DEVELOPING NON-DESTRUCTIVE 3D MATERIAL ANALYSIS OF CULTURAL HERITAGE OBJECTS: PLANS FOR 'BLACK BOXES' AS TEST OBJECTS TO BE ANALYSED IN THE ANCIENT CHARM PROJECT

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Abstract

*In the framework of the Ancient Charm Project (*Analysis by Neutron resonant Capture Imaging and other Emerging Neutron Techniques: new Cultural Heritage and Archaeological Research Methods, http://ancient-charm.neutron-eu.net/ach), *imaging potentials of non-destructive neutron analytical methods are evaluated for archaeological applications. Prior to working on real archaeological specimens, so-called 'black boxes' were constructed (and characterised) for tests of the various methods. This paper is about the planning of the test boxes.*

Kivonat

*Az Ancient Charm Program keretében (*Analysis by Neutron resonant Capture Imaging and other Emerging Neutron Techniques: new Cultural Heritage and Archaeological Research Methods, http://ancient-charm.neutron-eu.net/ach), *különféle neutron analitikai vizsgálatok képalkotási lehetőségeit vizsgáljuk a kulturális örökség körébe tartozó tárgyakon. Mielőtt a régészeti műtárgyakat vizsgálnánk, a különféle vizsgálatok lehetőségeinek felmérésére kísérleti tárgyakat, úgynevezett "fekete dobozokat" készítettünk, amelyeken a módszereket kipróbálhattuk. Az alábbi cikk a próbatestek tervezéséről szól.*

KEYWORDS: NEUTRON BASED IMAGING ANALYSIS, EXPERIMENT PLANNING

KULCSSZAVAK: NEUTRON ALAPÚ KÉPALKOTÁSI TECHNIKÁK, KÍSÉRLETEK, TERVEZÉS

Purpose and aim of the constructions

In the framework of the Ancient Charm Project, several European research institutes cooperate in developing new non-destructive methods for 3-dimensional elemental composition and phase analyses (PGAI/NT and NRCI/NRT with NDT) to be applied on cultural heritage objects. In a first step of the collaboration of physicists and engineers, objects were needed that should be characterised by,

i) simple geometrical forms and

ii) simple elemental compositions in order to provide easily controllable situations fit to help with designing, setting up and exploring the new technologies.

The second step of work concerns testing the kind of archaeological and art objects that *in praxi* qualify for the new analyses. This means that it should at least be recognised to which extent the measurements require special care and how to conduct them without danger to the precious original objects. Besides studying these important questions it is also intended to test the kind of additional new data provided by the new methods as compared to conventional composition analyses.

In order to tackle these complex problems it was decided in the course of an early Ancient Charm project meeting (2006) to construct series of suitable calibration objects, so called 'black boxes'. This task was declared part of the work package responsible for the cultural heritage aspect.

Considerations in planning the constructions

The discussions about the 'black box' arrangements commenced with referring to a list of the most frequently encountered elements prepared by Tamás Belgya and Zsolt Kasztovszky. This table summarised detailed information about which elements are easily visible by means of gamma radiation spectroscopy and for thermal neutrons, how these elements affect the visibility of other sample components as well as to which sample thickness (in cm) measurements are feasible. The 'black box' elements were then chosen according to the Belgya & Kasztovszky absorption and scattering data and on their abundance in archaeological and art objects. 10-12 boxes were asked by the physicists and engineers. 2 or 3 of them should be open ones in order to improve and calibrate the respective methods. Another 8 or 9 pieces should be sealed for ensuring 'blind tests'.

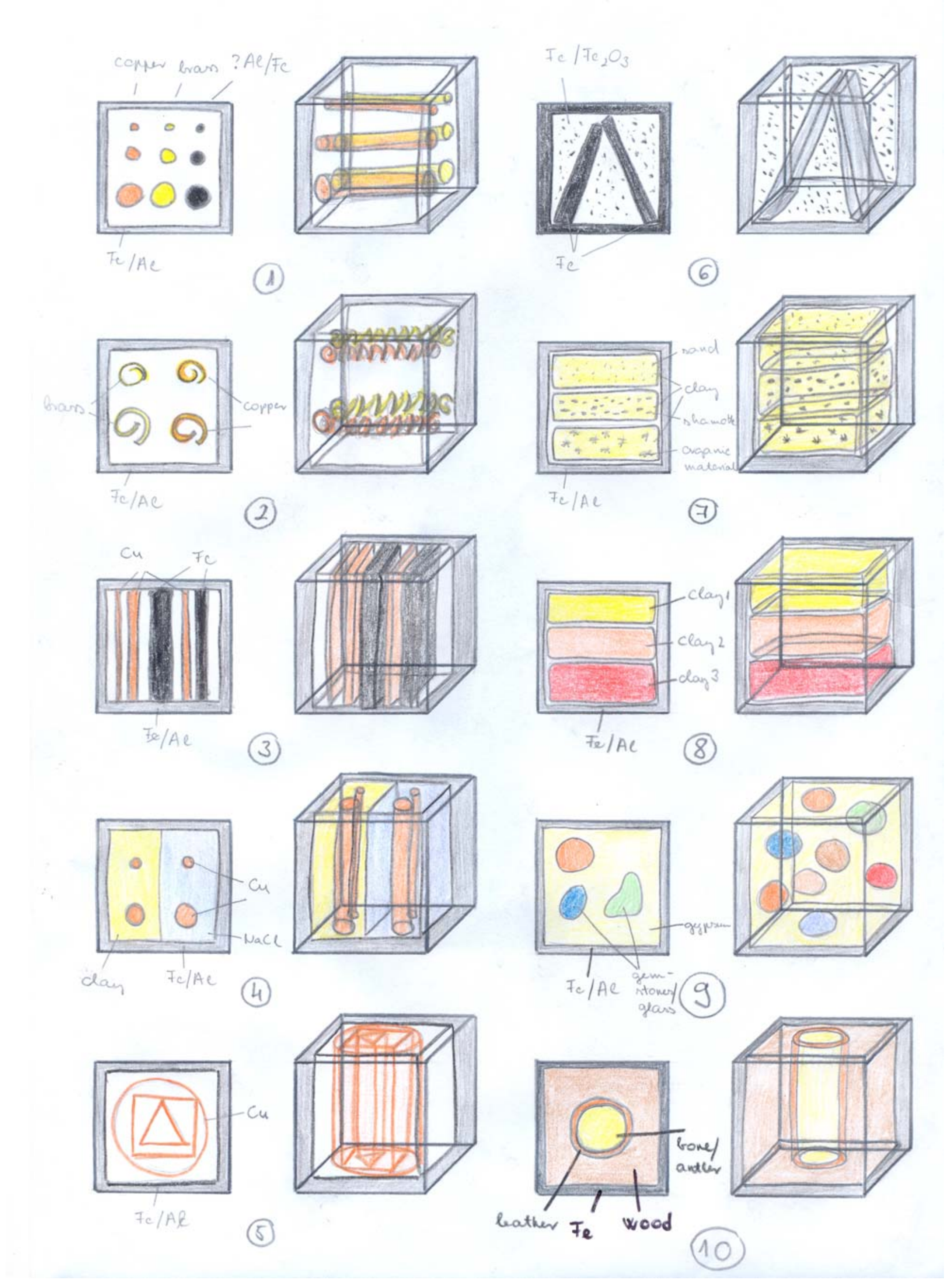

Fig.1. Plans for the test objects ('black boxes')

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Since it was also decided to produce for the last phase of testing, elaborate and noble copies of the chosen historic objects, with elemental compositions similar to those of the originals, some boxes were already planned to offer the same difficulties that the future measurements on the original objects would probably hold.

Plans of the boxes

In the plans (**fig. 1.**), the boxes were designed as cubes with 40 – 50 mm edge length and about 1 mm wall thickness. Apart from these constraints, they were mostly defined in terms of general types, leaving some liberty of using available raw materials. The number of each box correlates roughly with the expected difficulties met in the characterisation of the box content with respect to element detection, material identification and spatial arrangement of the components. The first group of boxes (Nrs. 1-5.) contains simple elements and simple geometrical forms; the second group (Nrs. 6-10.) includes boxes approximating archaeological objects, i.e. boxes with more complex compositions and/or arrangements of more complex materials with different geometrical forms.

Individual descriptions of the planned boxes

Nr. 1.

Fe or Al plate box (bent, soldered or glued) with 2 sides remaining open. Inside: cylindrical rods of different diameter made of 2 or 3 different materials (like brass/copper or iron/copper, or bronze/copper).

Nr. 2.

Fe or Al plate closed box (bent, soldered or glued). Inside: 4 spirals made of cylindrical wires of 2 different materials (brass/copper or Fe/copper, or Fe/Al) and with different diameters.

Nr. 3.

Fe or Al plate box (bent, soldered or glued) with 2 sides remaining open. Inside: several parallel, but separate metal plates of different thickness made of 2 different metals (brass/Fe or Fe/copper, or Fe/Al).

As an additional or alternative box of this type a closed version was suggested with the rest volume filled with rock salt (NaCl) or sand (SiO_2). This was with the intention to see the difference between air and other materials that surround the objects, i.e. the effect on the clearness and/or resolution of the image.

Nr. 4.

Fe or Al plate closed box (bent, soldered or glued). Inside: 2 pairs of cylindrical metal rods of different diameter and made of 2 different metals (brass/Fe or Fe/copper, or Fe/Al). Each pair of rods occupies one half of the cube which is divided into two parts, one filled with salt, the other with sand or dry clay. Thus, Nr. 4 is a variant of box Nr. 1. allowing for assessing the effect of a solid rod environment on the imaging.

Nr. 5.

Fe or Al plate closed box (bent, soldered or glued). Inside: a concentric arrangement of 2 or 3 hollow objects with axial symmetry (cylinder, prisms with triangular and square cross sections) made from metal (copper, brass or Fe) plates. No filling material.

Nr. 6.

Fe or Al plate closed box (bent, soldered or glued). Inside: 2 rectangular iron plates forming a ’Λ’ with one cube face as basis. The rest volume is filled with iron rust (Fe-oxides) or iron powder. The intention of this design concerns the questions: can the metal bulk and rust be observed and distinguished, what is the effect of the weathering products on the core object image and can the new methods help with ’fresh’ archaeological objects and possibly support conservation?

Nr. 7.

Fe or Al plate closed box (bent, soldered or glued). Inside: 3 equally thick layers of burnt or dried clay containing different materials, traditional slimming materials: ground organic matter, ground chamotte and added minerals (sand and small stones) in order to test the possibility of distinguishing and identifying different ceramics and defining corresponding archaeological questions to be answered.

For the Hungarian National Museum realisation process discarded small original pieces of ancient ceramics could be used.

Nr. 8.

Fe or Al plate closed box (bent, soldered or glued). Inside: 3 or 4 layers of burned clay bricks of different mineral and chemical compositions taken from ancient ceramic waste of different origins and periods. As for box Nr. 7, it is aimed to study the methods with respect to ceramic findings, their analyses and definitions of related archaeological questions. Nr. 7 is for the small inclusions and

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additional materials and Nr. 8 is for the original chemical and mineralogical composition of the clays.

Nr. 9.

Fe or Al plate closed box (bent, soldered or glued). Inside: embedded in a filling of gypsum or salt is a random arrangement of separated items like gemstones (large single crystals), coloured glass beads and metal pieces (silver, gold). Such arrangements concern the localisation, identification and characterisation of items buried in a difficult environment. Particularly interesting are the detection of single crystals (gemstone inlays) and the effects of silver and gold in the sample.

Nr. 10.

Fe or Al plate closed box (bent, soldered or glued). Inside: a solid wooden box with a cylindrical hole in the middle, which houses a bone/antler object (maybe wrapped in leather).

From the very beginning it was clear that PGAI is not well suited for the analysis of organic material because elemental compositions are difficult to determine and images of other than ’organic elements’ are blurred. Neither suitable is NDT due to the amorphous nature of most of the sample, except remains of bio-mineralisation (bones, teeth etc). Nevertheless, since archaeologists have always questions about organic remains, the case should be tested.

Finally, it was also intended to have 2 or 3 boxes with guilt (silvered or tinned) walls in order to assess the effects of coating and the possibility of imaging thin layers.

Realisation

Based on the above box designs two series of boxes were manufactured, one with Al-walls by the Mineralogisch-Petrologisches Institut of the University of Bonn, the other with Fe-walls by the Hungarian National Museum in Budapest. The contents, exact structures and components of the closed and sealed boxes remained exclusively known to the producers until the research groups had declared their various experiments complete. Thus, investigating the cubes was under realistic circumstances, similar to those of non-destructively analysing a cultural heritage object of unknown composition and internal design.

Acknowledgement

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Reference

BELGYA, T. & KASZTOVSZKY, Zs. (2006): Half thickness for gamma radiation and for thermal neutrons in various materials. *Manuscript for Ancient Charm Kick-off meeting 20-21 January 2006, Abingdon.*