

5. Eureka3D case studies

5.2. BIBRACTE

Bibracte provided 500 3D scans of furniture, structures, and terrain from the archaeological site of Mont Beuvray (Burgundy, France) to the Eureka3D project. These scans cover various periods, ranging from the Gallic oppidum (fortified settlement) seat of the Aedui tribe from the end of the 2nd to the late 1st century BC, to more recent occupations, such as the Cordeliers convent. The latter, established in the 14th century in the Pâture du Couvent district, was frequented by Franciscans until the end of the 17th century. The scientific partners of the establishment are involved in all stages of the production, use, and dissemination of these 3D scans, which are divided into three distinct collections aimed at supporting archaeological research and enriching the visitor experience on the site and in the museum.

The acquisitions were carried out in controlled environments, ensuring the precision and quality of the data produced. The mathematical treatments applied for the reconstruction of the 3D models benefited from the expertise of Bibracte's scientific partners to ensure the rigour and accuracy of the process.

For each 3D model, two sets of metadata have been produced:

1. The first set documents the production of the file by indicating the method employed, the equipment used, the type of data produced, the type of mesh, the number of polygons that the model has, the number of points of the model, the scale, the resolution, the name of the operator, the name of the editor, the volume of the file produced, and its format.

2. The second set provides information about the 3D modelled object with a title and description, supplemented by a theme, a subject, a material, a chronology, a location, a scientific supervisor, and a bibliography.

To improve the indexing of the produced files, specific thesauri have been implemented and aligned with web pivot thesauri such as Getty, Library of Congress,¹ PerioDO,² GeoNames,³ and VIAF.⁴ This approach will facilitate research and access to information, making the data more usable for researchers and the general public. In addition to the 3D models, supplementary documentation (drawings, photos, reports, etc.) has been deposited in repositories that provide permanent links. These documents are integrated into the metadata accompanying the 3D models, thus offering a complete and contextualised view of the artefacts and excavations.

The integration of the French protocol of the Conservatoire national 3D into the digitisation process ensures the long-term archiving of the produced 3D models. In partnership with Archéovision⁵ in Bordeaux (CNRS, France), this protocol ensures the longevity of the data and its future accessibility within the framework of the valorisation of models published on the Europeana portal.

5.2.2. 3D DIGITISATION OF COLLECTION OBJECTS

This collection includes 130 artefacts representative of the material culture of the oppidum of Bibracte, a fortified city from the 1st century BC located on Mont Beuvray. These objects illustrate various aspects of Gallic life, ranging from agriculture to weaponry, including art, hygiene, building materials, and means of transport.

The *Collection Objets* was created with the technical support of the Maison des Sciences de l'Homme et de l'Environnement

1 <https://www.loc.gov/librarians/controlled-vocabularies/>

2 <https://perio.do/en/>

3 <https://www.geonames.org/>

4 <https://viaf.org/>

5 <https://archeovision.cnrs.fr/>

INTRODUCTION

(MSHE) Claude-Nicolas Ledoux (Besançon, France), which has a structured light object scanner operating on an Atos Core system developed by GOM. This scanner projects precise models of parallel fringes onto the object and measures the deformation of these fringes on the object's surface based on known beam paths. The deformation is recorded by two cameras operating on the principle of stereoscopy. Two scanner heads, with a distance between the two stereoscopic sensors ranging from 85 to 150 mm, measure the fringe spacing. The small head scans up to 3 microns, offering a smaller field of view but higher resolution. The large head has a wider field of view but lower resolution (7 microns). The scanned volumes rarely exceed 1 m³. The produced files take the form of meshes.

Some objects are less suitable for this range of scanners, such as a terracotta antefix, which has too many reliefs and cavities, and therefore irregularities. Additionally, certain materials interfere with digitisation due to their reflective surfaces, such as glass, ceramic pastes with certain inclusions (e.g., quartz), or metal restored with resins or electrolysis. This results in sometimes incomplete measurement data, with holes and erratic triangles. The acquisition time varies from a few hours to several days, depending on the size and complexity of the objects. The texture (colorimetry) of the model is obtained by photogrammetry, in addition to the scanner.

Three examples from this Collection singular are provided:

HELMET REUSED AS A FOUNDRY LADLE (INV. 2001.32.258.1)



Figure 41. Helmet reused as a foundry ladle. The object and its 3D model

If Bibracte was the stage for key episodes of the Gallic Wars, it suffered no battles. The relative rarity and dispersal of weapons and military accessories discovered seem to confirm that Bibracte was frequented by soldiers but not exposed to their conflicts. Among these militaria, a helmet of the “Port” type (named after a Swiss site), worn by Roman legionaries and recognisable by its repoussé eyebrow arches, seems at first glance to be part of this site’s history. However, the nature of the context of its discovery, a metal craftsman’s workshop, and the detailed observation of its shape reveal that the object was transformed to serve a purpose other than protecting a soldier’s head.

As metal is a precious resource, it is frequently recycled; for example, this iron helmet found a new life as a foundry ladle.

Keywords: Armament (warrior); Helmet; Iron

Chronology: 1st century BC

Location: Bibracte, Mont-Beuvray. The Côme Chaudron district

Excavation: Guillaumet, Jean-Paul (CNRS, Dijon, France)

Bibliography: 2001 - Research program on Mont Beuvray. Intervention n°514 (L 21.5 cm; W 19 cm; H 11.5 cm - Bibracte Museum)

SPOUT IN THE SHAPE OF A BOAR'S HEAD (INV. 2003.34.116.1)



Figure 42. Spout in the shape of a boar's head. The object and its 3D model

This bronze spout, in the shape of a boar's head, probably equipped a jug or basin that could have been used for libations or drinking. It was covered in a residential sector at the centre of the site, near the PC15 platform, interpreted as a Gallic public space.

This object attests that luxury tableware, particularly that linked to the banquet whose ritual had spread from Greece to Rome and then to the Celtic world, was not always imported from Mediterranean regions but could be manufactured locally and inspired by Gallic motifs, such as the boar. The stretched head and large tusks, the bulging eyes, and the very developed ears evoke the animal in an attacking position.

The boar, although rarely consumed by the Gauls, enjoyed great prestige among them, as evidenced by its frequent representations. It is invariably the boar that adorns military insignia, as shown by the few preserved examples and their numerous representations on Gallic coins and on the sculpted trophies of Roman monuments. The strident war horn of the Gauls also invariably bears a threatening boar's head bell with an open mouth and erect ears.

Keywords: Metal tableware; Pouring spout; Alloy

Chronology: 1st century BC

Location: Bibracte, Mont-Beuvray. The PC14 terrace

Excavation: Vitali, Daniele (University of Bologna, Italy)

Bibliography: 2003 - Research program on Mont Beuvray. Intervention n°551 (L. 4.5 cm - Bibracte Museum)

BOTTLE WITH PAINTED DECORATION DEPICTING A DEER (INV. 985.5.8.39)

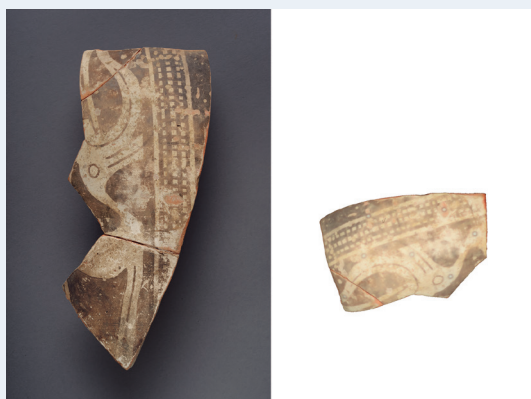


Figure 43. Bottle with painted decoration depicting a deer.
The object and its 3D model

This fragment of a ceramic bottle, featuring a deer between vertical friezes, testifies to the skill of Gallic potters. Made from fine clay, this object was decorated before firing with white kaolin flats. Oxidative firing allowed them to be fixed. This type of pottery, typically Gallic, was very widespread in the 2nd century and at the beginning of the 1st century BC.

Keywords: Pottery; Bottle; Terracotta

Chronology: 1st century BC

Location: Bibracte, Mont-Beuvray. The Porte du Rebut

Excavation: Buchsenschutz, Olivier and Guillaumet, Jean-Paul (École Normale Supérieure and CNRS, France)

Bibliography: 1985 - Research program on Mont Beuvray. Intervention n°11 (H 17 cm; W 6.6 cm - Bibracte Museum)

5.2.2. 3D RECONSTRUCTION: COLLECTION MORPHOMÉTRIE

This collection includes 120 theoretical 3D models of ceramic vessel shapes. These models allow for the visualisation and calculation of reference morphometric parameters, thus facilitating the identification of sherds found on the site by archaeologists.

The *Collection Morphométrie*, initiated by Josef Wilczek, doctor of the University of Burgundy and the University of Masaryk in Brno (Czech Republic) and associate professor of digital archaeology at Sorbonne University / Centre André Chastel (Paris, France), was created using an EinScan-SP scanner from Shining 3D. Composed

of 120 models, this collection aims to document the morphometric criteria of Bibracte ceramics in 3D, in reference to the typology published in 2021 (Barrier, Luginbühl 2021).⁶

Designed specifically to serve as a morphometric comparison reference, the collection assists archaeologists in the typological identification of newly scanned 3D sherds. Thanks to this reference, newly scanned ceramic fragments can be systematically compared to existing models, facilitating their identification and classification. Over time, these new sherds will enrich the reference collection, making it increasingly relevant and comprehensive. In other words, each newly identified and integrated sherd increases the quality and reliability of this tool, thereby refining future archaeological research.

Currently, a first algorithm already allows several operations on a newly scanned sherd: orientation, creation of 2D drawings (linear drawing and photography), measurements (diameters, volumes, percentages of vessel conservation, etc.). A second algorithm allows finding the best morphological match (rim, body, base) with the 3D reference collection models.

An example from this collection is provided:

6 <https://catalogue.frantiq.fr/cgi-bin/koha/opac-detail.pl?biblionumber=731963>

BOTTLE BT1A



Figure 44

Tall, closed shape, with a height greater than 1.5 times the maximum diameter. Narrow opening (usually less than 10 cm) and generally developed neck. Annular base, sometimes raised (pedestal).

Keywords: Pottery; Bottle; Bottle Bt1a

Category: Regional fine ceramics - PEINTA

Chronology: 1st century BC

Presumed functions: serving and consuming liquids

Authors: Barrier Sylvie; Luginbühl Thierry; Wilczek, Josef

Bibliography: The ceramic tableware of Bibracte; Morphometrics of Second Iron Age ceramics - strengths, weaknesses, and comparison with traditional typology

5.2.2. DOCUMENTING AN ARCHAEOLOGICAL SITE: COLLECTION TERRAIN

This collection includes 250 terrain models from the archaeological site, documenting the history of archaeological research on Mont Beuvray. These models, primarily orthophotographs, provide an overview of the different excavation phases and discoveries made over the years.

The *Collection Terrain* reflects the continuous adaptation of archaeological methods to advances in digital technologies. Ortho-images, also known as orthomosaics or orthophotographs, derived from photogrammetry, have gradually replaced traditional paper millimetre-scale drawings of archaeological remains in plan, section, and elevation. This technique allows for the measurement of 3D scenes from 2D photographic data. However, the proper

practice of this process involves mastering a set of knowledge and techniques during the acquisition and processing phases. Resulting from mathematical processing, the base image is recomposed pixel by pixel: optical distortions of the lens are corrected, all pixels respect a perfectly vertical viewing axis, each pixel is associated with coordinates, and the ground relief and the curvature of the earth are taken into account. The principles of photogrammetry also allow for the production of point clouds describing the captured scene in a three-dimensional form, as in the example of the masonry cellar of the domus PC2. However, this possibility is little exploited at Bibracte, as it does not provide more information than an orthomosaic, while requiring longer processing time and generating larger files.

The collection brings together 250 models that document the history of archaeological research on Mont Beuvray and the technological evolution of the practice of photogrammetry applied to archaeology. In collaboration with the UMR 6249 Chrono-environnement (Besançon, France) and as part of the doctoral thesis of Quentin Verriez (2023, University of Burgundy, UMR 6298 ArTeHis), the experiments conducted each year at Bibracte have led to a complete methodological process for the production of an orthomosaic from several digital photographs. The entirety of this process has been published in open access.⁷

An example is provided:

7 <https://books.openedition.org/pufc/5078>

MASONRY CELLAR OF THE DOMUS PC2



Figure 45. Masonry cellar of the domus PC2. The archaeological site and its 3D terrain model

The site of Bibracte, the capital of the Gallic people of the Éduens, was occupied from the end of the 2nd century BC until the beginning of the 1st century AD. This occupation is particularly materialised by buildings first constructed in earth and wood, according to the Gallic technique, and then, from the middle of the 1st century BC, in masonry, according to the Roman construction mode. Throughout the oppidum, buildings are regularly remodelled or even rebuilt, with a succession of 3 to 4 buildings on the same site being the norm at Bibracte.

The residential district of the Parc aux Chevaux, the largest flat area on Mont Beuvray, occupied at the end of the period by domus organised according to typically Roman plans, is representative of this succession of buildings. Thus, the domus PC2, built on a vast artificial terrace, rests on imposing masonry foundations that have allowed the preservation of vestiges prior to its construction. Its extensive exploration since 2016 has revealed a complex stratigraphic scenario that spans the entire 1st century BC.

- The initial occupation (first quarter of the 1st century BC), explored so far in a fragmentary manner, is manifested by several pit structures, without any characterised architectural remains.
- The following state (2nd quarter of the 1st century), is characterised by a set of timber-framed buildings, one of which was associated with a wooden cellar.
- During the 3rd quarter of the 1st century, these buildings were remodelled or replaced by new constructions, some of which (terrazzo floors, lime-plastered walls, terracotta tiles) already show clear Italian influences. This sequence ends with the construction of a masonry cellar near the wooden cellar of the previous phase.

All these structures are covered by the construction of the stone domus in the last quarter of the 1st century BC.

The digitisation of the masonry cellar, carried out following its excavation in 2016, aimed to document a structure representative of the transition between Gallic and Roman construction modes, as well as to preserve its memory in the face of the material impossibility of conserving the vestiges of this cellar in situ.

Location: Bibracte, Mont-Beuvray. The domus PC2

Excavation: Field school, Bibracte

Bibliography: 2016 - Research program on Mont Beuvray. Intervention n°848

5.2.2. USE, REUSE AND DISSEMINATION OF 3D

The overarching goal for Bibracte in advancing digital transformation of its collections is to offer visitors an enriched experience through the discovery of archaeological methods and work, through permanent scientific documentation that contributes to the preservation and valorisation of archaeological heritage.

The reuse of our models by other stakeholders and external parties take several forms depending on the professionals concerned, with different expected impacts. General communication and promotion of the collections through various types of channels (newsletter, social media, press release), and targeted communications for education, tourism, and research professionals is an integral part of Bibracte's strategy, also conducted via our professional networks.

Beyond their interest for the scientific community and for the preservation of heritage, a diversified use of the produced 3D models is envisaged, both in valorisation (promotion and mediation) and training, in several forms: in situ, off-site, and remotely.

The in situ use on the archaeological site has already been initiated on the panel of the domus PC2: a QR code has been added to allow the visualisation of the digitisation of the masonry cellar. This provision will continue for 3D models of the archaeological site and emblematic objects from the different excavated sectors, through site panels and complements to La Boussole de Bibracte.⁸ An application for smartphones has been developed to offer an enhanced discovery of the archaeological site with 55 georeferenced points of interest, three of which already benefit from enriched content (360° and restitutions).

The presentation of 3D models, when in the museum, is particularly interesting as they complement the view of the real objects by allowing access to non-visible parts (back, interior, etc.). Therefore, the guides of Bibracte are able to enrich the presentation of these objects to visitors by using these digitisations on a tablet.

8 <https://www.bibracte.fr/la-boussole-de-Bibracte>

The 3D models can also be used off-site, for example during tourist fairs to present some emblematic views and objects of the archaeological site and the museum, and also by mediators and guides who work on the territory. These new resources will also be an asset for Educational Artistic and Cultural Actions in classrooms, allowing for the complementary discovery of the collections. Moreover, they will be particularly relevant for conducting actions aimed at disabled audiences in retirement homes, hospitals, or prisons.

Remote use will be based on the website www.bibracte.fr, particularly through two existing devices: the Bibractothèque,⁹ an online space that offers several hundred resources (photographs, videos, audio content, publications, etc.) concerning the archaeological site and the collections of the Bibracte museum, and the Virtual Gallery,¹⁰ which, through data visualisation, invites internet users to explore the collections of the Bibracte museum. This exploration can be done freely, by navigating from one object to another through semantic links, or in a guided manner, by following the museum's tour.

Another crucial sector for the expected reuse of the 3D collections is education, in which Bibracte already deploys an intensive effort in training. The training sessions for teachers and mediators, normally organised at Bibracte and in other heritage sites as part of the Pôle de Ressources pour l'Éducation Artistique et Culturelle "Patrimoine archéologique", will benefit from these 3D models. Thus, the training organised in November 2023 on the theme of the raw materials of archaeological objects could not yet benefit from these models. However, its re-edition planned in Dijon in early 2025 will be able to integrate them to demonstrate the interest of 3D models of archaeological objects for better understanding the material and manufacture of objects through the marks left by their shaping.

Interactive 3D models present many advantages in the school context. They allow students to study the representations of objects in all their dimensions to better understand their manufacture,

9 <https://www.bibracte.fr/bibractotheque>

10 <https://www.bibracte.fr/galerie-virtuelle>

uses, and facilitate the observation of any decorations. This more detailed and interactive study offers more advantages than that of a simple photograph, while allowing access to all faces of an object without having to handle it. The expected impact is significant as it concerns all French teachers. In addition to the mediation, training, and communication actions indicated, we will approach the managers of Foxar,¹¹ an application and library of educational 3D models designed with the Ministry of Education, to propose integrating some of our models to allow for greater use.

Teachers can use our 3D models profitably in their history, art history, ancient languages and culture, visual arts, and technology courses. For example:

- The entire set of 3D models from Bibracte can illustrate the CM1-CM2 history program “And before France?: Traces of ancient occupation - Celts, Gauls, Greeks, and Romans”.
- Those of the helmet ladle, other militaria, vestiges and objects testifying to relations with the Roman Empire and more broadly the Mediterranean world, such as the pouring spout, for the 6th grade history program “The Roman Empire - Conquest, Roman peace, and Romanization” as well as those of 4th and 3rd grade in ancient languages and cultures “The Roman Empire: The army and the Pax Romana and ‘Mediterranean world - Rome, Greece, Gaul: exchanges and influences’”.
- Those of animal representations for the 6th grade visual arts program “Plastic representation and presentation devices: Resemblance and Visual Narration”.
- Those objects made of wood, ceramic, metal, etc. for the 6th grade history of arts program “Identifying the technical and formal characteristics of a work of art through observation: Identify the materials. Retrieve the forms” and in visual arts “The materiality of plastic production and sensitivity to the constituents of the work: The physical qualities of materials”.
- Those of the archaeological site and several objects from the museum for the 5th grade history of arts program “Arts and

11 <https://foxar.fr/>

societies (antiquity and Middle Ages): City - Architecture - Myths - Representations”.

Finally, the 3D models available on Europeana offer the advantage of being easily integrated into the construction of e-learning activities on Historiana, the platform made available for teachers and students to access digital cultural collections and resources. The use of the helmet ladle model will enrich an existing activity on the theme of archaeological looting. Created as part of the Erasmus+ PITCHER project (Preventing Illicit Trafficking of Cultural Heritage: Educational Resources), this activity explains how the object and its archaeological context complement each other (the discovery site of the helmet, a workshop, allowed understanding its final function) and that this information is destroyed when the object is looted. Other themes are also envisaged for new activities, such as “Construction methods in Celtic Europe”, “Raw materials, exchanges, and craftsmanship in Celtic Europe”, “Animal decorations in Celtic Europe”, etc. These activities will be based on the archaeological site and the collections of the Bibracte museum, particularly the mentioned case studies, complemented by other European examples, to invite teachers to propose these activities to their classes.

Europeana Galleries dedicated to each of these topics will collate the most relevant 3D models chosen by a teacher assigned to the Bibracte museum.

As for the sector of cultural tourism, the use of our 3D models by tourism professionals can be of particular interest to local tourism offices to promote Bibracte on their websites, as well as nearby accommodations, also for their websites but also to enrich the slideshows that some present inside their accommodations. They can also be used by departmental and regional tourism bodies. The expected impact is significant, as these various uses can trigger a visit to the archaeological site and the museum.

Furthermore, professionals in the Cultural and Creative Industries may also be interested in reusing our models in multimedia creations, video games, etc.

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