ARCHAEOLOGY DATASHEET 107
X-radiography and archaeometallurgy

The HISTORICAL METALLURGY Society

Summary
X-radiography is an imaging technique that has numerous applications in archaeology and archaeometallurgy. The primary uses are to examine form, structure and condition of artefacts in order to provide identifications and descriptions. This datasheet concentrates on how X-radiography can contribute to the archaeometallurgical evidence, from metal preparation to waste products and artefacts.

What to X-ray
Depending on the nature of the site and fieldwork, the programme of radiography may be principally geared towards artefact study, conservation and the archival record. Where there is evidence of certain types of metalworking activity, radiography may be invaluable to investigate the technological evidence, for example to identify residues, to distinguish between metalworking processes, or to assist metallographic examination of artefacts to study their metallurgy.

Many artefacts associated with metalworking processes will not need X-raying because they can be readily identified and studied visually, unless they are heavily accreted. Assemblages of slag are usually screened visually and seldom are the effort and cost of X-raying justified. However, there are always exceptions, such as uncertain identifications and the examination of soil samples for hammerscale.

Artefacts are usually X-rayed prior to any assessment of potential for further analysis, with the costs normally subsumed within the fieldwork budget. Invariably, there are requirements for additional X-radiography during the assessment and the analysis phases when unexpected groups of finds are recognised, or when more detailed X-ray examination is needed.

Applications for archaeometallurgy
Examples of where X-radiography may contribute towards our understanding of archaeometallurgical processes and products are listed below and illustrated examples are available elsewhere.

- Ceramic crucibles in which metallic components have been incorporated into the fabric
- Failed castings such as clay moulds with embedded metal
- Refining vessels of clay or bone ash with absorbed metals or metal oxides, such as cupels, heating trays and parting vessels. Pottery and other sherds are known to have been reused for metal refining.
- Non-ferrous scrap metals, such as scrapings from wrought working, and metal spills from casting and other molten processes
- Stone moulds, mortars and abrasive stones, with entrapped metals and slag
- Evidence of cast manufacture in finished artefacts, such as armatures and cores, cavities due to casting faults and porosity due to trapped gases
- Some ferrous blooms, billets, smithing hearth bottoms and lumps of minerals (if facilities permit)
- Ferrous slag and hammerscale, in soil samples or within the accretions surrounding artefacts. Flake and spheroidal hammerscale can be differentiated.
- Evidence of forging, such as hammer marks, chisel cuts, weld lines and fibrous microstructures
- Complex metal structures, for example weld lines in edged blades and in pattern-welded blades
- To assist metallographic examination of ferrous artefacts by enabling selection of the most appropriate sampling positions according to areas of interest and local condition
- Evidence of artefact construction from single or multiple components, and methods of joining such as pins, studs, rivets, seams, casting-on and soldered joins. Also negative evidence such as rivet holes.
- Surface features such as tool marks, inlays and metal coatings
- Stereo-radiography of artefacts with complex internal structures — to separate components in the image, such as lock mechanisms and pattern-welded blades
- Soil blocks and vessels which potentially contain complex artefact groups.

The X-ray image
The X-ray process is the same as medical X-radiography, and similarly, the image is captured digitally or on photo-sensitive film. Conventional equipment will yield a two-dimensional image with the features superimposed. On film, the image is transparent and like a negative, shows a gradation of densities. The X-ray film used in archaeology is industrial rather than medical; the latter is not suitable because of its limited dynamic range.

The items under investigation are submitted to an X-ray beam, which can be varied in intensity, energy and duration of exposure, depending on the equipment employed. The radiographic image is governed by the chemical nature of the object and its accretions, its density, thickness, and its geometry and orientation in the X-ray beam. Materials that are relatively transparent to X-rays will appear dark in the image whereas materials that absorb X-rays will be opaque and appear light.

Most soil components, as well as ceramics, bone and other organic materials, are all relatively transparent to X-rays and will therefore appear dark or barely discernible against a dark or black background. Conversely, metals are comparatively opaque to X-rays and these tend to show as white or light areas. This applies particularly to metals and alloys of tin, lead, silver and gold.

Metal corrosion will affect the radiographic image in a variety of ways because the items will be less dense where corroded and the corrosion products may diffuse outwards around the object or into the surrounding soil. In particular this applies to ferrous alloys, which corrode differently from other metals. Ferrous items often show a fuzzy halo around a more solid core, or they may become totally mineralised or even voided but can still reveal the shape of the original object in the radiograph. Corroded iron also tends to form thick concretions with soil and stones.

Ferrous slag will usually reveal its porous structure in a radiograph, and fuel ash slag will appear even more porous but can usually be distinguished from other residues.

Limitations

- A two-dimensional radiograph will show all the components in the image superimposed. Ambiguities can arise, which can sometimes be alleviated by altering the angle of the object in the beam, for example turning an object 90 degrees. It is also preferable to examine artefacts and radiographs together.
- Dimensional distortions occur in the radiograph due to thickness or geometry of the items. Large and unwieldy items may not respond well to X-radiography if they are too close to the X-ray source.
- X-radiography cannot identify the precise nature of the metals and other materials under examination but these can normally be inferred from morphology and densities in the radiograph. The precise compositions of the metals under investigation can be identified by laboratory techniques such as X-ray fluorescence analysis (see Datasheet 106).
- The X-ray equipment employed may be limited in energy and intensity of the radiation, and in physical ways such as access and clearance. Large scale industrial units have less of these problems.
- Radiography can upset certain dating techniques such as thermoluminescence and may therefore be an inappropriate technique for some ceramic and other materials. Metals are not affected.

X-ray facilities

Radiography requires specialised equipment and knowledge and is therefore usually only available in institutions where staff are experienced and also trained in the relevant health and safety matters. Seek advice from your technology or finds advisors.

There are two main types of X-ray generating units that are available for archaeological imaging, the small cabinet type units and the more powerful industrial units.

Cabinet type units are bench-top units that are often available in conservation laboratories, museums and other institutions. They are limited by scale and geometry, as well as by the intensity and energy of the X-rays produced. These units have the advantage of integral lead shielding meaning that additional radiation protection is not required.

Industrial units are very much more powerful and are capable of producing higher energy and more penetrating X-rays, suitable for larger, denser and complex finds such as soil blocks, metalworking features, blooms and billets. These units are available in institutions such as hospitals, universities, larger museums and other organisations.

Other radiographic techniques

There are other X-radiographic techniques that have been successfully applied to archaeological materials for specific investigations although these techniques require specialised facilities which are not always readily available. These techniques include image enhancement, tomography, real-time imaging, xeroradiography and micro-focus radiography. Perhaps the most significant change in recent years has been the development of truly digital X-ray systems where digital X-ray sensors are used instead of traditional photographic film. Such systems have not yet been universally adopted within archaeology but offer some advantages over traditional film (e.g. speed).

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