

# Geoscience for cultural heritage: challenges and innovative methods

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Crystallographic techniques, firmly established within geoscientific research, have long played a crucial role in the study and characterisation of cultural heritage materials. Many archaeological and artistic artefacts are composed of geomaterials whose provenance, structural identity, and conservation state can be significantly elucidated through detailed mineralogical and microstructural analysis. X-ray diffraction (XRD) provides critical insights into these attributes, with non-destructive approaches being particularly valuable when working with rare or irreplaceable objects that cannot be sampled or physically altered.

The full potential of crystallographic analysis in heritage science is best realized when it is integrated with a broader suite of X-ray-based techniques, including X-ray fluorescence (XRF), computed tomography (CT), and synchrotron radiation methods. This multimodal approach enables a comprehensive understanding of both the composition and internal structure of cultural heritage materials across multiple spatial and analytical scales, thereby informing more precise and evidence-based conservation strategies.

The increasing accessibility of large-scale research facilities has further expanded opportunities for the investigation of complex micro-samples from invaluable artefacts. These integrated analytical frameworks—X-ray-based methods in particular—facilitate the identification of crystalline phases in a range of materials, including pigments, ceramics, mortars, and metals. They are instrumental not only in material characterisation, but also in supporting technological reconstructions, authenticity assessments, and the monitoring of degradation processes.

A selection of significant recent research—both published and unpublished—will be discussed to illustrate the application of these methods across diverse materials and heritage contexts. These case studies demonstrate how integrated crystallographic and X-ray-based approaches contribute to diagnostics, reveal material identities, support authenticity verification, and inform conservation interventions.

The synergy between crystallography and broader geoscientific methodologies underscores the importance of interdisciplinary approaches in heritage science. This overview highlights the essential role of collaborative, scientifically informed strategies in advancing heritage diagnostics and the long-term preservation of cultural materials.