determination of age and provenience to modelling of material properties and estimation of future stability of heritage objects. Modelling of material stability with non-destructive methods is most interesting in the assessment environmental risks to heritage collections and will give hints about the processes governing the degradation reactions.

Luca Uzielli (*Univ. of Florenc*e, *Italy*), chair of COST Action IE0601, "Wood Science for Conservation of Cultural Heritage", discussed applications of Materials Science to conservation issues. This COST action aims to improve the conservation (including study, preventive conservation and restoration) of European wooden cultural heritage objects, by fostering targeted research and multidisciplinary interaction between researchers in various fields of wood science, conservators of wooden artworks and scientists from related fields. The action's final conference will take place in Paris in November 2011. Cultural Heritage results from this action was presented. A better understanding of *ageing processes and their effects* on wood is needed, as well as *techniques for their detection and evaluation*. Although processes might be very slow, they could still be very serious after a few decades. Further *improvement of non- or minimum-invasive techniques*, mainly dealing with instrument portability, efficiency, resolution, cost and ease of use are needed. The *connection between climate and degradation* is important, in particular in a world where the climate is changing. *Better preservation techniques and consolidants for degraded wood* are needed, as well as better *methods for assessment of the load-carrying capacity of timber structural elements*. Better general *guidelines for assessment and documentation of cultural heritage artefacts* are also needed.

Philippe Colomban *(CNRS, Université Pierre-et-Marie Curie, Thais, France)* stressed the importance of *portable instruments and non-invasive analysis* for scientific study of cultural heritage materials. Development of such devices is linked to progress made in other fields, such as instrumentation for military and aerospace applications. Together with the rapid development of computers, this has led to a revolution in the scientific instruments: their size and weight have decreased by one order of magnitude, as illustrated by the development of *portable Raman devices*. Raman spectroscopy offers a "bottom-up" approach to nano materials and amorphous compounds such as glass. The information obtained by Raman spectra may help in tracing the origin of an artefact. Thus, the development of preparative chemistry since the 14^{th} century has led to new inorganic and organic pigments, giving reliable chronological markers. Using mobile instruments, the study of artefacts such as pastels, bronze, pottery, glass and enamels is possible in the museum rooms or even outside; building parts (e.g. stained glasses), rock art paintings, etc, can be studied. At present, laser wavelengths available for portable instruments are limited to green for inorganic samples and red for organic compounds; the near infrared or ultraviolet/visible spectral range may be obtained by portable sources; convenient miniaturized spectrometers will be available in the near future.

Posters dealt with the effects of thermohygrometric variations on wood panel paintings, development of biopolymers of microbial origin for cleaning of stone artwork and of polymeric systems for cleaning of painted surfaces, use of composite hydroxide/silicate nanomaterials for conservation of architectonic surfaces, techniques based on solid-phase immunoassay and amino acid assay for analysis of protein binders in paintings, and analysis of the effects of fungi colonization and blackening on artistic marbles and limestone.

Subsession 2.2: Archaeometry

This is a broad interdisciplinary field covering the application of many scientific branches (chemistry, physics, geology, mineralogy, biology, material science, etc.) to Archaeology and History of Art.

Vincent Serneels (*Univ. Fribourg, Switzerland*) discussed the archaeology of iron production. Iron is the most efficient metal for the production of tools and weapons and of high strategic and economic importance for pre-industrial societies. At a regional scale, the global approach offers the opportunity to reconstruct the socio-economic patterns and to describe the organization of the production. Ancient production technology of iron can be reconstructed using different approaches such as analysis of excavations, and (the generally scarce) leftover materials such as slag heaps, charcoal remains etc, combined with experimental reconstructions. It was emphasized that in Northern European countries, mining and metallurgical remains from production of iron and other metals are now being recognized as a significant part of the cultural heritage (15 sites on the UNESCO list involve mining or metallurgical remains), whereas in Southern Europe, attention has been paid almost only to the most ancient periods. This gap should be filled by cooperative work in the next future.

David Bourgarit (*Centre de Reserche et Restauration Musées de France, Paris, France*) demonstrated the usefulness of *experimental laboratory simulations of ancient metallurgical processes* for their clarification and quantification. Multiple-scale simulation is developed, ranging from the modelling of the theoretical mechanisms underlying the processes, to the field reconstruction of the real operation. Experiments based on model systems where complexity is gradually increased, is a way to optimize the scanning of working conditions. In this way, ancient brass cementation processes have been elucidated. A plus value of this experimental approach is education (of students and of a larger audience, and self-education) taking advantage of the fact that people with a variety of backgrounds are working together, including archaeologists, historians, archaeo-metallurgists, founders, curators, restorers, metallurgists from the modern industry, and furnace designers.

Aurelio Climent-Font (*Universidad Autonoma de Madrid, Madrid, Spain*) presented the use of *Ion Beam Analyses (IBA)* to the study of works of art, with particular reference to lustre ceramics. Lustre is a process for decorating glazed ceramics by inserting metallic nano particles into the existing glaze covering the ceramic object, a method first developed in the Middle East (9^{th} AD). A variety of analytical techniques have been dedicated to characterize the lustre. The complementary use of IBA techniques like *Rutherford backscattering spectrometry (RBS)* and *Particle Induced X-ray Emission (PIXE)* has been successful for the characterization of lustre ceramics.

Vivi Tornari *(IESL, Heraklion, Greece*) provided an overview of the development of *laser technology* as an analytical and structural tool and as a surface cleaning method together with a presentation of state-of-the-art instrumentation. The specific case of structural diagnosis has been developed in the last decade through two specific projects of FP5 and FP6, resulting in new applications ranging from direct surface monitoring to assessment of impact and tracing of fraud art market.

Posters described methods for analysis and preventive conservation of contemporary artworks by pyrolysis and GC/MS, the use of various spectroscopic microanalyses (Raman, ATR, LIBS) for pigments used in Ethiopian rock art paintings, characterization of ancient mortars and manufacture of modern ones to be compatible when used for restoration or consolidation of ancient buildings, Surface-Enhanced Raman Scattering (SERS) for analysis of micro-invasive samples of textile dyes, novel consolidants for wood conservation with structures similar to wood, and experimental monitoring of the poplar wood panel of the Mona Lisa painting.

Subsession 2.3: Climatology and influence on monuments and artefacts

Carlota Grossi Sampedro (*Univ. East Anglia, Norwich, UK*) stressed that the chemistry of the atmosphere is changing in response to climate changes and new environmental policies. The environment is rapidly changing and new models are needed to predict the fate of our cultural heritage. Even a cleaner atmosphere is a factor of increasing importance. Research on the impact of climate change on cultural heritage, such as the pioneering NOAH's ARK and the "Climate for Culture" projects is important in this context. The concept of *"Heritage Climatology"* is the study of how climate parameters affect monuments, materials and sites.

A future challenge is the need of extensive research in the area of climate change and stone heritage. Such research should include:

- Improving the knowledge of stone vulnerability to climate (proxies for damage, climate parameterisation and damage functions);
- Monitoring long-term changes;
- Development and down-scaling of high spatial and temporal climate resolution models to modelling work for urban areas;
- Estimation of reliability and uncertainty;
- Management and development of long-term strategies to prevent damage.

Koen Janssens (*Department of Chemistry, University of Antwerp, Belgium*) presented the potentialities of *macroscopic scanning X-ray fluorescence (MA-XRF)* as a non-destructive analytical technique suitable for monitoring of artefacts, in particular paintings by Old Masters, where it may provide a wealth of novel information. Underlying paint layers may be

investigated, demonstrating for instance underdrawing, underpainting and alterations. Abandoned compositions on paintings can be discovered, illustrating the artists' practice to re-use a canvas or panel. Such information is also often highly relevant in conservation, when stability problems such as paint discolouration or delamination are studied. Work of this kind is a common research theme shared by curators, conservators and conservation scientists. The method has a great potential, both for art-historical studies as well as for conservation studies of painted works of art and associated value judgements.
A poster discussed the importance of climate monitoring and -control and its importance for the best conservation conditions for objects exposed inside museums.

Subsession 2.4; Novel non-destructive techniques for diagnostics

Rinaldo Cubeddu (*Physics Department, Politecnico of Milano, Italy*) described the development of non-invasive methodologies and portable instrumentation for in situ studies of works of art. *Optical and laser spectroscopy* techniques offer possibilities to identify both the inorganic and organic components of artistic objects with high sensitivity and reproducibility. The possibility to operate with instruments capable to collect spectral information from adjacent points in order to reconstruct spectral maps of artefacts was described. The advantages of imaging techniques, rather than single point measurements, were emphasized. No single technique can face the complex problems encountered in cultural heritage analysis, while the synergic combination of in situ measurements and laboratory techniques allows one to gather the information required for a well designed conservation intervention.
Motoyuki Sato (*Tohoku University, Japan*) presented the *ground-penetrating radar (GPR)* technology, capable of recording information about the subsurface. GPR is mainly employed in prospecting campaigns allowing discovery, mapping and imaging of buried archaeological remains not accessible using traditional field methods. It can be used to guide excavations or to define sensitive areas containing remains to be avoided. The success depends on soil and sediment mineralogy, clay content, ground moisture, depth of burial, surface topography and vegetation. These aspects were discussed also in relation to the consequences of the earthquake and tsunami that attacked Japan on the 11th March, 2011.
Posters presented a multitude of novel instrumental methods for monitoring of cultural heritage objects, such as non-destructive technologies for in situ analysis by use of portable spectrometers, novel early-warning systems for protection of indoor cultural heritage (detecting volatile organic compounds), Hyper-Spectral Imaging for non-invasive diagnostics of paintings and surfaces, remote sensing laser technology for detection of instability of cultural heritage due to geohazards, tetrahertz imaging technology for investigation of artworks, microwave interferometers as a tool for detection of vibrations in buildings, technology for measure of moisture content in historical masonry, radar interferometry for detection of structural deformation and terrain motions, and –finally- infrared thermography (IRT) for detection of heat diffusion processes in samples, providing information on material, structure and processes.

2. Summary and Conclusions

Some general conclusions can be drawn from the material presented in this session.

- **New instruments and technologies**

  There is a current rapid technical development of instrumentation and methods for investigation of cultural heritage artefacts stimulated by the rapid and accelerating progress in computer technology, physics and chemistry, and by easier access to large scale instrumental facilities. It is easy to foresee that this development will continue and accelerate even more. Two main lines can be identified:

  1. Development of novel portable, easy-to-use instruments enabling non-invasive investigation of artefacts, often directly on site in the museum, usually without need of transport or destructive sampling, and often based on spectroscopic techniques.

The workshop has given a multitude of examples of such methods. Another line of development in this field is the construction of instruments for remote sensing like the ground-penetrating radar and the remote sensing laser technology.

2. Easier access to large-scale international facilities, such as synchrotrons (e.g. ESRF Grenoble, SSRL Stanford, MAX Lund, Daresbury, UK) and neutron sources (like the European Spallation Source, ESS, now under construction). Use of these facilities enables detailed chemical analysis of speciation and distribution of chemical species in artefacts, not accessible by the small-scale instruments. However, they usually require destructive sampling. Development towards more powerful radiation sources will enable smaller samples.

In general, new technologies such as *time-resolved laser spectroscopy, ultrasound techniques and micro-calorimetry* might offer further possibilities for elucidation of the state of art of archaeological materials. Synchrotron radiation-based *X-ray Absorption Spectroscopy (XAS)*, an already well established investigation method, and synchrotron-based *infrared micro-spectroscopy* will develop further for studies of artefacts, as well as *neutron tomography and computer tomography*.

Development of techniques based on *microbiology or molecular biology* will be important for the diagnosis of artefacts in terms of their historical and current microbial status. They are also important for the understanding of microbial degradation processes.

Development of *advanced computer simulations* involving finite element methods will be important for extrapolation of physical data determined for structural elements to complex macroscopic structures such as bridges, buildings and ships, as a basis for strategic decisions on future preservation measures.

- ## New preservation methods

Novel materials and procedures for stabilization and preservation of heritage materials are being developed. For instance, novel consolidants for archaeological wood could be based on spontaneous assembly to supramolecular structures, and be given properties allowing capture of free radicals and detrimental metal ions. This will be an important field for future research in organic synthesis and supramolecular chemistry. Methods for extraction or neutralization of detrimental chemicals from artefacts are other important fields of future research.

A number of contributions have described the development of novel materials for consolidation or cleaning of surfaces of heritage objects like stone and buildings, paintings and mural artwork. In this field research in nanoscience, material science and chemistry will offer future advances. Laser technology has proven to be an alternative very efficient cleaning method.

Methods for removing undesirable substances and conservation agents followed by re-conservation with state-of-the-art techniques are also a field of current great importance.

- ## Lacks of knowledge

Determination of ageing processes and ageing rates of heritage materials are fundamental parameters for strategic decisions on their long-term preservation. Satisfactory methods to determine the rates of degradation processes in various materials are still not available but urgently needed.

A future challenge is the need of extensive research in the area of climate change and cultural heritage artefacts. Understanding the connection between climate and deterioration is extremely important, in particular in a world where the total climate is changing. For example, a deeper understanding of degradation mechanisms of paint layers (in particular on wooden panels) as a function of local climate fluctuations is urgently needed. In general, high-tech climate installations and monitoring systems are necessary for long-term safe preservation of valuable artefacts.

- **Forefront topics**

  Can be shortlisted as, for instance:
  - Development of novel portable, easy-to-use instruments
  - Increased utilization of large-scale international research facilities
  - New techniques for evaluation of nature and absolute rates of degradation processes
  - Methods to stop/decelerate degradation processes
  - New technologies for non-destructive analysis and monitoring
  - Elucidation of connections between climate and deterioration
  - Better techniques and materials for consolidation and cleaning of artefacts
  - Methods for assessment of load-carrying capacity of structural elements
  - Development of standards and guidelines for care of European cultural heritage

- **Interdisciplinary research**

  Conservation and preservation of heritage materials is by nature interdisciplinary. For instance, current research on the Vasa warship involves close co-operation between scholars from e.g. wood chemistry and technology, molecular biology, physical, inorganic and organic chemistry, materials science, nanotechnology, mechanical engineering, computer science and conservation science. Similarly, preservation research on artwork such as paintings, ceramics, glassware, sculptures and buildings will need close co-operation between specialists in various branches of natural sciences together with those in history, history of art, architecture, etc. The investigations exemplified by the studies of early metallurgical processes and mining offer possibilities for co-operative research involving technology, chemistry, history, economy and social sciences. The exposure of heritage artefacts to a changing climate and to environmental pollution of various kinds necessitates close co-operation between specialists in climatology, atmospheric chemistry and preservation science. The ground-penetrating radar is an example of cross-fertilization between archaeology and geophysics. Thus, interdisciplinary research is and will be of paramount importance for future successful preservation research in the Cultural Heritage area in total.

  At the same time, a close co-operation between scientists, who are usually based in universities or other research institutions, and those responsible for the practical preservation work will be necessary and should be stimulated through educational efforts.

- **Educational aspects**

  Novel investigation and preservation methods and new instrumentation are usually developed at university laboratories or other research institutions. A successful knowledge transfer to those responsible for the cultural heritage will most certainly in the future necessitate increased recruitment of scientifically educated and trained museum staff, as well as an improved university education at advanced level in natural sciences and technology directed towards the cultural heritage area.

  Research in the area of cultural heritage stimulates cross-fertilization between different fields of competence. Noteworthy, scientific research on cultural heritage problems is usually very interesting for the general public, mass media and school children, and could enforce the interest for and understanding of research in natural sciences and technology in Europe, which will be an important bonus effect.