Innovation and Technology Transfer

Radiographs on archaeological finds from the necropolis of "Colle del Forno" in Montelibretti (Rome).

Ombretta Tarquini,[a] Marcello Colapietro,[a] and Augusto Pifferi[a]

As part of the Mu.Sa Museum experience project, funded by the Lazio Region (POR Funds 2014-2020), some soil blocks from the deposit of the Museo Civico Archeologico in Fara in Sabina were analyzed. The Colle del Forno necropolis, from which the archaeological finds come, is located within the boundaries of the Research Area RM1 - Montelibretti (Rome) of the National Research Council. The analyzes were carried out at the X-ray Laboratory of the Institute of Crystallography (secondary office in Monterotondo (RM)). The article shows the results of the analyzes carried out.

Keywords: X Ray imaging, Not Destructive Testing, Archeometry, Cultural Heritage

1 Introduction

Museum Experience (project financed by the Lazio Region within the 2014-2020 POR Funds) aims to create an innovative approach to the "museum system" using the latest technologies of augmented reality, virtual reality and video mapping, together with targeted communications on social networks, to increase the interest in the places of culture, the touristic offer and to improve the knowledge of the ancient centers of Lazio region. Archeology, art and ancient history thus become a lively and engaging show that makes the visit to the museum a "playful" opportunity for learning and understanding the cultural heritage, through the active participation and interaction of the visitor. A new approach aimed at all types of visitors, from tourists to schools, to fans of these themes and which also provides museum managers, as well as the public bodies that also they depend, of new ways of accessing and using the precious finds they preserve.

The Archaeological Civic Museum of Fara in Sabina has been identified as the first cultural reality to carry out the project that will see the inauguration of virtualizations and their operational experimentation by 2021.

One of the topics shown in this educational tour are the archaeological finds, especially from the necropolis of Colle del Forno, which are kept in the warehouses of the Fara museum. It is shown how from the archaeological excavation are extracted blocks of soil inside which the finds are contained. By means of X-ray imaging, the hidden contents can be observed. This will give archaeologists a lot of information about the historical period to which the finds refer.

1.1 The civic museum of Fara in Sabina

The Civic Museum of Fara in Sabina tells the history of the territory from prehistoric times to the Romanization which took place in 290 BC. by the Roman consul of Sabine origins Manio Curio Dentato. The museum mainly collects the archaeological finds from the excavations conducted, starting from the 1970s, in the two most significant sites of the historical evolution of the municipal territory and more generally of the Sabina Tiberina: the settlement of the Sabines on the left bank of the river Tiber valley with the foundation of Cures, the historical capital of Sabina and the necropolis of "Colle del Forno".

In the museum there are many archaeological findings from the Sabina necropolis of Colle del Forno. Some of these finds are the subject of the analyzes presented in this article.

1.2 The Colle del Forno Necropolis

The first mention of the necropolis[1,2] dates back to 1934, when, during the construction of a stable, a section of the XVIIIth tomb was found and partially excavated; the recovered material, which was left in storage at the local Command of the Royal Italian Army, was lost in the events following 8th September 1943. In 1970, during the works for the construction of the CNR Research Area, tomb XI was accidentally found. Unfortunately it was immediately sacked; the materials (or at least part of them), including a horse-drawn carriage covered with bronze sheets, were then recognized in a lot received by the Ny Carlsberg Glyptotek in Copenhagen. The legal action brought by the Italian State, complicated by the fact that the Danish museum is a private and not a public institution, took a very long time. Fortunately, the story ended positively with the return to

[a] *CNR-Istituto di Cristallografia, Area della Ricerca RM1, Monterotondo, Italy*

Italy of the gig and other finds in 2016.

2 Survey technique

Diagnostic imaging based on the use of X-rays[3] allows, in an increasingly efficient way and with high resolutions, a non-invasive analysis of the internal structures of artifacts, the study of pictorial stratigraphy and identification of regrets and paintings underlying and, more generally, the study of the discontinuity or inhomogeneity of the material. In the field of cultural heritage, X-ray imaging has found widespread use as it is very suitable for non-invasive analysis, both structural and compositional, through the different radiopacity of the materials making up the work of art, and is often complementary to other imaging techniques.

The acquired radiographs are then processed by means of techniques and software for image processing.[4,5]

2.1 X-ray: theory

X-ray is a non-destructive investigation technique, which allows you to obtain images of the internal structures of an object through the use of penetrating X radiation. The measurement takes place in transmission: the sample to be analyzed is interposed between the source and the detector. The principle on which the radiography is based is the selective absorption of X-rays by matter. The X-ray beam that strikes a heterogeneous object will undergo variations in the intensity of the transmitted beam which depend on the thickness, structure and type of atoms that constitute it.

For a radiation of a certain wavelength λ the decrease in intensity is expressed by the Lambert-Beer law (or absorption):

$$I_t = I_0 \, e^{-\mu l} \tag{1}$$

where is it:

I_t is the intensity of the transmitted beam;

I_0 is the intensity of the incident beam;

l is the thickness of the material;

μ is the linear attenuation coefficient which depends on the wavelength of the incident beam and the density of the material passed through.

Consequently, the radiography is essentially a map of the total density along the linear path of the X photons that pass through the object.

2.2 Image acquisition system

The radiographs were made with an X-ray tube with tungsten anti-cathode and focal spot 0.5 mm in diameter, powered by an experimental generator that can reach up to 100 kV of acceleration voltage with a tube current of up to 2.5 mA. The detector is an electronic plate or Image Plate that allows you to create digital images with dimensions of 27.7 cm X 14.40 cm, with 16-bit gray scale and 600 dpi resolution. The radiographic investigations on the soil blocks were performed keeping the objects inside their packaging and on their supports.

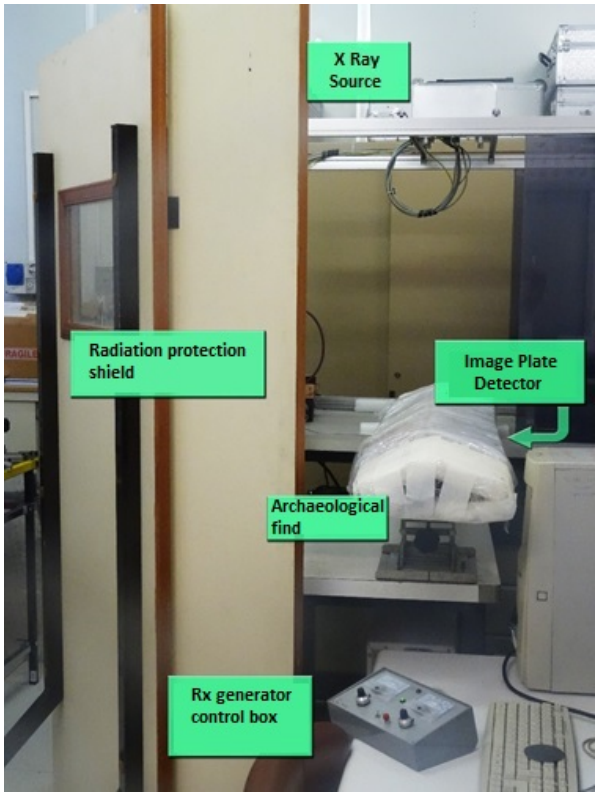

Fig. 1 Experimental setup

The soil blocks have a larger size than the X-ray detector used, therefore it was necessary to take several shots to reconstruct the X-ray image of the entire block using appropriate software. About 80 radiographs (test and definitive) were performed to identify the best experimental conditions in order to enhance interesting details of the objects contained therein.

A KODAK CR 7400 Digital Radiograph was used to read the Image Plate

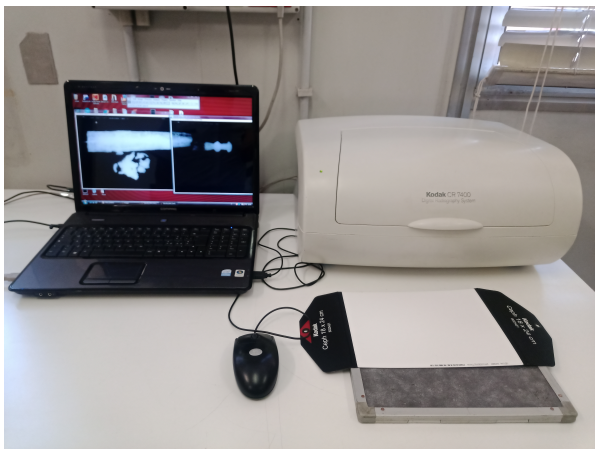

Fig. 2 KODAK CR 7400 Digital Radiograph

3 The soil block analyzed

A "soil block" is literally a block of excavated ground containing archaeological finds of various kinds. This methodology in the recovery of artifacts is used when the object to be extracted requires special care and attention that cannot be given to it during the excavation and therefore it is preferred to do it in a more appropriate location, such as a restoration laboratory.[6]

This minimizes the risk of damaging fragile materials. The soil blocks arrived in the laboratory inside a cellophane wrapper and placed on a rigid support (wood or foam). Digital X-ray radiography was used to identify the objects were placed in the soil block and their state of conservation. The radiography provides an image of the internal structure of the analyzed object, a kind of transparency, in which it is possible to distinguish more or less transparent materials (radiopaque) to the X radiation. So a metal object, being more radiopaque than the ground, is clearly distinguishable in the radiographic image.

X-ray images were taken on the soil blocks indicated below. The cataloging of the archaeological finds is that used in the Fara museum

- Colle del forno – tomb 24 deposition 1, number 3
- Colle del forno – tomb 24 deposition 1, number 5
- Colle del forno – tomb 26, niche 3, find 2
- Colle del forno – tomb 26, niche 3, find 3
- Colle del forno – tomb 26, niche 4, number 2
- Colle del forno – tomb 26, niche 6, find 1
- Colle del forno – tomb 35, chamber 1
- Colle del forno – tomb 39, niche 3, number 3

3.1 Colle del Forno - Tomb 24 deposition 1, number 3

The soil blocks under consideration contains a spearhead. The complete radiograph was performed with three partial radiographs and reveals a state of precarious conservation: the object is broken into two parts. Fig. 5 shows the detail of the hollow body of the lance (in which the rod was inserted), the red arrow indicates the metal pin with which the rod was fixed to the spear. The metal appears deeply corroded as the contours of the object are not well defined.

Fig. 3 Tomb 24 deposition 1, number 3 - The soil block under analyzes

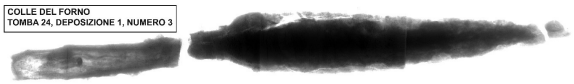

Fig. 4 Processed radiographic image

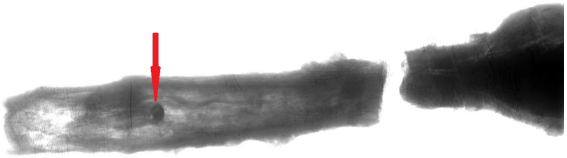

Fig. 5 Detail of the hollow body of the lance in which the metal pin with which the rod was attached to the lance is visible (indicated by the red arrow)

3.2 Colle del Forno - Tomb 24 deposition 1, number 5

The soil block contains a dagger inside its scabbard. The complete radiograph was performed with two partial radiographs and reveals the object broken into four parts. The object is deeply corroded and the outlines are not well defined. Fig. 8 shows the detail of the tang (red arrow) and the chain of the sheath with which the object was fixed to the body (green arrow). Fig. 8 shows the detail of the sheath tip.

Fig. 6 Tomb 24 deposition 1, number 5 - The soil block under analyzes

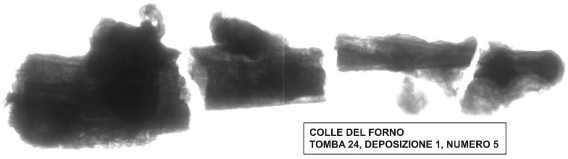

Fig. 7 Processed radiographic image

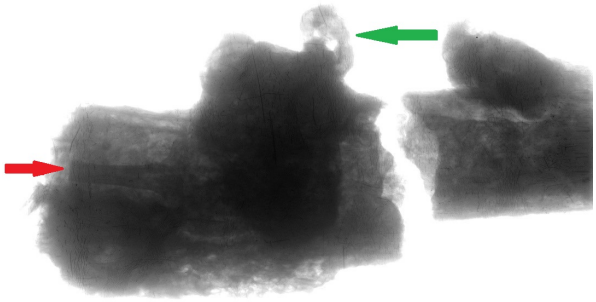

Fig. 8 Detail in which the tang and the chain of the scabbard are visible, indicated by the red and green arrows respectively.

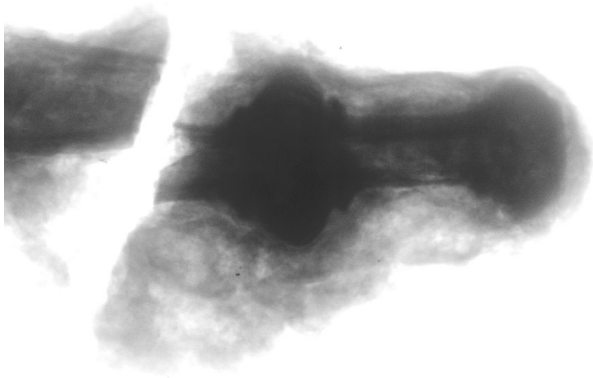

Fig. 9 Detail of the scabbard tip.

3.3 Colle del Forno - Tomb 26, niche 3, find 2

This soil block contains a dagger inside its scabbard. The object is broken into three parts as shown in Fig. 11. The creation of the complete radiographic image required two partial radiographs.

Fig. 10 Tomb 26, niche 3, find 2 - The soil block under analyzes.

Fig. 11 Processed radiographic image

Fig. 13 shows the detail of the ring and the chain with which the scabbard was fixed to the belt. The ring is broken and deeply corroded, as is the chain.

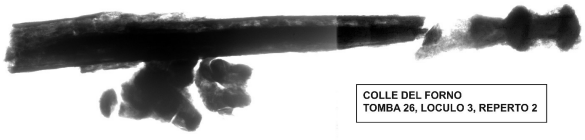

Fig. 12 X-ray image processed, with the object rotated by about 45°.

Fig. 14 shows the detail of the sheath containing the dagger. The tang has two small fractures (red arrow). The notches of two nails are visible, indicated with yellow arrows, which probably fixed the handle, generally made of organic material (eg. leather), to the tang. The blue arrow indicates the traces of the metal bands that fixed the chain to the scabbard.

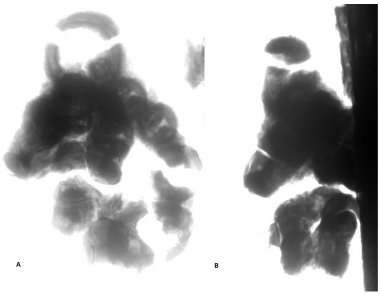

Fig. 13 detail of the ring and the chain with which the scabbard was fastened to the belt. A) forehead, B) rotated 45°.

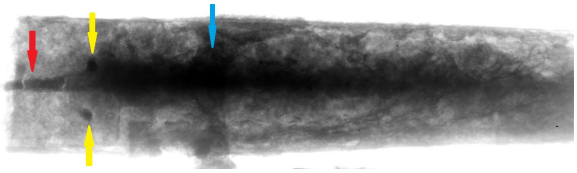

Fig. 14 detail of the scabbard containing the dagger.

From Fig. 15 to Fig. 21 are shown the radiographic images of the soil block obtained at different acceleration voltage values of the X tube corresponding to different X-ray penetration values. As the voltage increases, details hidden by the ground are still visible present around the find.

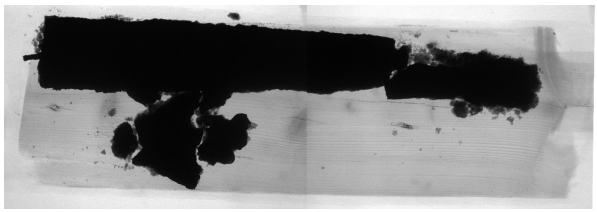

Fig. 15 Radiograph obtained at 30 kV, 2.5 mA, 10 s.

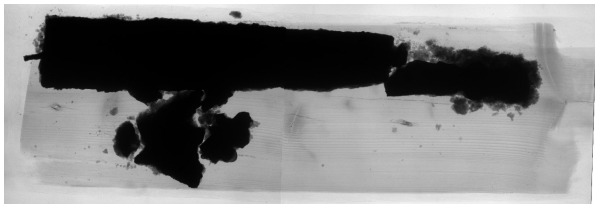

Fig. 16 Radiograph obtained at 40 kV, 2.5 mA, 10 s.

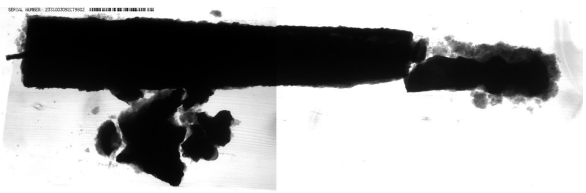

Fig. 17 Radiograph obtained at 50 kV, 2.5 mA, 10 s.

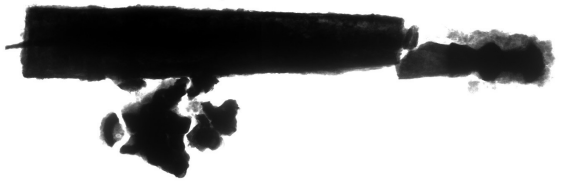

Fig. 18 Radiograph obtained at 60 kV, 2.5 mA, 10 s.

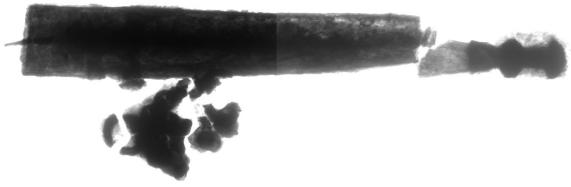

Fig. 19 Radiograph obtained at 70 kV, 2.5 mA, 10 s.

Fig. 20 Radiograph obtained at 80 kV, 2.5 mA, 10 s.

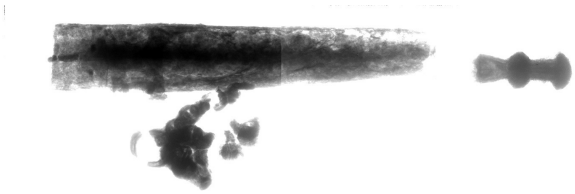

Fig. 21 Radiograph obtained at 90 kV, 2.5 mA, 10 s.

3.4 Colle del forno – Tomb 26, niche 3, find 3

The soil block Colle del Forno - Tomb 26, niche 3, find 3 contains the tip of a spear. The object is broken into three parts Fig. 23. The creation of the complete radiographic image required three partial radiographs. The hollow body of the lance into which the rod was inserted is clearly distinguishable. The central part is more radiopaque, but the poorly defined contours reveal a deep corrosion.

Fig. 22 Tomb 26, niche 3, find 3 - The soil block under analyzes.

Fig. 23 Tomb 26, niche 3, find 3 - The soil block under analyzes.

3.5 Colle del forno – Tomb 26, niche 4, find 2

The soil block Colle del Forno - Tomb 26, niche 4, number 2 seems to contain a cutting weapon, probably a spearhead, even if the hollow end where the rod was inserted is not visible. The find is broken into two parts. The creation of the complete radiographic image required four partial radiographs. Fig. 26 shows the end of the blade which is deeply corroded. In the dashed red box, better highlighted in Fig. 27, a metal nail is visible.

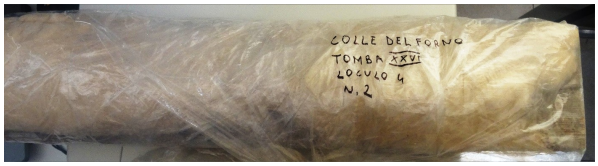

Fig. 24 Tomb 26, niche 4, find 2 - The soil block under analyzes.

Fig. 25 Reconstructed and processed radiographic image.

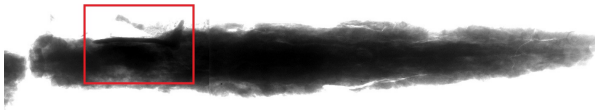

Fig. 26 Detail of the blade.

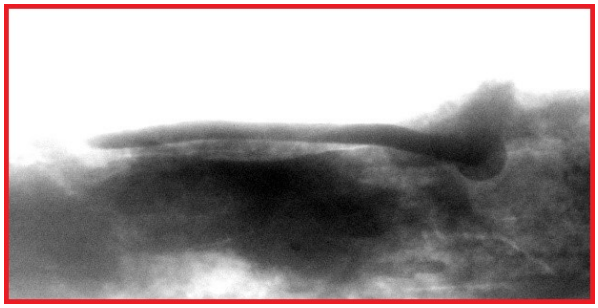

Fig. 27 Detail of a nail along the blade.

3.6 Colle del forno – Tomb 26, niche 6, find 1

The soil block Colle del Forno - Tomb 26, niche 6, number 1 contains a spearhead. The find is deeply corroded, as revealed by the undefined contours and widespread fractures, including the broken tip. The creation of the complete radiographic image required two partial radiographs. Fig. 30 shows the hollow part of the spear point where the rod was inserted and the nail with which the rod was probably fixed is visible in the dashed red box, better highlighted in Fig. 31.

Fig. 28 Tomb 26, niche 4, find 2 - The soil block under analyzes.

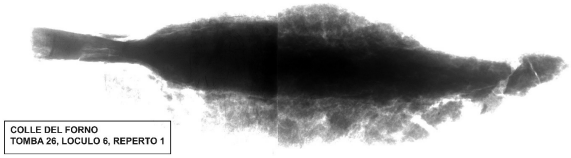

Fig. 29 Reconstructed and processed radiographic image.

Fig. 30 Focus on the hollow body of the spearhead.

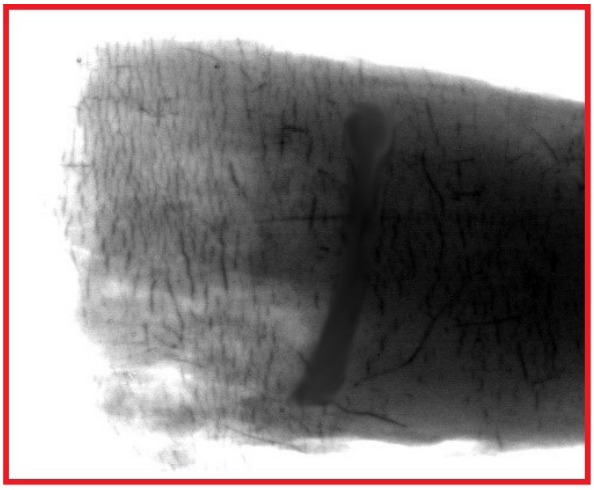

Fig. 31 Detail of the nail found in the hollow part of the spearhead.

3.7 Colle del forno – Tomb 35, chamber 1

The soil block Colle del Forno - Tomb 35, chamber 1 contains a hollow metal object. Broken into at least six parts and deeply corroded. The creation of the complete radiographic image required three partial radiographs.

Fig. 32 Tomb 35, chamber 1 - The soil block under analyzes.

Fig. 33 Reconstructed and processed radiographic image.

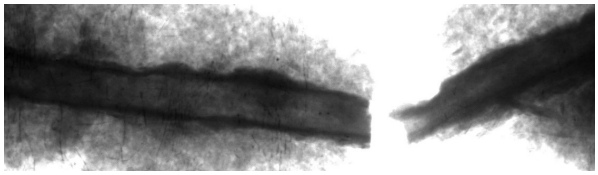

Fig. 34 Detail of the broken hollow body.

3.8 Colle del forno – Tomb 39, niche 3, find 3

The soil block Colle del - Tomb 39, niche 3, number 3 is very long (Fig.36) and the x-ray revealed it containes a series of deeply corroded metal objects broken in different parts, mostly difficult to identify. The creation of the complete radiographic image required twelve partial radiographs.

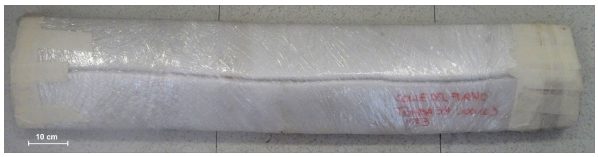

Fig. 35 Tomb 35, chamber 3 - The soil block under analyzes.
soil block

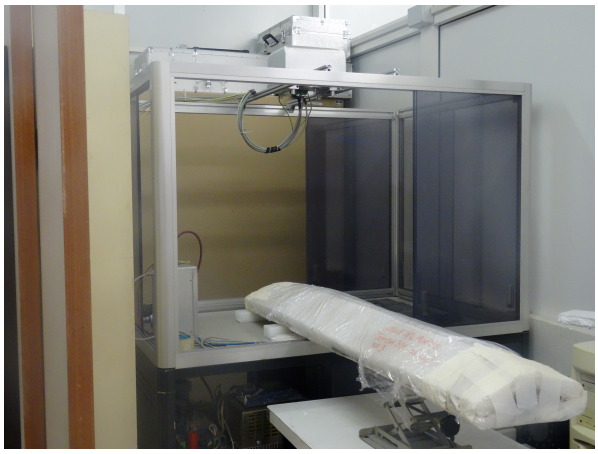

Fig. 36 the block in the box for the measures. Due to its length, several shots were taken and then the entire artefact was digitally reconstructed

Fig. 37 Reconstructed and processed radiographic image.

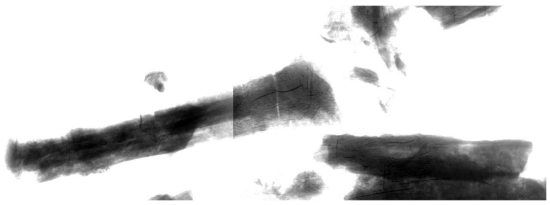

Fig. 38 Detail of hollow tubular objects.

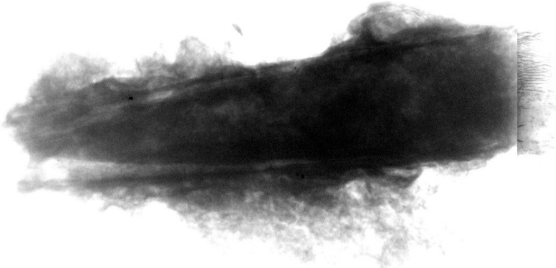

Fig. 39 Detail of a hollow object.

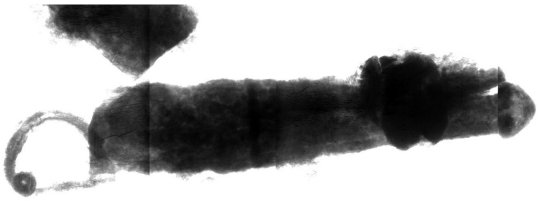

Fig. 40 Detail of fibula with probable dagger sheath.

4 Conclusions

The radiographic investigations revealed the objects present inside the soil blocks and made it possible to evaluate their state of conservation. Overall, the metal that constitutes them is completely or partially mineralized and has deep fractures.

The identification of the archaeological finds inside the soil block will allow, in the future, the restorers to decide whether to proceed with the extraction of the finds for their restoration, knowing their exact position inside the casing and their degree of deterioration.

References

1 P. Santoro, Scavo della necropoli di colle del forno., NS (1977) 211–298.

2 P. Santoro, Colle del forno (roma). loc. montelibretti. - relazione preliminare di scavo della campagna settembre-ottobre 1979 nella necropoli, NS (1983) 105–140.

3 J. Lang, A. Middelton, Radiography of Cultural Material., Butterworth-Heinemann, 2005.

4 W. Burger, M. J. Burge, Principles of Digital Image Processing: Fundam., Springer, 2009.

5 L. MacDonald, DIGITAL HERITAGE Applying digital imaging to cultural heritage., Butterworth-Heinemann, 2006.

6 O. Tarquini, M. Colapietro, B. Belelli Marchesini, Application of x-ray imaging to study soil blocks: a case study from crustumerium (italy)., in: European X-ray Conference EXRS-2012, Vienna, 2012, p. Abstracts p.127.