Neutrons in the service of archaeological research

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Introduction

Archaeology, as a discipline, is classified generally more to scholarly arts than science. Seemingly, it is very far from 'hard core' natural sciences. On a closer look, however, we find that it has many elements of natural sciences, in fact, modern archaeology cannot do without the effective help of scientific methods, physics included.
At the primeval era of the discipline, archaeology relied most on visual observation and classification, much similar to 'style critics' approach of contemporary art historians. Prehistoric archaeology relied more on ethnographical observation, in a spirit of cultural anthropological research of our days. The necessity of setting up a reliable time scale, however, led to stratigraphical observations borrowed from earth sciences sneaking in the business.
The break-through event in the relation of archaeology and natural sciences was obviously the invention and general spreading of radiometric dating methods, notably ^{14}-C dating. This Noble-prize winning physical discovery has dramatically changed the paradigm of archaeology as a discipline and with the resulting change in thinking (i.e., archaeological argumentation can and should include natural sciences) gave rise to the revolutionary changes known as 'New Archaeology' (RENFREW-BAHN 1999).

Neutron analytical techniques

Neutrons were discovered relatively late among the constituents of the atom (Chadwick 1935). Analytical techniques using neutrons started to appear shortly after, including Neutron Activation Analysis (Hevesi and Levi 1936) which later became the most widely accepted multielement geochemical research method. Its application in archaeology started much later, in close relation to the development of 'New Archaeology' by the 1960-ies (Perlman-Asaro 1969). Since that time, neutron analytical techniques have been applied widely on various types of archaeological material and the resulting data are stored at various institutional databases (e., g., Missouri University, Manchester, Bonn (MURR) to cite some of the biggest. Apart from Neutron Activation Analysis, neutrons can be used for various purposes to investigate the samples including texture, structure and chemical composition.
Recently, in the framework of the Ancient Charm project we had the possibility to learn more and try some of these techniques. Our starting point is a very useful summary of these methods and their potentials in archaeometric analysis of archaeological objects, written by W. Kockelmann and A. Kirfel. In accordance with the main objectives of the project, they concentrate on imaging techniques mainly, but they also give a short overview of other neutron-based techniques used in the practice of archaeometry (Kockelmann--Kirfel 2007, Table 1.).
We would like to present here some topical examples of current application, possibly with relevance to Hungary and with direct relevance to our collection and/or personal research.

NAA, INAA

Neutron activation analysis has been used on most types of raw material. The first applecations concentrated on the study of a special type of Roman pottery of high technological standard, i.e., Terra sigillata, both in international archjaeometry research and also in Hungary. Staff of the Tanreaktor (Budapest Polytechnical University) started these measurements, with Márta Balla as scientist in charge of most projects.. We have considerable experience on pottery, some on lithics and other types of resources. The case study mentioned here is related to another highly standardised pottery type, the so-called grey pottery of the Avars (Early Mediaeval Period, 7^{th} century AD.) Investigations could delimit important workshops as well as spread of correcponding archaeological finds in the Central parts of Hungary.

PGAA

The invaluable advantage of this method for us is its non-destructive character. In collaboration with MTA-IKI we were trying to work on various types of stone tools like chipped stone raw materials, polished stone tools and other stone utensils and the reference library is gradually extended. We had also the possibility to participate in major projects including (mainly prehistoric) pottery. The case study presented here is part of a long-lasting program to compile reference library for various prehistoric lithic (='stone') raw materials. We have good results with specific raw materials like obsidian or felsitic porphyry but it is very difficult to work on varios kinds of silex (like flint, hornstone, radiolarite, limnic quartzite etc. that all have SiO_2 over 90 %. The number of known sources, which should be compared to the artefacts, is also very large and it is a time-consuming process to collect PGAA data on adequate amount of reference materials.

SANS

Small angle neutron scattering can be basically used to study the structural properties of certain materials. Its archaeological use is less common for the time being. Interesting experiments were made however on archaeological material, for example on Late Mediaeval organs, comparing them to modern specimens (not much difference found) and trying to extend methodology for marble provenancing (promising results).

ND-TOF

Similarly, neutron diffraction is mainly supposed to give structural information. Applications are concentrated on metal objects like axes or buckles. The resulting images can show technological details like hammering vs. casting.

NR/NT

Probably the most perspective for immediate use, neutron radiography and tomography can help in visualizing internal structures very fast. If routine application were possible, it could be of invaluable help for conservators and could support important decisions on the objects to be made by the curators. It is beginning to be a routine technique wherever it is directly available. There are interesting results, e.g., on belt garnitures with metal inlay. In Hungary, M. Balaskó made some nice images for conservation purpose on a Late Iron age helmet. In an ongoing project, pottery samples are currently under investigation.

Experiences

Neutron techniques can and should help the work of archaeologists and in general, people entrusted with the curatorial tasks of cultural heritage objects. The biggest problems, as we can see now, are:
- neutron analythical techniques require, as a rule, high technology environment, localised in major scientific research centres. Transport, safety and cooling conditions make the investigation of museum objects often tedious if not impossible.
- the costs involved are very high. Typically, it works to study specific objects on a cooperation basis but in most cases a representative series of measurements would be necessary to arrive at historically meaningful conclusions
- there is still major communication gaps between analysts and CH people which is not easy to overcome. CH persons tend to expect a miracle, but fast and cheap. Analyst contributing to the

knowledge of the material quality of the object need help in interpretation that is typically possible only by a lot more work, whether it will be fruitful or not.
- there is still too much data in the drawers waiting for publication, interpretation etc. because we cannot afford to work for the dustbin. By launching a fast and good possibility for publication in the form of the Archaeometry Workshop also serving as data repository if needed we hope to make analythical data accessible for all before they lose importance altogether. This has been the case, unfortunately, for a lot of important studies in the not very distant past.

Conclusions

Obviously, the neutron-based analytical techniques are very important for us. We can get important information on provenance, technology, workmanship, authenticity, guidelines on conservation and good ideas for visualization/presentation of our objects. The problem is, that neutron-based techniques are expensive and some of them time-consuming and therefore problematic to perform as routine means for CH studies. We have to work on meaningful projects with professional background both on the analythical and the archaeological side.

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