Commission on Crystallography in Art and Cultural Heritage

CRYSAC ACTIVITIES TOWARDS A CRYSTALLOGRAPHY-BASED KNOWLEDGE OF ARCHAEOMETRY AND CONSERVATION

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Abstract

The Commission on Crystallography in Art and Cultural Heritage of IUCr (CrysAC) is active in promoting crystallographic culture and methods in the field of cultural heritage (CH). Since symmetry is at the core of crystal -lographic analysis, by tradition and cultural background the commission is concerned with the application of symmetry analysis to natural systems and human artefacts, especially in the built heritage and architecture. However there is a growing demand of crystallographic knowledge from artists and conservators. Furthermore crystallographic methods and techniques are of vital importance in the modern analysis of materials and may greatly contribute to the demanding challenges facing the valorization and conservation of cultural heritage. As a consequence the activities of the commission are also focused towards extending the crystallographic culture among the diverse communities dealing with the management and investigation of art, archaeology, and architecture. The pervasive and intrinsic fascination of symmetry perceived macroscopically in artistic and architectural decorations is now extended to the perception of the beauty and importance of crystal structures for the microstructure of cultural heritage materials.

Introduction

The relationship between crystallography, art and cultural heritage has existed for a long time. Both scientists and artists learned from and often inspired each other. At the XX Congress of IUCr in 2005 in Florence, Italy, during the microsymposium 'Crystallography and Understanding of Cultural Heritage' chaired by H. Schenk and S. Siano, the concept of a new IUCr commission emerged. Eric Dooryhée, who delivered a lecture on 'Powder diffraction in art and archaeology'at the microsymposium in Florence, then guided the proposal for the creation of the new IUCr commission. CrysAC was formally launched at the Osaka Congress in 2008.

The Commission is concerned with two main issues:
Crystallography and symmetry in art;

Crystallographic analysis (e.g. diffraction-based) of artworks and ancient materials [1].

Let there be symmetry….

Virtually all crystallographers commonly employ C.M. Escher's two-dimensional periodic patters as graphical examples to introduce lattices, unit cell vectors, multiplicity, plane space groups, and a number of other fundamental concepts of crystallographic symmetry. The intrinsic fascination of symmetry is at the core both of the crystallographic description of matter and the artistic search for beauty. It is nothing else than natural that the symmetry analysis of art and decoration has played an important role in the relationship between crystallography as a scientific discipline and the broader community dealing with artworks, architecture, and graphics. Starting from the pioneering analysis of Escher's graphics by Caroline MacGillavry (Fig. 1), which resulted in a volume that each crystallographer perused in his/her life, the research on the theoretical and practical aspects of symmetry (… and symmetry breaking) has greatly advanced into non-periodic and quasi-periodic symmetry, N-dimensional space-groups, incommensurate structures, fractal structures, and many more. In parallel, the identification and description of symmetry in art and architecture has advanced, showing that quasi-dimensional symmetry is indeed found in ancient Arabic patterns and architectural decorations. The relationship between the formal description of symmetry (the task of the crystallographer) and the fascination of decorative patterns (the work of the artist) is nowadays becoming more complex, but it inevitably maintains the charm of discovering the inner beauty of nature, besides the mental processes governing human evolution and artistic creativity [2, 3].

The quest for understanding and describing symmetry has been and continues to be a major and very successful effort by the crystallographic community. It has found adequate resonance in the activities of the CrysAC Commission and wide public display at conferences and meetings, including the review lectures presented at the Opening Ceremony (Paris, France – 20-21 Jan 2014) and Legacy Conference (Rabat, Morocco - 22-24 April 2015) held during the International Year of Crystallography 2014.

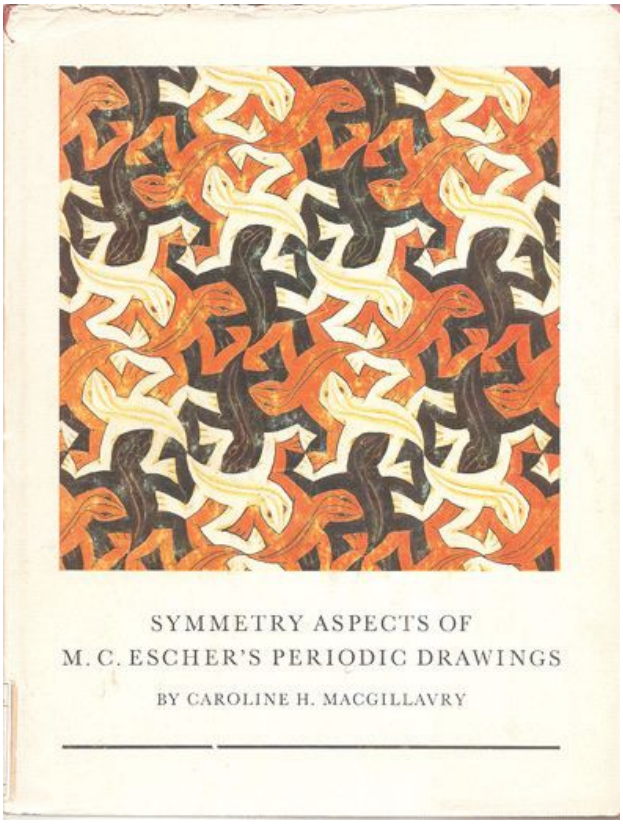

Figure 1. Original edition of Caroline H. MacGillavry's symmetry analysis of Escher's graphics [4].

The materials of cultural heritage: new challenges for crystallography

Beyond symmetry, the major contribution of crystallography and crystallographic techniques during most of the 20th century has been to accurately describe natural and synthetic crystal structures and their relationship with their physico-chemical properties. The traditional concept of structure-properties relationship is now generally extended in modern materials science as a more complex interaction between materials structure, properties, processing, and performance (Fig. 2). The crystallographic characterization of the system of course remains at the core of the whole process of understanding the material, including its thermodynamic history and fate.

It is straightforward to translate the basic concepts of materials science into the common problems to be faced when analysing artistic and archaeological materials, i.e. the materials of cultural heritage. However it should be kept in mind that CH materials may present specific problems for technical analysis, especially related to issues of heterogeneity, preciousness, and alteration.

On one hand the typical questions asked during archaeometric investigation are "how, why, when and where was the object made?" That is the knowledge of the archaeological materials needs to be translated into the interpretation of human activities and its past history. As an example, the phase composition of the same pigment may have evolved over time and space, and determining pigment composition and microstructure in historical artworks can give clues about provenance, quality, etc. For instance, the ubiquitous lead white pigment is traditionally made of a

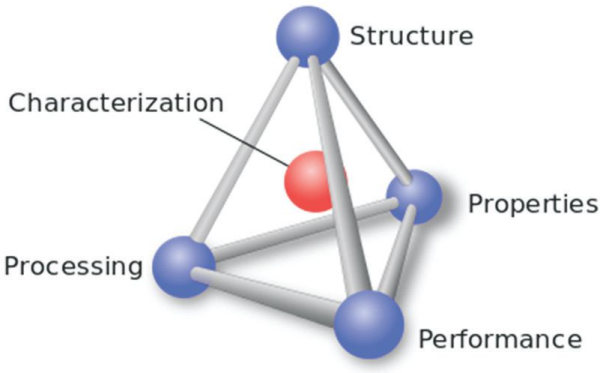

Figure 2. The structure-properties-processing-performance tetrahedron in modern materials science (modified from [5]). The crystallographic characterization of the system remains at the core of the whole process of understanding.

mixture of cerussite ($PbCO_3$) and hydrocerussite ($Pb_3(CO_3)_2(OH)_2$). The determination of the ratio of these two phases and of the crystallite size in tiny fragments from historical paintings gives indications about the processing and post-processing (e.g. washing, heating, levigation) steps of the pigment synthesis and shows clear historical evolutions [6]. Related to that, another important area of intervention is the authentication and the complex issues concerning the illicit traffics of art and archaeological artefacts. Crystallographic techniques are of great relevance to define the origin and state of the materials, and to help setting the space-time frame of the problem.

On the other hand conservation science is rapidly broadening its typical fields of action such as the conservation of museum objects, built heritage, and archaeological sites. Challenges are escalating, mostly in relationship to the demanding pressure of touristic fruition and consumption of land resources. Climatic changes are changing the parameters and the extent of degradation of existing structures and infrastructures, so that the safeguard of UNESCO sites is a global challenge. Although the basic concepts of conservation are well established, mainly through the ICOMOS charters, the practical protocols of intervention and management are often open problems. One analytical issue is that while original artistic compounds may usually be well crystallized, their degradation products may be less ordered, making their characterisation more difficult. Besides, compatible and reversible materials for restoration and conservation is one area where materials science and crystallography have a say.

Indeed, the two above classes (i) reactions operated by the artists and craftsmen during the manufacturing of the object and ii) posterior reactions, mainly due to environmental factors such as pollution, light), cannot be fully decoupled since the stability of artworks directly depends on its composition. As an example, chrome yellows age differently depending on their composition: monoclinic $PbCrO_4$ are rather stable, while orthorhombic $PbCr_{1-x}S_xO_4$, rich in SO_4^{2-} ($x \geq 0.4$) darkens under UV-visible light. Artists such as Van Gogh have used in the same paintings different qualities of chrome yellow, which therefore exhibit, more than one century later, different state of conservation [7].

It worth mentioning that extensive networks of laboratories are now active, many through international projects involving large scale facilities and museums. Competences and technical know-how for characterization of cultural heritage are regularly available in many countries, although adequate interface between the scientific laboratories and the humanities-related actors may be lacking. A particularly interesting program of collaboration is being developed in Mexico between the National Laboratory of Sciences for Research and Conservation of the Cultural Heritage (LANCIC [8]) and the two main federal government agencies in charge of protecting and preserving cultural patrimony of the country. LANCIC is funded by CONACYT, the Mexican National Scientific Funding Agency, and was established as a network of laboratories of national academic institutions working in the area of cultural heritage. The federal government agencies involved are the National Institute of Anthropology and History (INAH) and the National Institute of Fine Arts and Literature (INBAL). INAH is responsible for the archaeological (paleontological and pre-Hispanic) and historical structures, museums, zones and remnants. On the other hand, INBAL is responsible for monuments, art museums, galleries, artistic buildings and other properties of significant aesthetic value. A good number of undergraduate and graduate thesis, books and book chapters, scientific publications and other printed materials have already been produced.

For example, the treatment and interpretation of the high-throughput data produced at synchrotron and neutron facilities is still a common problem. Also, data policy and open access to experimental data is an important subject of discussion, and starts to be implemented at some facilities.

The CrysAC Commission believes that the crystallographic community may greatly contribute towards finding new solutions to such challenges and towards a better integration of science and CH.

Besides stimulating research, creating connections, and organizing specific presentations at meetings (X-ray and Other Techniques in Investigations of the Objects of Cultural Heritage, every two years, Krakow, Poland [9]; ALMA interdisciplinary conferences, every two years, Czech Republic [10]) and workshops, one of the most successful recent initiatives of the Commission is the organization of the CrysAC Workshop, with an innovative formula that brings crystallographers to different communities on specialized topics concerning CH.

The first three CrysAC Workshops were focused on "Cultural heritage authentication and forensic science" (Krakow, Poland – 18 May 2016), "Applied crystallography in the study of pigment degradation" (Brno, Czech Republic – 2 June 2017), and "Recent advances in the investigation of ancient mortars and binders" (Merida, Mexico – 20 May 2018). The 4th CrysAC Workshop CHEMFORS was a satellite event of Latin American Conference of Analysis by X-ray Techniques (SARX-2018) in Pucon, Araucania, Chile (November 8-9, 2018) and 5th Workshop "Crystallography of ancient metals and metal corrosion" is going to be organized in Vienna on 17 August 2019, before 32nd European Crystallographic Meeting. More Workshops are planned, with the intent of sharing crystallographic knowledge and bringing crystallographers and CH scientists to diverse audiences.

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