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Radiation methods in research of ancient monuments

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Abstract

A "Laboratory of Quantitative Methods in Monument Research" is being built at the CTU Prague. Its primary orientation is the investigation of historic architecture, although other objects of art can also be investigated. In the first phase, two radiation methods are being established, but it is set up in such a way, that various other methods can readily be added in its future development. The radiation methods chosen for the initial development of the laboratory are: thermoluminescence dating and X-ray fluorescence analysis. The design of the automated TL-reader, built in our laboratories, is adjusted for the purpose of dating of historic brick architecture (which, of course, does not exclude applications for ceramics and other materials). The investigation of renaissance architecture in southern Bohemia and Moravia is under preparation as the first large campaign of this kind in the Czech Republic. Radionuclide X-ray fluorescence analysis has been chosen as the basic analytical method in the laboratory. The possibility of analyses of paintings and fired building materials (bricks, roof tiles) have been investigated. The first results in both the areas are very promising.

Keywords: Thermoluminescence dating; X-ray fluorescence analysis; Ancient monuments; Historic architecture

1. Introduction

Traditional research methods in the history of art and architecture, deriving their conclusions from stylistic, typological, archival or similar evidence cannot always solve questions of the age or the origin of archaeological artefacts or works of art, or their conclusions are not convincing. Therefore, research in historic disciplines, particularly in monument conservation, is increasingly applying investigative methods based on the hard sciences. These methods can be roughly divided into three groups:

1. Dating methods: usually they were specifically developed for solving the problems in the fields of the history of art and architecture, archaeology, or closely related fields.
2. Analytical methods (where "analytical" is used in a very wide sense of the word): these methods have a much wider range of application than only in archaeology and in the history of art and architecture, but have given these areas a powerful new tool.
3. Various topographic and geometric methods: these can also contribute to the total sum of knowledge

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about some works of art, especially in the field of architecture (however, these methods are not of interest to this paper).

Specialised laboratories have been established to carry out investigations using these methods (a typical example of such a laboratory is the "Research Laboratory for Archaeology and the History of Art" at Oxford University, UK).

A wide variety of dating methods has been developed for the purposes of archaeology and history of art: Radiocarbon (^{14}C) is the best known one; other frequently used dating methods applying ionising radiation are thermoluminescence (TL), optically stimulated luminescence (OSL), electron spin resonance (ESR), decay chains of natural radionuclides, etc. Dendrochronology, a biological method, is a very interesting possibility of dating, allowing in some cases the determination of the exact year when a tree was felled (in many instances this concurs with the year when a wooden artefact was manufactured, or less frequently, a wooden element inserted into a building). It does not use ionising radiation, but it is often applied for the cross-checking of radiation methods.

Analysis of materials from which artefacts are manufactured can give important information about the origin, production technologies and about the authenticity of an archaeological find or a work of art. Trace elements, such as rare earths, are usually the most important indicators from this point of view. Various methods for the analysis of the composition can be used, such as activation analysis, all modifications of X-ray fluorescence analysis, atomic absorption spectrometry, inductively coupled plasma, Mössbauer spectroscopy, "classical" chemical methods, etc. X-ray radiographic, gammagraphic or neutronographic imaging and autoradiography can also be included in this group, as these methods are closely related to these analytical methods, both in regard to the possible results and to some methodical and instrumental aspects.

As it is seen from this review, nuclear radiation has become a powerful tool for research in dating of various artefacts and their analysis for trace elements, which can substantially contribute to the traditional methods of research in this field.

2. Laboratory of quantitative methods in monument research

A "Laboratory of Quantitative Methods in Monument Research" is being set up at the Czech Technical University in Prague, in collaboration between the Faculty of Nuclear Sciences and Physical Engineering and the Faculty of Architecture with the financial support of a grant from the Ministry of Education, Youth and Sports of the Czech Republic. Its primary orientation is the investigation of historic architecture, although other objects of art can also be investigated. In the first phase, two radiation methods are being established, but the laboratory is set up in such a way, that various other methods can readily be added in its future development. The radiation methods chosen for the initial development of the laboratory are thermoluminescence dating and X-ray fluorescence analysis.

3. Automated TL-reader

Dating brick walls within a historic fabric is an important aid not only for architectural history, but also, in the decision-making process for the adaptation, revitalisation, restoration and reconstruction of architectural monuments. Though the basic principle of thermoluminescence dating is analogous to the dating of ceramics, volcanic materials or sediments, the dating of bricks is rarely discussed and is less widespread. Nevertheless, some investigations leading to valuable findings, both about the method and about the architectural development of historic buildings, have been published and show the need for this application, e.g (Goedicke et al., 1985; Erlach and Vana, 1988; Goedicke and Holst, 1993; Chiavari et al., 1999).

Due to the specific TL characteristics of bricks and the complexity of the historical questions asked of this method, it becomes necessary to analyse samples from many locations (bricks) in order to obtain a relevant date for the building of the wall (or, more precisely, the firing of its bricks). Moreover, the necessity of

1. TL sensitivity calibration of the brick material, and
2. an exhaustive statistical evaluation of measurements for minimising the random error,

requires multiple sub-samples (up to 30) from each sampling location (i.e. each brick). The analysis of the necessary number of samples is very time consuming, and the development of a maximally automated reader seems the only acceptable solution to obtain historically relevant results in a reasonable time-frame.

On the other hand, this modification of the method leads to substantially more accurate results when compared with its application to ceramics of archaeological provenience. Generally, the physical and statistically justifiable error margin (thus, the date range usable for historic interpretation) is heavily dependent on the physical behaviour of the samples, and on the location from which the samples were removed. The specific physical and chemical conditions in a brick wall led to a 're-thinking' of the traditional error calculation used for archaeological dating. Providing sufficient samples are taken from a homogenous brick wall of sufficient