Look into the objects – why?

Assessment of cultural heritage motivations of neutron-based imaging techniques

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Methods used by Ancient Charm Collaboration for 3D mapping/imaging using neutrons (after Kockelmann-Kirfel 2006)

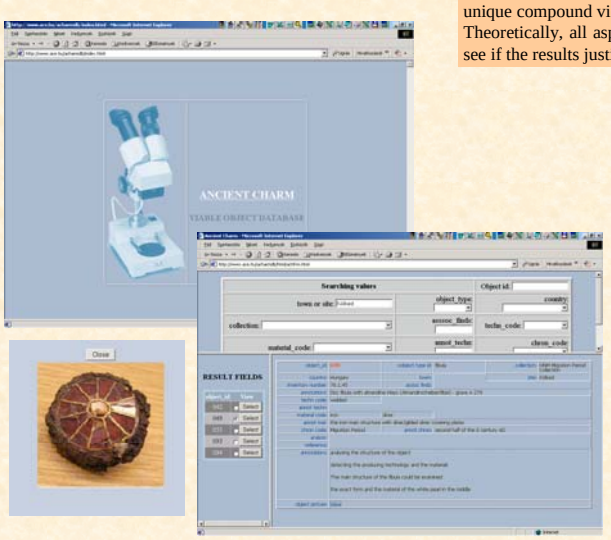
Introduction

Neutron Activation Analysis is routinely applied to archaeological materials for provenancing. Imaging capabilities of neutron analyses are hardly used as yet. Ancient Charm project aims at using the imaging features accessible by these techniques. The question addressed here is: why? Is it worth the trouble, who is the possible consumer and what is the suggested „best practice" we can foresee?

The techniques covered by Ancient Charm include elemental analysis techniques based on nuclear reactions. These techniques may provide different images of the interior, normally invisible parts of the objects: 3D contrast images, structural information on the (mineral) phases included, and elemental distribution. The application of these methods individually may provide important new information concerning the objects; their joint application offers a unique compound view .
Theoretically, all aspects of the objects can be studied - practically, we have to see if the results justify the effort.

Neutron imaging techniques (after Kockelmann--Kirfel 2006)

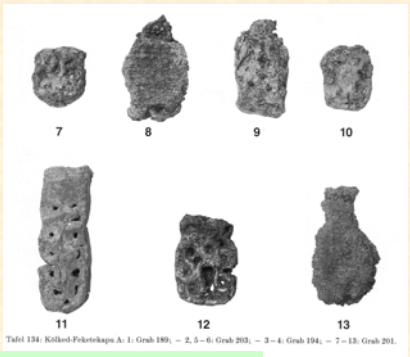
PGAI	Prompt Gamma Activation Imaging	based on thermal and cold neutron capture; prompt γ's; applied non-destructively on intact objects; high sensitivity for some light elements (H, K , Cl)
NRCA	Neutron Resonant Capture Analysis	based on epithermal neutron capture; prompt γ's; applied non-destructively on intact objects; good sensitivity for some heavy elements (Au, As, Ag, Sb, Sn)
NR/NT	***Neutron Radiography/Tomography***	real space imaging based on the capture and scattering of thermal and cold neutrons to provide an inside view of objects with a spatial resolution down to 100 micrometers; exploits the attenuation of a neutron beam passing through an object; attenuation contrast for different elements, high sensitivities for some light elements (e.g. hydrogen); contrast variation by variation of neutrons energies. Further imaging prospects are provided by phase contrast radiography which is based on neutron refraction
TOF-ND	***Time-of-Flight Neutron Diffraction***	based on the elastic scattering of thermal neutrons by periodic, long-range ordered (crystalline) or non-periodic, short-range ordered (glass) arrangements of atoms. Many structural aspects can be studied: phase and structure analysis, texture analysis, microstructure analysis; residual stress analysis. Bragg-Edge transmission for mapping of strains and phases is based on Bragg scattering
SANS	***Small Angle Neutron Scattering***	based on the elastic neutron scattering of thermal neutrons. Porosity of a material, and size and surface characteristics of mineral aggregates can be studied



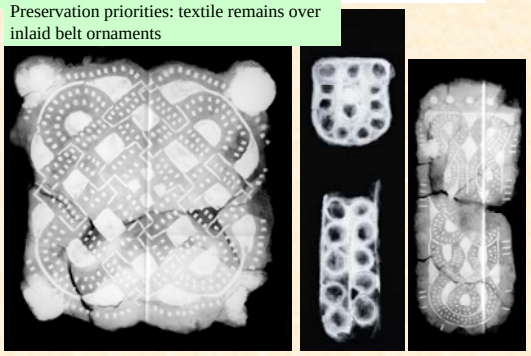
Objects for 3D elemental mapping
Archaeologists' choice
- Importance of the object
- Complexity
- Constraints
- Administrative ("value")

Analysts' choice
- Constraints
- Size
- Neutron scattering
- Remaining radiation

Purpose
- visualising, demonstrations
- "real" questions:
- technology (indirect: workshops, authenticity)
- conservation decisions



Preservation priorities: textile remains over inlaid belt ornaments

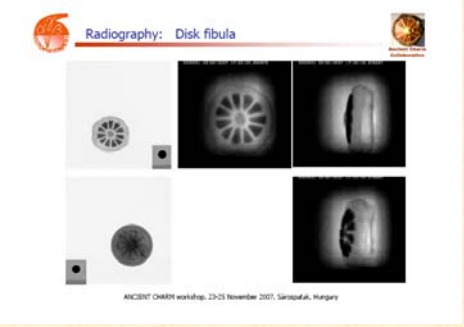


Conservation priorities: find out best treatment

Knowing simple physical parameters like dimensions, weight and specific gravity, archaeologists/conservators may find it necessary to investigate the internal parts of an object. Depending on the actual find circumstances, investigations can be carried out both on 'excavation fresh' or 'gem of collection' pieces, typically to define

a, best treatment
b, visualisation (for presentation)
c, increase scientific information available on the object

Technology priorities: find out production technology details



Presentation priorities: show the 'invisible' for a wider professional or lay audience, in context of exhibition, media events or publications

Suggestions for 'Best Practice'

It is suggested to start with the visualisation techniques first, which are fast and offer high resolution. They might be adequate for deciding if further neutron-imaging techniques for the determination of phase composition (=minerals) or elemental composition might be necessary, and if so, on which part of the objects. The next step is an assessment of bulk chemical composition (to be able to predict the behaviour of the object during the further steps of analysis). The continuation of the process may turn towards the identification of the spatial ordering of atoms (crystalline structure, orientation) and suspected different elemental composition of hidden parts. It is important to note that the resolution of neutron radiography/tomography is in the order of 100 microns, whereas the resolution of neutron diffraction and elemental analysis is a minimum of 1 millimetre, so their visualisation possibilities are widely different.
All observations should be carefully recorded in an unambiguously defined 3D coordinate system within the object. The interpretation of the data should involve both analysts and experts from the CH field. It is necessary to construct reference libraries for typical ancient techniques, even on simple objects.

Conclusions

Neutron imaging techniques can be widely applicable in 3D of mapping archaeological and other CH objects. These methods can be applied individually or as a package, providing both visual information on whereabouts of high/low contrast parts (NR/NT), phase composition of hidden "inclusions" and different phases inside the object (TOFND, SANS) or pinpointing parts of different chemical composition inside the objects (PGAA/PGAI, NRCA/NRCI).
The most likely candidates for in-depth analysis will be composite objects of elaborate workmanship, typically made, at least partly, of metal(s). Organic composite objects will probably give poor contrast for elemental mapping, as hydrogen is a strong neutronscatterer.

More on Ancient Charm Collaboration:

Central webpage: http://ancient-charm.neutron-eu.net/ach

WP1 webpage: http://www.ace.hu/acharm/