The British Museum

Newsletter

Scientific Research

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X-ray imaging of the Snettisham Great Torc

The Snettisham Great Torc showing the complex detailed design of the terminals.

X-radiograph of the Snettisham Great Torc. The terminals appear 'transparent' to the high energy X-rays, indicating that the metal is relatively thin and therefore unlikely to have been cast.

Daniel O'Flynn, Scientist

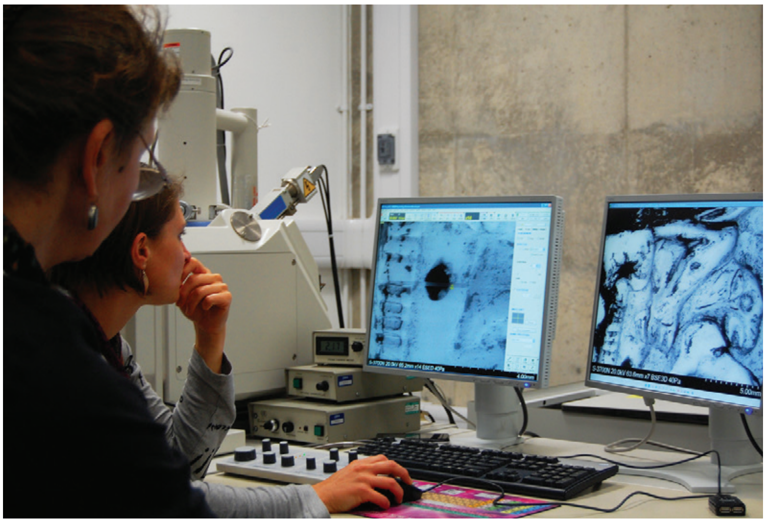
The Snettisham Great Torc (c. 150–50 BC) is one of the most important Iron Age objects in the British Museum. The torc is a neck ring made of over a kilogram of gold alloy, with two highly decorated terminals at the ends. The terminals of similar torcs from Snettisham were typically made by casting (pouring liquid metal into moulds), but recent research has suggested that this may not always have been the case. Because the torc is intact, one way to study the internal structure of the terminals to learn about their manufacturing technology is with the use of X-radiography.

In January 2017, the Department of Scientific Research opened its new X-radiography suite. This X-ray imaging facility has the capability of generating high energy X-rays (up to 450 keV) which can penetrate through dense, thick material. Gold is very difficult to 'see through' using lower energy X-rays, and so imaging the Snettisham Great Torc was an ideal test for the new system. British Museum Scientists Duncan Hook, Nigel Meeks and Aude Mongiatti worked with Curator Julia Farley to take these images, in discussion with independent archaeologist Tess Machling and replica maker Roland Williamson.

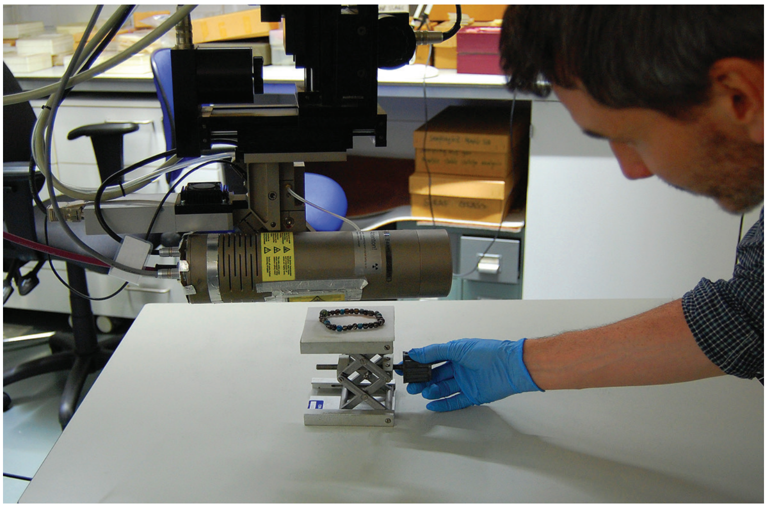
By taking X-radiographs of the torc, we found that the terminals appeared to be different from comparative radiographs taken on the Sedgeford torc. The Sedgeford torc has a similar design to the Snettisham example, but the terminals are dense and have characteristic casting features. The Snettisham Great Torc has thinner gold terminals, which are more 'transparent' to radiography than we expected, and show much fine detail. There is evidence of overlapping sheets of gold alloy in the central 'core', which appears to be soldered to the main doughnut-shaped terminal body on which the intricate decorations were formed. This suggests that the terminals were unlikely to have been made by casting.

Our research investigating the full range of metalworking processes used in the terminals' manufacture is ongoing. This discovery provides us with a great insight into the different manufacturing methods used during the Iron Age.

Scythians under investigation



Scythian metalwork examined by the scanning electron microscope.



Scythian glass beads analysed by X-ray fluorescence.

Rebecca Stacey, Scientist

Several members of the Scientific Research team – Caroline Cartwright, Andrew Meek, Aude Mongiatti, Daniel O'Flynn, and Diego Tamburini – have been engaged in an intensive programme of scientific study related to the BP exhibition *Scythians: warriors of ancient Siberia* (14 September 2017 – 14 January 2018). Their research took place during the exhibition installation period (7–25 August), taking advantage of a unique opportunity to study objects while they were on loan from the State Hermitage Museum.

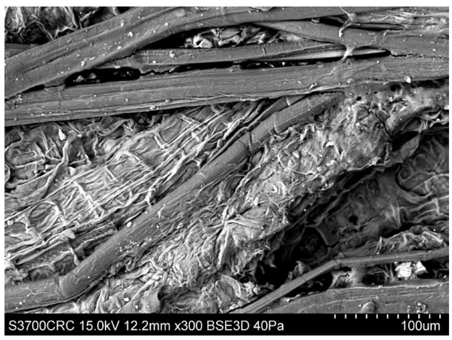
Rebecca Stacey coordinated this scientific programme following a visit to St Petersburg in November 2016. Our scientists worked with visiting curators from the Hermitage – Dr Svetlana Pankova, Dr Elena Korolkova and Dr Elena Stepanova – to undertake non-invasive analysis using digital microscopy, scanning electron microscopy (SEM), X-ray fluorescence (XRF) and X-radiography. We were able to examine a range of objects on display in the exhibition, including gold, textiles, seeds and glass beads. Many of the scientific results are presented alongside the objects in the exhibition and more detailed accounts will be presented at a conference on 27–29 October.

Researching Pacific barkcloth

Caroline Cartwright, Scientist

I have been invited to participate in a three-year research project that aims to transform our understanding of Pacific barkcloth (*tapa*) manufacture. This project, *Situating Pacific Barkcloth Production in Time and Place*, funded by the Arts and Humanities Research Council (AHRC), is based at the University of Glasgow under the leadership of Frances Lennard. Three internationally important collections of barkcloth form the project's core research material – those of the Hunterian (University of Glasgow), The Economic Botany Collection (Royal Botanic Gardens, Kew), and the National Museum of Natural History, Smithsonian Institution.

The project team is analysing these collections to learn how the materials, manufacture, style, condition and degradation of barkcloth may have changed over time. In particular – and this is where my scientific expertise comes into play – we are examining to what extent those factors varied between barkcloths made from different plant species. I am using a variable pressure scanning electron microscope (SEM) to characterise the traditional plant materials that have been used for making *tapa*. These include *Pipturus albidus* (*māmaki*), *Broussonetia papyrifera* (*wauke*/paper mulberry), *Artocarpus altilis* (breadfruit), *Hibiscus tiliaceus* (*hau*) and different species of fig, *Ficus* spp. This research follows on from my intensive SEM studies of barkcloth from the Pitt Rivers Museum in Oxford, and also from the British Museum's collection of barkcloth, many examples of which were seen in the 2015 exhibition *Shifting patterns: Pacific barkcloth clothing*.



SEM image (captured at 300 times magnification) of *Artocarpus altilis* (breadfruit) bast fibres and adjacent plant cells.

Introducing our Andrew W Mellon Fellows

Lucia Pereira-Pardo, Andrew W Mellon Fellow

I trained as a conservation scientist at the Institute of Spanish Cultural Heritage in Madrid and the University of Santiago de Compostela, where I took part in a number of projects preserving Galician cultural heritage, from Bronze Age petroglyphs to the Baroque vaults of the cathedral. In 2015, I completed my PhD on the material analysis, conservation issues and environmental risks of 16th-century wall paintings. I then moved to Cambridge to take part in the MINIARE project, performing non-invasive analysis of medieval illuminated manuscripts at the Fitzwilliam Museum.

In 2016 I became an Andrew W Mellon Fellow at the British Museum, where I am investigating new applications of lasers in conservation. I am exploring the potentialities and limitations of a new laser (called erbium YAG) to conserve a wide range of materials, from metals and ceramic to frescoes and polychrome sculptures. I first test the laser on model samples to determine the optimal energy levels to be used and investigate the effects of the laser on the materials. When the treatment proves efficient and safe, we can consider using the laser on Museum objects. So far, we have had many successful case studies – the treatment of corrosion on a Roman silver gilded pin, the cleaning of adhesives from ceramic sherds of a Greek vase, or the removal of modern overpaint and varnish from a Coptic fresco.

My favourite example is the treatment of a group of polychrome limestone and terracotta statuettes from Cyprus. Many of them were affected by disfiguring biological growth and therefore could not be displayed. As the statuettes are polychrome, conventional cleaning treatments, such as swabbing with solvents, are inappropriate. Laser cleaning has the advantage of being non-contact, precise and in some cases very selective. When we tested the laser on the Cypriot figures we saw that it softened the mould stains without altering the polychromy.

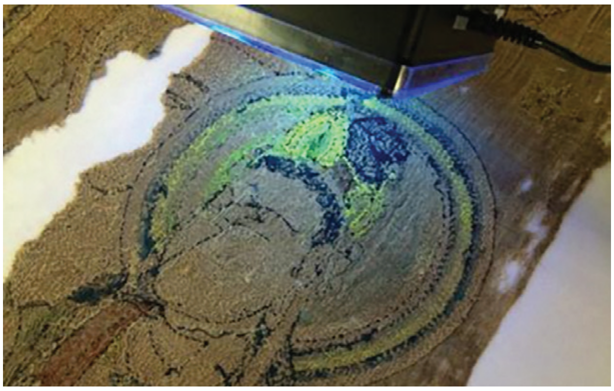
The laser project is enabling us to look more closely at objects and the kinds of the conservation treatments we sometimes use. We are also revealing new information about objects' origin, manufacture and history. For example, when I was studying the surfaces of the Cypriot figures using a scanning electron microscope, I could recognise microfossils in the limestone, but only after they had been cleaned with the laser. This observation proves that the stone is local and might help to determine the quarry of origin. Technical imaging of some of the statuettes also revealed the characteristic luminescence of Egyptian blue, one of the first synthetic pigments ever used.

Using an ErYAG laser to remove modern overpaint from a Coptic fresco.

Diego Tamburini, Andrew W Mellon Fellow

I am an analytical chemist by training and I studied at the University of Pisa in Italy, where I completed my PhD in 2015. I specialised in the development and optimisation of mass spectrometric techniques (GC-MS and Py-GC-MS) to analyse organic materials in historical/archaeological objects, with particular attention to archaeological wood and Asian lacquers, but also organic binders, amorphous organic residues, resins, waxes and varnishes.

I have worked in the Department of Scientific Research for almost a year and a half, and I am halfway through my three-year postdoctoral fellowship funded by the Andrew W Mellon Foundation. My main focus at the Museum is the use of liquid chromatography mass spectrometry (LC-MS) for the recognition of organic colourants in ancient textiles. I also use scanning electron microscopy (SEM) to identify natural fibres and document their preservation conditions. Since joining the Museum, I have focused on several projects, including investigations of Indian yellow in Rajasthani wall paintings (published in the journal *Dyes and Pigments*, 2017, 144, 234–241) and identification of the dyes in Late Antique textiles from Egypt, and a Hellenistic votive figurine from the south of Italy.

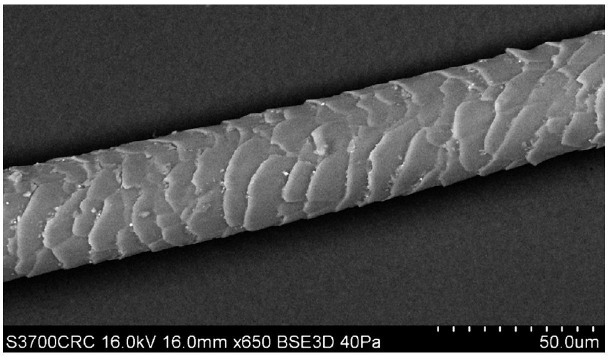


The UV-induced fluorescence of a protoberberine-based yellow dye present in the embroidery.

One project, in particular, is worth highlighting. *Sakyamuni preaching on Vulture Peak* is one of the largest known Chinese silk embroideries from the Tang dynasty (8th century AD). The Museum has recently undertaken major conservation work, which has been documented in a series of videos on our YouTube channel. I had the opportunity to take 25 samples representative of the dye palette used to create this outstanding work of art. In some of the areas that are now extremely faded, analysis revealed the use of safflower (*Carthamus tinctorius*) to create the colour red. More than one source of indigotin was probably used for the blues, and the greens were obtained by mixing these with at least two sources of yellow dye – a berberine- and a luteolin-based dye. Two sources of reds were also present – a plant of the Rubiaceae family for the central figure and an unknown source of red. The presence of shikonin, probably from gromwell (*Lithospermum erythrorhizon*), was revealed in a purple stripe in mixture with sappanwood (*Caesalpina sappan*) to obtain a particular hue.

These results allow us to reconstruct the original colours, especially where fading has occurred. This research also helps to shed new light on the nature and diversity of ancient Asian colourants.

Interesting use of dog hair on a Polynesian pectoral



Caroline Cartwright, Scientist

In June 2016 I was invited to the Museo de América in Madrid as part of a grant-funded collaborative research project. My scientific contribution to the project has been the identification of plant fibres, wood and hair (both human and animal), which have been used in the manufacture of clothing and objects from Oceania that form part of this museum's ethnological collection.

I sampled 26 objects, ranging from an octopus lure, mats, skirts, belts, feathered capes and helmets to *tapa* barkcloth and fishing nets. Tiny samples were brought back to the British Museum so that I could carry out the identifications using our variable pressure scanning electron microscope. One particular object, a pectoral ornament (*taumi*) from the Society Islands (Polynesia), was made up of several different types of plant fibre including paper mulberry (*Broussonetia papyrifera*) and olonā (*Touchardia latifolia*). An interesting addition to this 18th-century pectoral was provided by dog hairs tied to the external border. These pectorals were prestige ornaments, usually worn by tribal chiefs. In order to reflect the status of the bearer, as in this example, they were often decorated with hard-to-obtain materials, including mother-of-pearl shell discs and shark teeth, as well as an array of plant fibres and dog hair.

Crystal gazing

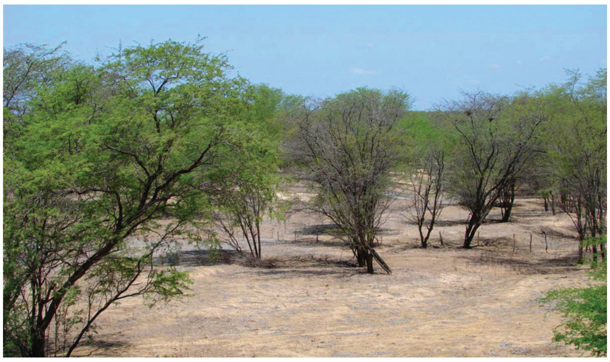
Caroline Cartwright, Scientist

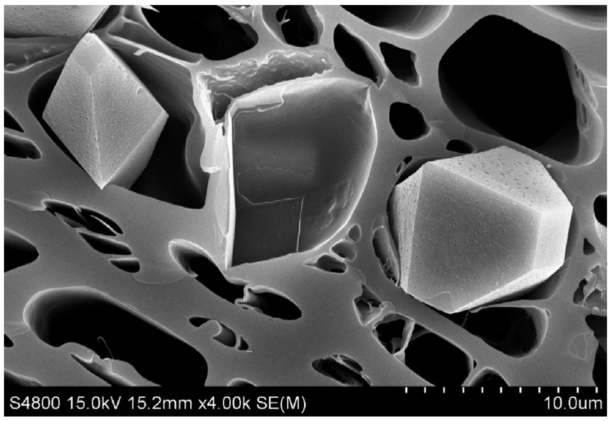
As part of a collaborative project with the Royal Botanic Gardens Kew, I have been using a scanning electron microscope to characterise the fuelwood properties of four different species of trees that are currently being sustainably managed in the caatinga (dry deciduous forest) in the state of Pernambuco in north-east Brazil. The results have been published in several specialist wood anatomy articles, as well as in *New Scientist* magazine in July 2017 ('The spongy fuel that's made from trees').

Many different features within the wood cells give me useful information about how long the wood will burn, what quality of charcoal it will produce and the temperatures it will reach when used as fuel for various domestic activities, such as cooking or heating the home.

This image shows a field emission scanning electron microscope image (captured at 4,000 times magnification) of prismatic calcium oxalate crystals nestling in their specialised chambered ray parenchyma cells. Although these crystals are not anatomical features as such – they simply testify that the tree grew in calcium-rich soils – the structure of the crystals changes at different temperatures when the wood is burnt as fuel.

In Mimosa trees (although every tree species is different), the crystals become pitted and spongy at first, usually at around 600 degrees centigrade, then at around 800 degrees they start to disintegrate, rather like a sugar cube that is dunked into tea. So these crystals, apart from being visually beautiful, provide me with very useful information when I am investigating all the features that reveal which trees will produce the most efficient and long-lasting charcoal for use as sustainable fuel.





SEM image showing the lime bast fibres used to make the basketry container.

The basketry container. © Dartmoor National Park Authority.

Caatinga, dry deciduous forest, Brazil. Image: Glauco Umbelino.

SEM image (captured at 4,000 times magnification) of prismatic calcium oxalate crystals in their specialised chambered ray parenchyma cells in Brazilian Mimosa wood.

New imaging techniques for the study of ancient polychromy

Joanne Dyer, Scientist

The development of novel, non-invasive imaging techniques and methods for the study of ancient polychromy is one of my main research interests. Photo-induced luminescence imaging techniques, such as UV-induced visible luminescence (UVL) and visible-induced infrared luminescence (VIL), have been invaluable for the study of ancient polychromy, allowing the detection and mapping of luminescent materials, such as varnishes, consolidants, organic binders, and crucially, traces of pigments, organic and inorganic, that are often not visible to the naked eye.

In the context of works from the Hellenistic period onwards, the detection of two pigments – Egyptian blue and rose madder lake – has been crucial in advancing the field. Current conventional methodologies for the digital mapping of these two luminescent pigments rely on the separate application of two techniques (VIL and UVL), each requiring a different illumination source and acquisition set-up. Together with colleagues in Greece, I recently developed a novel approach, combining the use of VIL with a relatively new technique, visible-induced visible luminescence (VIVL), to locate these two pigments.

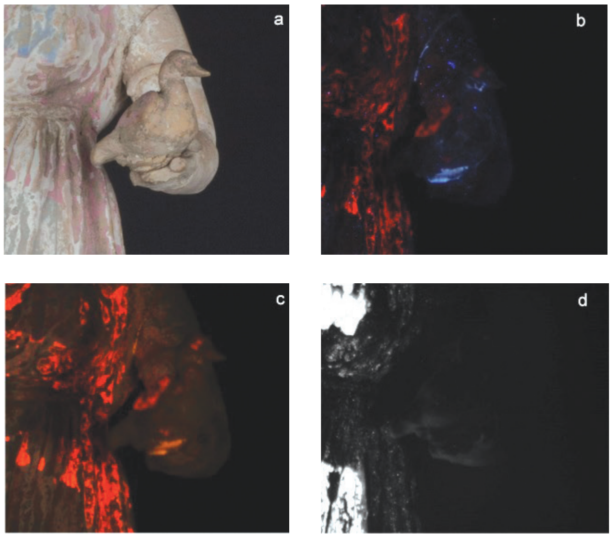
The set-up uses the same source of illumination (LEDs) in both cases, requiring only minor filter changes between luminescence modes. The increased portability and safety compared to the use of methodologies that employ UV radiation represent notable advantages of this integrated system. The significantly simplified experimental set-up is a user-friendly methodology for both experts and non-specialists alike, and eliminates the need to adjust the object or equipment between acquisitions. This ensures better reproducibility of the data acquired and reducing risk to the object.

The approach was trialled on three Hellenistic period terracottas all characterised by large well-preserved areas of decoration in Egyptian blue and red lake. One of these was a statuette of a woman with duck and conch shell from Canosa di Puglia in Italy. Comparisons were made with the more standard techniques of VIL and UVL, and it was shown that the combined method efficiently detects and maps both of these pigments with analogous results to those obtained by more established methodologies.

It is important to highlight that the observations made from these images have also been verified analytically, confirming not only the identities of both pigments investigated at the locations indicated by the luminescence images but, in some cases, also providing evidence for regions where these pigments coexist as mixtures. The images are therefore more than just pigment maps but are also evidence of the techniques used to create the polychrome finishes. Although these methods were trialled on Hellenistic terracottas, they also have wider applicability as a significant contribution to the more general study of luminescent materials.

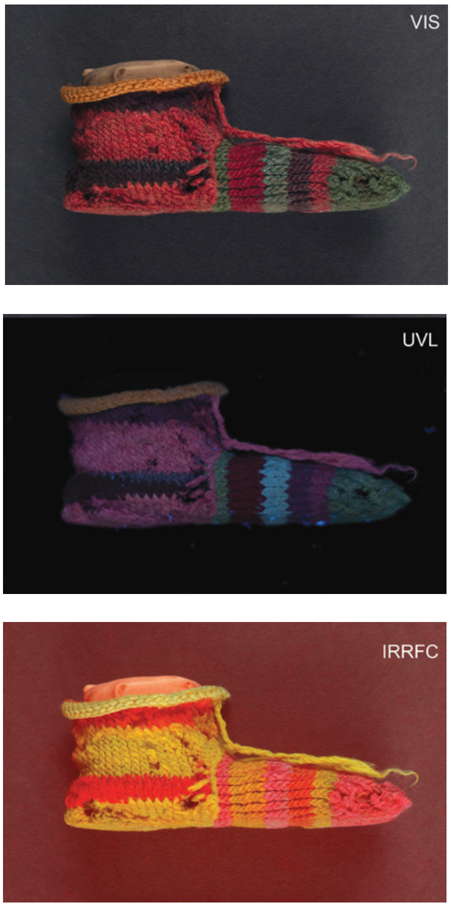
To find out more about this research, visit blog.britishmuseum.org and search 'Ladies aglow'. The blog has a link to the paper published in the journal *Heritage Science*.

Statuette of a woman with duck and conch shell from Canosa di Puglia in Italy, 270–200 BC. From left to right: in visible light (VIS), and showing the combination of visible-induced infrared luminescence (VIL) and visible-induced visible luminescence (VIVL) images acquired from the integrated methodology.



Detailed images of the statuette. a, in visible light (VIS); and showing b, UV-induced visible luminescence (UVL); c, visible-induced visible luminescence (VIVL); d, visible-induced infrared luminescence (VIL).

Scientific approaches to first millennium AD textiles from Egypt



Joanne Dyer, Scientist

In early 2017, following a successful application to the Museum Research Fund, I began work on a pilot project using multispectral imaging (MSI) and liquid chromatography coupled with mass spectrometry (LC-MS) to explore the research opportunities which these methods, and other scientific approaches, could provide for the study of Late Antique textiles from Egypt. Two objects were chosen as part of this pilot – one from a capital city, Antinoupolis, and one from the Monastery of Apa Thomas at Wadi Sarga, both located in Middle Egypt. Both sites are the subject of British Museum research projects led by Elisabeth R O'Connell, Curator in the Department of Ancient Egypt and Sudan.

I presented the findings of this preliminary study to an interdisciplinary working group of international curators and scientists at a meeting that I co-organised together with Elisabeth. Titled 'Scientific approaches to First Millennium AD textiles from Egypt', it was held at the Museum in March 2017. Following the meeting there has been a lot of interest in maintaining the network that the working group created and to continue discussions on a variety of topics, ranging from dye analysis to how to best make analytical data available to researchers in this field. Discussions with the other participants have led to the planning of a series of workshops to address the use of new techniques, their potential and limits, and how best to facilitate the exchange of knowledge on this subject with other researchers. Updates on the project will be presented at the tenth conference organised by the international research group *Textiles from the Nile Valley* at Katoen Natie (Antwerp, Belgium) on 27–29 October 2017.

For more information, visit britishmuseum.org/research and click on Research projects.

MSI images of a child's stripy sock from Antinoupolis, AD 200–400. From top to bottom: in visible light (VIS), showing UV-induced luminescence (UVL), and in infrared-reflected false colour (IRRFC).

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