pca

european journal of
postclassicalarchaeologies

volume 8/2018

SAP Società Archeologica s.r.l.

Mantova 2018

pca

Post-Classical Archaeologies (PCA) is an independent, international, peer-reviewed journal devoted to the communication of post-classical research. PCA publishes a variety of manuscript types, including original research, discussions and review articles. Topics of interest include all subjects that relate to the science and practice of archaeology, particularly multidisciplinary research which use specialist methodologies, such as zooarchaeology, paleobotany, archaeometallurgy, archaeometry, spatial analysis, as well as other experimental methodologies applied to the archaeology of post-classical Europe.

Submission of a manuscript implies that the work has not been published before, that it is not under consideration for publication elsewhere and that it has been approved by all co-authors. Each author must clear reproduction rights for any photos or illustration, credited to a third party that he wishes to use (including content found on the Internet). For more information about **ethics** (including plagiarism), copyright practices and guidelines please visit the web site www.postclassical.it.

PCA is published once a year in May, starting in 2011. Manuscripts should be submitted to **editor@postclassical.it** in accordance to the guidelines for contributors in the webpage http://www.postclassical.it

Post-Classical Archaeologies's manuscript **review process** is rigorous and is intended to identify the strengths and weaknesses in each submitted manuscript, to determine which manuscripts are suitable for publication, and to work with the authors to improve their manuscript prior to publication.

This journal has the option to publish in **open access**. For information please visit the web site www.postclassical.it

How to **quote**: please use "PCA" as abbreviation and "European Journal of Post-Classical Archaeologies" as full title.

Cover image: vectorialised cadastre of Borgo Rudena, Padova (F. Giacomello).

"Post-Classical Archaeologies" is indexed in Scopus. It was approved on 2015-05-13 according to ERIH PLUS criteria for inclusion. Classified A by ANVUR (Agenzia Nazionale di Valutazione del sistema Universitario e della Ricerca).

DESIGN
Paolo Vedovetto

PUBLISHER
SAP Società Archeologica s.r.l.
Strada Fienili 39/a, 46020 Quingentole, Mantova
www.archeologica.it

PRINTED BY
Tecnografica Rossi, Via I maggio, Sandrigo (VI)

Authorised by Mantua court no. 4/2011 of April 8, 2011

For subscription and all other information visit the web site www.postclassical.it

ISSN 2039-7895

pca

european journal of
postclassicalarchaeologies

volume 8/2017

CONTENTS PAGES

PCA 8 (2018) ISSN: 2039-7895 (pp. 43-72)
Post - Classical Archaeologies

research

Methods of assessment and characterization for urban stratification at Tours and Bourges (France) and the question of early medieval dark earth deposits

MÉLANIE FONDRILLON*
AMÉLIE LAURENT-DEHECQ**
with EYMERIC MORIN,
XAVIER ROLLAND

* Service d'Archéologie Préventive de la Communauté d'Agglomération Bourges Plus, 23-31 boulevard Foch CS 20321, 18023 Bourges Cedex, France. Corresponding author: *fondrillonm@gmail.com*.
** Service d'Archéologie Préventive du Département du Loiret, Cité administrative Coligny, Bâtiment A1, 131 faubourg Bannier, 45945 Orléans, France, *amelie.laurent@loiret.fr*

Research studies have been carried out in the 2000s, concerning the assessment and characterization of city's archaeological soil in Tours. These are integrated into research of *Laboratoire Archéologie et Territoires*, historical developer of French urban Archaeology.
These works have involved the implementation and the application of measuring tools of urban soil, both archaeological, heritage and political targets. Since 2014 these methods are applied in Bourges, firstly, for assessing the archaeological potential on the scale of the city (modeling of roof substratum, time series plot ...), secondly, for understanding the early medieval dark earth deposits.
Keywords: GIS, urban archaeology, dark earth

Des recherches ont été réalisées dans les années 2000 sur l'évaluation et la caractérisation du dépôt archéologique urbain à Tours, dans le cadre de travaux universitaires menés au sein du Laboratoire Archéologie et Territoires, promoteur historique du développement l'archéologie urbaine en France. Ces travaux ont concerné la mise en place et l'application d'outils de mesure qualitative et quantitative du sol urbain, dans une visée à la fois archéologique, patrimoniale et politique. Depuis 2014, ces méthodes sont expérimentées à Bourges pour, d'une part, évaluer le potentiel archéologique à l'échelle de la ville (interpolations du toit calcaire, cartes de topographie historique ...) et, d'autre part, caractériser les séquences énigmatiques du Bas-Empire et du haut Moyen Age, matérialisées par des terres noires.
Mot-clés: *GIS, archéologie urbaine, terres noires*

1. Introduction

Two theses of urban archaeology, presented in 2007, examined the development and application of methods to analyse urban archaeological deposits at two complementary levels: the town, through urban assessment, and the site, through characterisation of deposits. The testing

Received: 05-01-2018 - Accepted: 20-02-2018 - Revised: 28-02-2018

ground for this research was Tours, a medium-sized town on the left bank of the Loire. This work extended urban archaeological studies carried out since the early 1970s by the *Laboratoire Archéologie Urbaine de Tours*, which subsequently became the *Laboratoire Archéologie et Territoires* (UMR 6173 CITERES, CNRS-*Université de Tours*). A combination of the two approaches was later applied in preventive and programmed research of the city of Bourges starting in 2014. This involved analysis of the characteristics and principles of superposition of "urban soil", defined as the volume of soil produced by human activities from the first to current occupation. This archaeological deposit is several metres thick and is very heterogeneous, revealing the sequence of urban occupations. As such, it is a source of information about the history of the town and its inhabitants.

This paper presents the methods and results of approximately ten years of studying the urban stratifications of Tours and Bourges. First, at the town level, the study is based on theoretical models used to quantify and qualify the volume of urban soil. Secondly, it explores issues about specific urban sequences, namely the 'dark earth' of the late Roman and early medieval periods. Their heterogeneous nature was revealed by the use of different geoarchaeological and archaeological analysis tools. Finally, the paper presents the initial studies carried out to assess and characterise the urban soil in Bourges. Their findings provide new in-depth knowledge about historical topography, and also highlight the need for a multidisciplinary approach when studying the formation processes of archaeological deposits.

2. Assessment at the town level: modelling the urban soil

2.1. Urban soil

The term "urban soil" was originally used by geotechnicians to refer to the "urban substratum", but with the rise of urban archaeology in the 1960s and the development of a stratigraphic approach, it was given a historical dimension. For archaeologists, urban soil is the whole of the archaeological deposit in historic town centres. It lies between the current surface and the top of the natural layers, with varying thicknesses (sometimes up to ten metres), depending on the density of occupation and use.

The archaeological understanding of urban soil is based on the principle of superposition, which prevailed until the middle of the 20th century. This superposition of layers is the result of anthropic processes, such as the addition of materials and commodities, the production and disposal of waste, or the use of materials for building. It is also the result of natural phenomena leading to deposition or erosion, which are usually responses to the impact of human activities on the environment. These mechanisms account for the heterogeneous nature of the soil in towns (Galinié 1999, p. 11; Breysse *et al.* 2002).

This urban stratification is the main source through which archaeologists understand the occupation of a town from a diachronic perspective. The heterogeneity of the archaeological deposit renders it both complex to study and a particularly valuable object of analysis for the reconstruction of past activities (Fondrillon, Laurent 2009, p. 80).

Urban soil thus provides evidence of the dynamic spatial, temporal and functional variations of the town:

- the urban soil is defined geographically as the former urban space, corresponding to a dense zone of successive occupations (Galinié 1999, p. 9); these spatial variations depend on the town's fluctuating shape, and can be illustrated schematically through the former urbanized area, theoretical spatial model developed by A. Laurent-Dehecq (Laurent 2007) (*espace urbanisé ancien*, see above);
- the urban soil is defined chronologically, between the first and current occupation, and undergoes temporal fluctuations (or trajectories) depending on variations in the intensity of human activity (Lepetit, Pumain 1999b, p. V), expressed by variations in the thickness of the layers;
- the urban soil is defined functionally by the diverse nature of the activities undertaken by the inhabitants, with major variations in the urban functions that produce it, from the dumping of waste to the construction of a building or to funerary use; the complexity of stratification depends on variations in social behaviour.

2.2. Assessment principles in urban archaeology

The practice of assessing the archaeological heritage of towns began in Great Britain in the early 1970s (Biddle, Hudson, Heighway 1973), linked to the post-war reconstruction of town centres. It then extended to several European countries, notably France as part of the development of urban archaeology (*Archéologie urbaine* 1982). It was motivated by the need to protect and study the sub-soil when it is affected by development projects. The first French towns involved in this type of work, including Tours, Chartres and Saintes, adopted the analysis grid used in London (Galinié, Randoin 1979; Joly 1979; Galinié, Boucard 1980). To tackle the phenomenon of "erosion" of this heritage (soil archives) and to incorporate the archaeological potential in urban development policies, these works were closely linked to the development of preventive archaeology measures in France (Dufaÿ 2001, pp. 37-38; Fondrillon *et al.* 2013, p. 278; Troadec 2014, pp. 6-7). The challenge today is to go beyond merely accumulating data, as has been the case since the introduction of preventive archaeology, and to balance the interests of scientific research and those of urban development (Laurent-Dehecq 2014, pp. 10-11). This requires developing a way of managing "soil archives" that acknowledges heritage priorities and scientific issues in relation to the urban phenomenon seen as a whole.

The evaluative (or prospective) approach to urban soil thus enables this archaeological potential to be measured qualitatively and quantitatively at a town level, without having to gather material about the whole urban space by systematic excavation surveys. From a theoretical viewpoint, the procedure involves determining the real archaeological potential (Pr), based on a theoretical potential, called "ideal potential" (Pi), and on the massive destructions that have affected the archaeological deposit (D). The calculation is weighted by a factor regarding the quality of the deposit (Q), which combines the topographical and sedimentary constraints that impact the capacity of the environment to conserve organic and mineral matter. The theorem can be expressed by the following equation, proposed by P. Garmy (1999, p. 94):

$$Pr = (Pi\text{-}D)^Q$$

To solve this equation, the following elements must therefore be determined:

- the ideal potential (Pi), defined on the basis of historical topographic hypotheses, formulated by studying the spatial transformations of the former urban space and changes in urban functions;
- massive destructions affecting the sub-soil (D), which must be inventoried and quantified;
- the quality of the soil (Q), which can be determined by quantification and stratigraphic characterisation tools.

The assessment thus involves hypothesizing at town level, starting from the archaeological site where the data are acquired (fig. 1). Limited by the state of knowledge and the degree of preservation of the remains, it involves first creating a model based on hypotheses about land use in a given place and at a given time *t*, from knowledge about occupation or abandonment, expansion or contraction (Galinié 1989, p. 69). Drawing up maps showing land use at different periods is thus based on this complex combination of historical considerations, empirical knowledge, and the level of preservation of the remains.

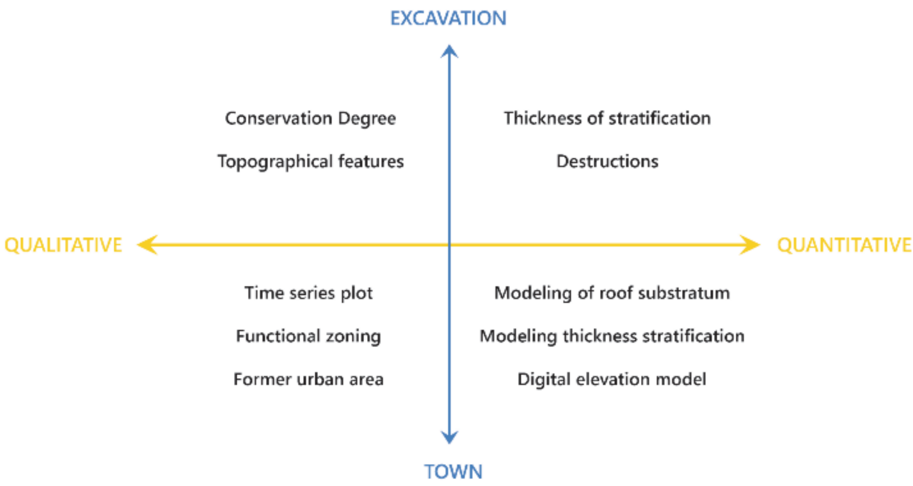


Fig. 1. Parameters of urban archaeological assessment.

2.3. The development of quantitative and qualitative models used in Tours

Quantitative models

A recent thesis on the assessment of urban archaeological potential in Tours led to the development of quantitative and qualitative modelling tools (Laurent 2007). The study is in line with research on Tours carried out since the end of the 1980s (Marlet 2000; Dubant 1989; Blin 1998; Taberly 1999; Noizet 2003), and was conducted in conjunction with a number of academic and research programmes led by the *Laboratoire Archéologie et Territoires* (Fondrillon 2007; Lefebvre 2009; Morin *et al.* 2014).

With regard to quantitative spatial modelling, based on highly developed mathematical matrices, two major models have been proposed for modelling urban soil volume:

- a map of the top-of-substratum layer;
- a map of the thickness of the archaeological deposit.

To construct maps showing the top-of-substratum and thickness of the urban soil, analysis involved generating surfaces from points using a spatial interpolation method. "Kriging", considered to be the optimal geostatistical method (Matheron 1970; Gratton 2002; Zaninetti 2005), was applied to each model at the level of the former urban space (Laurent 2011), and also at the level of the alluvial plain of Tours, such as the uppermost layer of alluvium (Morin *et al.* 2013, fig. 8) (fig. 2). This

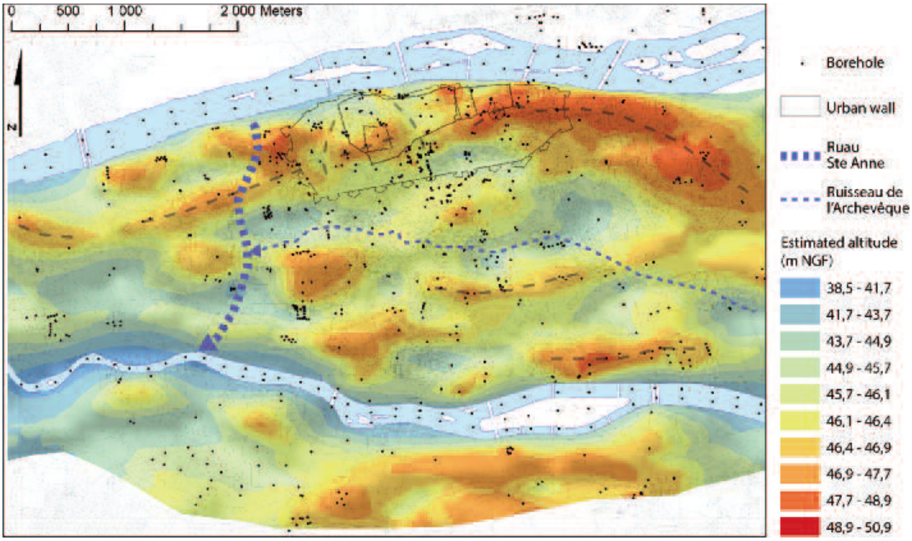


Fig. 2. Modeling of substratum roof in Tours (from Morin *et al.* 2013, fig. 6; Morin *et al.* 2014).

type of modelling is long and complex, notably in terms of data acquisition and mastery of geographical information systems (GIS).

Other models, based on the same set of data, can be applied to the former urban space, such as palaeo-digital elevation models (DEM) that can be used to reconstruct the topography of the urban site at time *t*, or maps showing thickness at different periods, identifying the archaeological potential of urban soil for a given period.

Qualitative models

Other qualitative models, with a theoretical aim, have also been proposed for Tours. In particular, these include maps of the former urban space, which are modified as new knowledge becomes available, and can be implemented more rapidly than the previous models. The former urban space is thus identified by adding and removing zones of dense occupation of the town, from its origins until pre-industrial times (Laurent 2007, p. 24) (fig. 3). The reconstruction of this former urban space is based on historical topographic plans drawn up for the relevant periods, providing working hypotheses that highlight the phases of expansion and contraction of a town, and define in practice a perimeter of "archaeological sensitivity" (Galinié 1992, p. 141). This type of highly predictive modelling can result in theoretical maps of the thickness of the urban soil based on a stratification production model, which models the expected thickness of stratification arising from the intensity of occupation (Laurent, Fondrillon 2010, pp. 328-334).

More often, archaeologists use other qualitative models to assess the archaeological potential of the town. These comprise historical topographical maps, generated for each period, based on current chronological, spatial and functional knowledge at the level of the urban site. These maps generally show point data, in the form of discoveries classified per type of deposit. The prerequisites for developing the topographical *corpus* of a town are the formalisation, interpretation, and finally spatial modelling of the topographical data (Galinié, Rodier 2004, p. 26). Between 1990 and 2013, the French National Centre of Urban Archaeology (no longer in existence), inspired by studies carried out following the seminal assessment work (outlined above), published a collection of twenty-two monographs (*Documents d'évaluation du patrimoine archéologique des villes de France - DEPAVF*), which provided an overview of a number of towns. The objectives of this collection, which

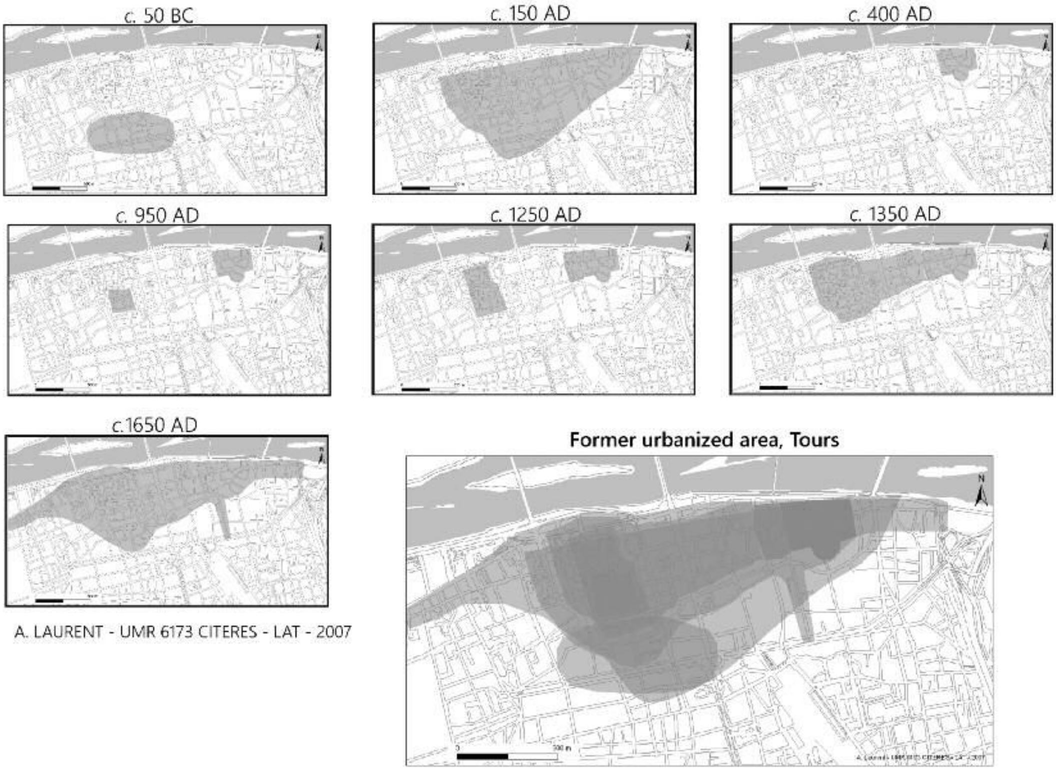


Fig. 3. Former urbanized area, Tours (from Laurent, Fondrillon 2010, p. 314, fig. 3).

focused on the "ideal potential (Pi)" in relation to the "real potential (Pr)", were subsequently used for academic research, centred on the use of GIS (CNAU 2004; Delahaye 2012; Gravier 2012; Pinhède 2012).

In Tours, the use of the geographic information system and the active management of data using a database management system (DBMS) led to the production of dynamic models at the level of the town or neighbourhood (Lefebvre 2009). For example, the TotoPI (*Topographie de Tours Pré-Industriel*) updates historical topographical maps for each urban period (Galinié, Rodier 2002). The system incorporates hypotheses of land use, notably for periods that are poorly or little documented, such as the earliest phases of site occupation during the final Iron Age (Riquier 2007, pp. 202-203), or the period from the Late Roman to the early Middle Ages (Galinié, Lorans 2007, p. 371). Of particular note is the chrono-chorematic workshop organized by the CNAU in 2001 to develop a system, halfway between quantitative and qualitative approaches, for modelling the shape and evolution of towns (Dufaÿ 2002; Boissavit-Camus *et al.* 2005, p. 67).

Against this scientific background, each new excavation allows these hypotheses to be tested and knowledge to be up-dated, based on a constant and crucial interaction between field observations and the model.

3. Characterisation at the site level: the central issue of dark earth

All the models show that stratification varies in complexity in different parts of the town. We may postulate that where human activities are intense, the urban soil is more likely to be thick and heterogeneous. In many sites, sequences that are more difficult to characterise have been identified, notably layers of dark earth dating back to the Late Roman and early Middle Ages, apparently homogeneous, but which are revealed by methods of soil characterisation to be more complex. Understanding these deposits at site level, when viewed in relation to the town level, sheds new light on these spaces and the way they were occupied at different periods.

3.1. The question of dark earth

Thanks to the development of preventive archaeology in France, dark earth has been discovered both inside and outside the reduced late antique city walls, in areas where there is evidence of the continuity and density of occupation since Classical Antiquity. 'Dark earth' is widely defined by specialists as a dark, humus-rich deposit, stratigraphically undifferentiated, with a thickness varying between 0.3 and 1.5 m (Fondrillon 2009).

The formation of these layers can cover nine centuries of the town's history, generally between the 4th and 12th centuries, which in the past has been inaccurately perceived as a period of decline and lethargy. During that period, the topography of towns is marked by a contraction of the urban space. Indeed, apart from Narbonne, the majority of administrative centres, such as Tours or Bourges, were enclosed by city walls built during Late Antiquity, with a surface area considerably smaller than that of the former open cities. In Tours, the *intra muros* area was 9 ha, just 10% of the surface area of the Early Roman town.

For a long time, it was thought that there was widespread abandonment of housing *insulae* during this period, which were at best transformed into fields, although this was not substantiated by any stratigraphic or geoarchaeological analysis (Galinié 2002, p. 98). This absence of documentary evidence led to the assumption that urban life in the Late Roman and early Middle Ages was extremely restricted. As a result, this led to an underestimation of the density and continuity of urban housing from the 4th century onwards.

Following the development of research in the UK at the end of the 1970s and then in France during the 1990s, joint archaeological and geoarchaeological study protocols were established, leading to a better understanding of these layers (Cammas *et al.* 1995). The main focus was on the dynamics of production and transformation of archaeological soils, prioritising the intra-site level. Since the mid-1990s, a number of studies have been conducted on pioneer sites including Paris, Château-Thierry and Wandignies-Hamage (Guyard 2003; Blary, Durey-Blary 1994; Louis 2004). These studies have led to improved methods of excavation, stratigraphic recording, sampling protocols, and studies of movable objects and sedimentary elements.

In Tours, a thesis on dark earth deposits in several town-centre sites excavated in the 2000s aimed to identify their usage and formation processes.

3.2. Microarchaeology: at the intersection of the study of archaeological artefacts and geoarchaeology

The study is based on understanding the mechanisms of soil production and on an interdisciplinary approach (Fondrillon 2012). This approach, which has been used in the United States and United Kingdom since the 1980s, and more recently in Belgium and France (Stein, Telster 1989; Laurent 2004; Desachy 2000), is based on analysis of sets of coarse components, in other words, all the anthropogenic and natural matter contained in the archaeological layers. The material is retrieved by wet-sieving 5- to 15-litre bulk sediment samples through a coarse mesh (usually 5 mm). It is then sorted by component category, counted and weighed (fig. 4).

In this study, we postulate that a particular type of human activity produced a specific type of layer that is recognisable through its specific sedimentary composition. The study of dark earth therefore has two objectives: first, at the level of individual layers, to characterise the use of the space that generated the dark earth (e.g. domestic, agricultural, artisanal) using a reference framework; secondly, at the level of the wider stratigraphic sequence, to identify how the deposits were formed by revealing patterns of accumulation and transformation of material (fig. 5).

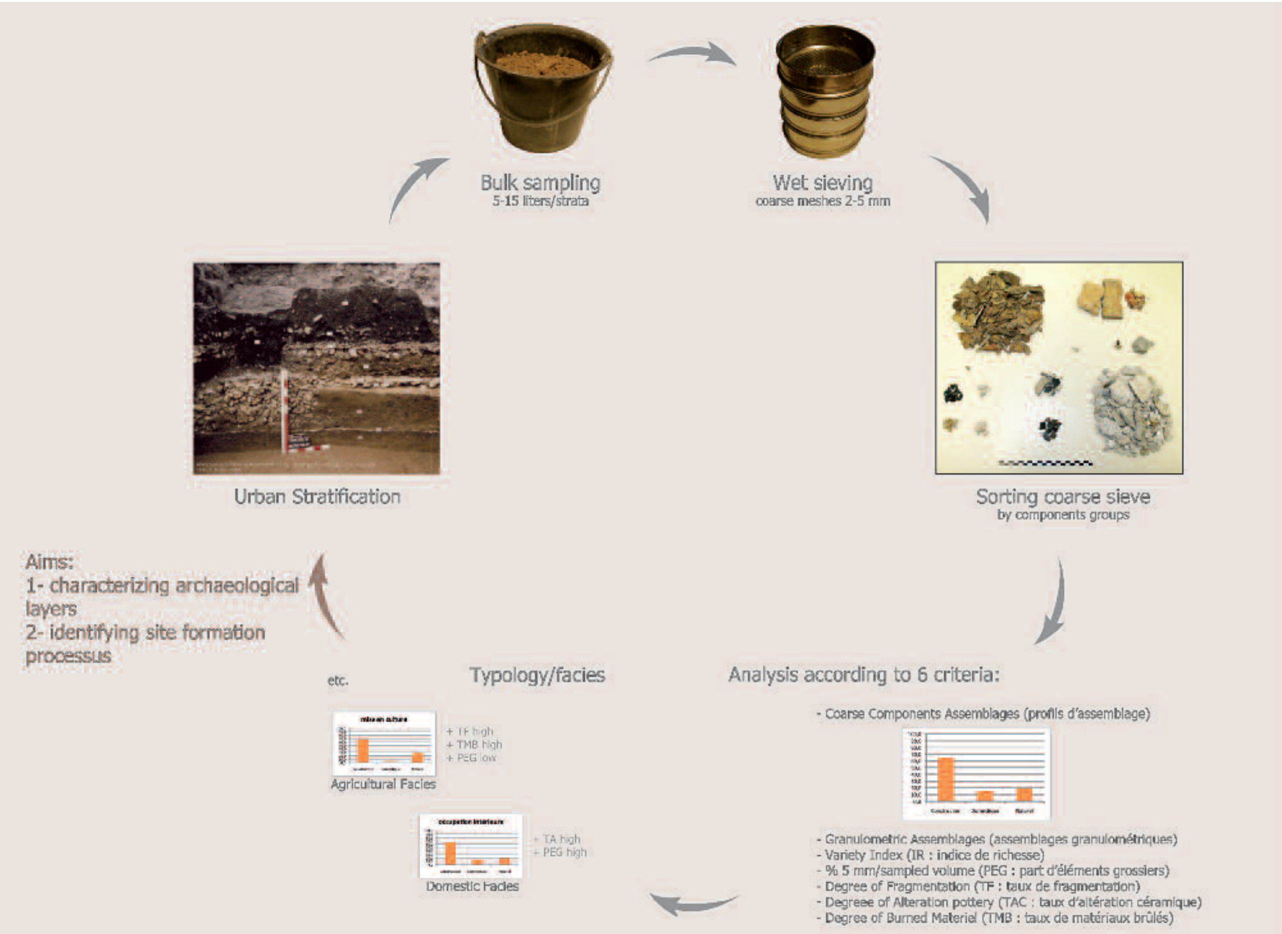


Fig. 4. Microarchaeological approach (from Fondrillon 2012, p. 148, fig. 5).

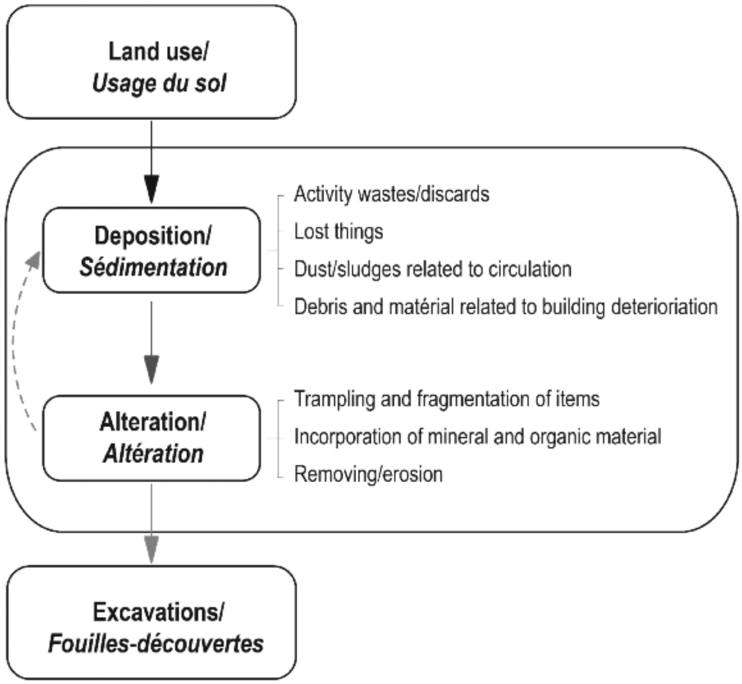


Fig. 5. Diagram of formation processes of stratification, using the example of occupation layers.

To characterise the deposits of dark earth, a working reference framework was created by including securely interpreted strata for all periods and functions. It is based on six criteria of distinction, including the sets of components generally used by microarchaeologists, as well as the variety index and fragmentation rates (see above fig. 4).

Characterisation of these deposits at the site level provides a means of understanding how they are formed and of reconstructing the past activities that produced them. Incorporating this topo-historical knowledge at the town level can give meaning to one-off remains that appear unequivocal (Fondrillon 2012, p. 145).

3.3. Application at the site level and revision of the urban model in the Late Roman and early Middle Ages

In the early 2000s, excavations including an interdisciplinary approach were led on the site of Saint-Julien, in Tours, near both a monastic church and the present southern boundary of River Loire, within the historical urban limits. They revealed seven meters of stratigraphy, extending from Roman levels to present surface. Within this stratification, dark earth dating to Late Antiquity and the Early Middle Ages represent about one to two meters. Excavations were undertaken mainly in order to characterize dark earth deposits, based on a systemic approach developed around traditional stratigraphic and material studies associated with geoarchaeological analyses.

In the West side of the excavation (section 10), dark earth deposits appear to be brown and homogeneous, five meters thick at one point (fig. 6). While excavating, no differences were observed, due to a lack of any visible stratigraphy; so a method of arbitrary spits or levels was applied.

The microarchaeological study revealed the stratigraphic variability of coarse component assemblages. The diagram shows dark earth deposits including principally fragments of Roman debris but it also shows variations involving regular accretions, not massive backfill.

The first sedimentary referential frames were developed by a large number of geoarchaeologists working on sequences of dark earth. The next step involves establishing new referential frames and new tools based on traditional artefactual studies. This requires analysis of movable archaeological objects in order to date strata of dark earth more accurately, and by extension to know more about the processes of deposit formation (Borderie *et al.* 2012, p. 244). Insofar as it is difficult to date these archaeological levels, due to a broad chronological spectrum that raises specific questions about residuality, other methods of representation and quantification are required to estimate the age of the deposits. The sequential study of the ceramic assemblage in the dark earth deposits in Tours used a seriation tool ("the seriographer") developed by Bruno Desachy (Desachy 2004). The graphs obtained through this tool are based on calculation of the positive deviations from mean percentages (fig. 7), and make it possible to date the different strata of dark earth in relation to each other and to identify phenomena such as hiatuses of activity. In line with R.I. Macphail's micromorphological analysis and Y. Graz's analysis of organic matter, the study of dark earth at Saint-Julien shows that these deposits were homogenised by agricultural practices and biological activity (Galinié *et al.* in press). In spite of considerable stratigraphic mixing linked to these natural and anthropic processes, the deposits are stratified and preserved; a total of eight different stratigraphic sequences were reconstructed, notably domestic occupation between two cultivation phases. The superposition, and sometimes juxtaposition, of these phases provides evidence of the diversity of land uses between the 4th and 11th centuries.

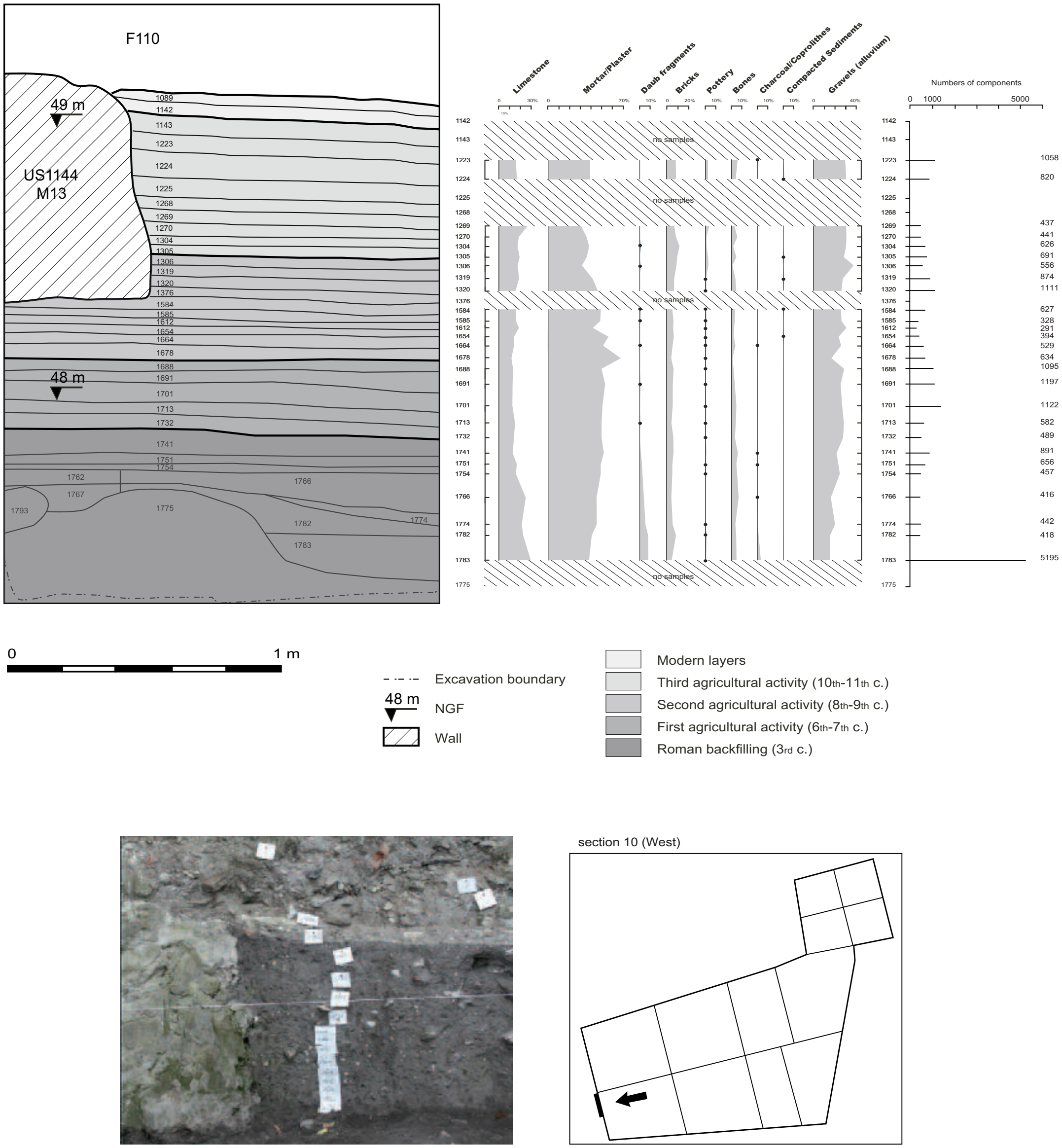


Fig. 6. Microarchaeological study of dark earth deposits, section 10 of Saint-Julien site (Tours).

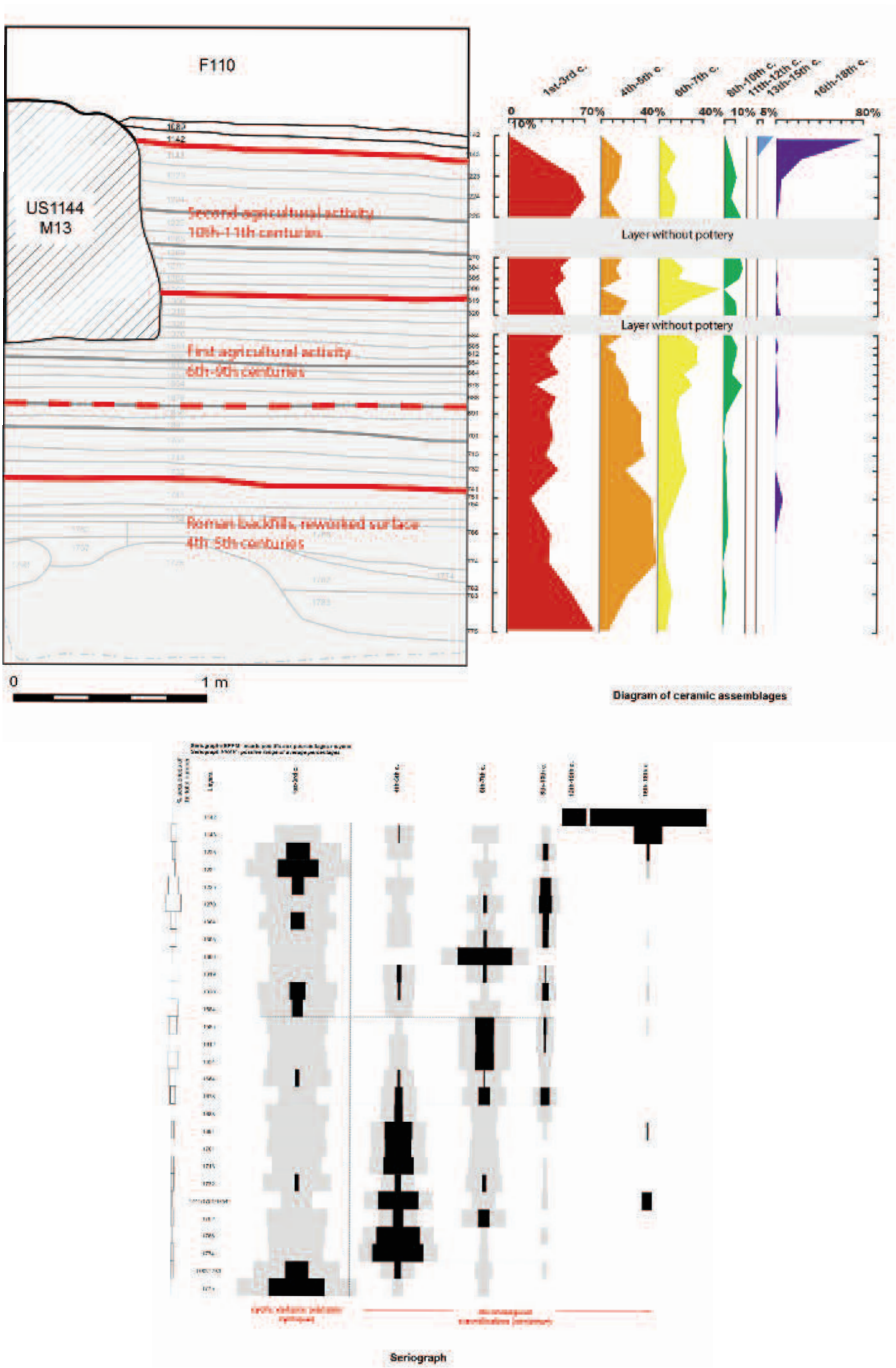


Fig. 7. Chronological approach and seriograph using pottery assemblages of dark earth deposits, section 10 of Saint-Julien site (Tours).

Integrating these site-level results into the *corpus* of topographical knowledge at the town level in Tours led to a redefinition of the urban space, based on a revision of the topo-historical models for the Late Roman and Early Middle Ages (Laurent, Fondrillon 2010, p. 339, fig. 28). In this way, characterisation of the archaeological deposit as a whole at the site level, including urban sequences with less obvious potential, becomes meaningful at the town level and provides a new way of understanding the trajectories and limits of the urban phenomenon in the *longue durée*.

4. From the site to the town, from the town to the site: application of methods to assess and characterise the urban soil of the Bourges site

4.1. Corpus *and method*

Since 2014, a comparable approach to assessing and modelling archaeological potential has been adopted in Bourges, involving both preventive and programmed research. The objective is not only historical – working by integrating archaeological discoveries into the historical knowledge of the town as a whole – but its predictive nature also impacts policy, by establishing areas where heritage factors need to be taken into consideration when planning development projects. Work started recently and mainly concerns data acquisition and developing dynamic topographical data management tools, a prerequisite for all comprehensive studies of urban sites. The development of preventive archaeology in Bourges over the last fifteen years has provided new historical topographic knowledge, acquired at the site level. However, increasing the number of observation points depends directly on regional development policies, inclined towards peripheral urban spaces (fig. 8). This has opened up possibilities of working on spaces that would not otherwise have been included in research programs, and which are generally "urban fringe" sectors. Moreover, data acquisition at these sites involved archaeological deposits as a whole, without the chronological discrimination that would have been given greater priority in targeted research (Fondrillon *et al.* 2013, p. 281).

When undertaking a comprehensive study of the town, the objective is to organise and examine this large *corpus* by developing functional and spatial analysis tools, based on previous studies (see above). At the site level, this involves first making an inventory of all available archaeological documentation, as well as all mentions of topographical elements or past

Fig. 8. Archaeological excavations map in Bourges.

discoveries, even if they are not entirely reliable. The objective is also to develop new data acquisition procedures by combining destructive and non-destructive assessment methods (geophysical or mechanical surveys, core sampling) in one or more poorly documented zones. One of the main methods used is PANDA©, a computer-assisted dynamic penetrometer device (Fondrillon *et al.* 2013, p. 284). This device works on the principle of measuring point resistance (Qd in MPa) while hammering a steel rod. The results of these surveys are presented in the form of a penetrogram representing the compactness of layers at different depths (Laurent 2006, p. 221, fig. 1).

The data are processed using the *Système d'Information Archéologique de Bourges* (SIAB), a research and urban assessment tool developed since 2014 in the urban district of Bourges. It was inspired by a document describing the assessment of urban archaeological heritage in Bourges produced in the 1990s (Troadec 1996, *Document d'Evaluation du Patrimoine Archéologique Urbain*), and has two main objectives, organised in two modules (fig. 9): first, to establish current topo-historical knowledge at the level of the town and its surrounding countryside (*SIAB-Topographie Historique*), and secondly to produce a synthesis of quantitative information about the sub-soil and remains (*SIAB-Évaluation*). The procedure is based on the principle of combining a relational inventory system (DBMS) and a system of georeferencing spatial entities (GIS).

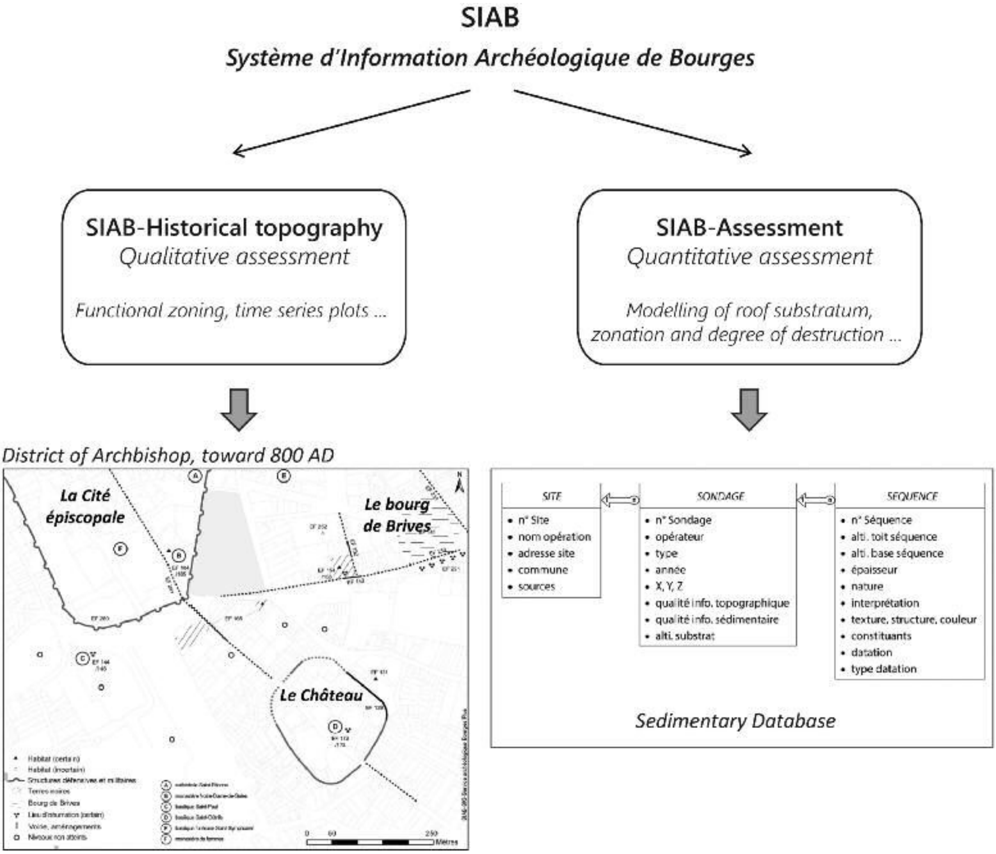


Fig. 9. System of archaeological data management in Bourges: the tool SIAB (*Système d'Information Archéologique de Bourges*).

4.2. Modelling trials

A qualitative approach to urban phenomena has also recently been adopted in Bourges. This combines an archaeological mapping system in the "Historical topography" module of the SIAB, which generates land use maps of different periods (see above, fig. 9), and more theoretical representations that enable the archaeological potential to be modelled diachronically. This led to the production of a map of the former urban space in Bourges, from the first urbanisation of the site in the 5th century BC until the 18th century (fig. 10). Seven historical periods can be identified, including the "princely residence" of the end of the Hallstatt period (6th and 5th century BC), and the former open town of the Early Roman period (1st to 3rd century AD). An attempt to model the urban soil based on the intensity of human occupation is planned, following the example of work carried out in Tours (Laurent, Fondrillon 2010, p. 334).

Another type of modelling, this time quantitative, has been trialled since 2010. This involves the creation of a map of the uppermost limestone layer, produced by L. Augier in collaboration with X. Rolland as part of research into the earliest periods of urbanisation of the Bourges promontory in the first Iron Age (Augier 2013). That work was based on data from about one hundred points, gathered either by archaeological investigation (assessment and excavation), or by a series of geotechnical surveys carried out as part of urban development projects. From this initial work it was possible to model the highest level of the natural at Bourges and the course of two large thalwegs cut into the limestone plateau to the south of the spur (fig. 11).

In 2016 and 2017, the acquisition of new geotechnical data in the south-east sector of the town led to the production of a new spatial interpolation of the highest limestone layer, based on a tool that takes into account the constraints of runoff and, by contrast, the contour lines. This method, provided by the ArcGIS "Topo to raster" tool, is based on the ANUDEM program in developement since the late 1980s, which can generate "hydrologically correct" digital elevation models (Esri 2016). In the case of Bourges, present-day ridges and watercourses were used as constraints. It was decided to apply global interpolation of the measures, smoothing out local micro-variations. This method enabled improvement on the first model, highlighting more clearly the two thalwegs south of the spur and the ancient alluvial terraces at the bottom of the north and west slopes.

Tests of other interpolation methods such as kriging are planned, inspired by modelling carried out in Bordeaux (RIVIERA project; Thierry *et*

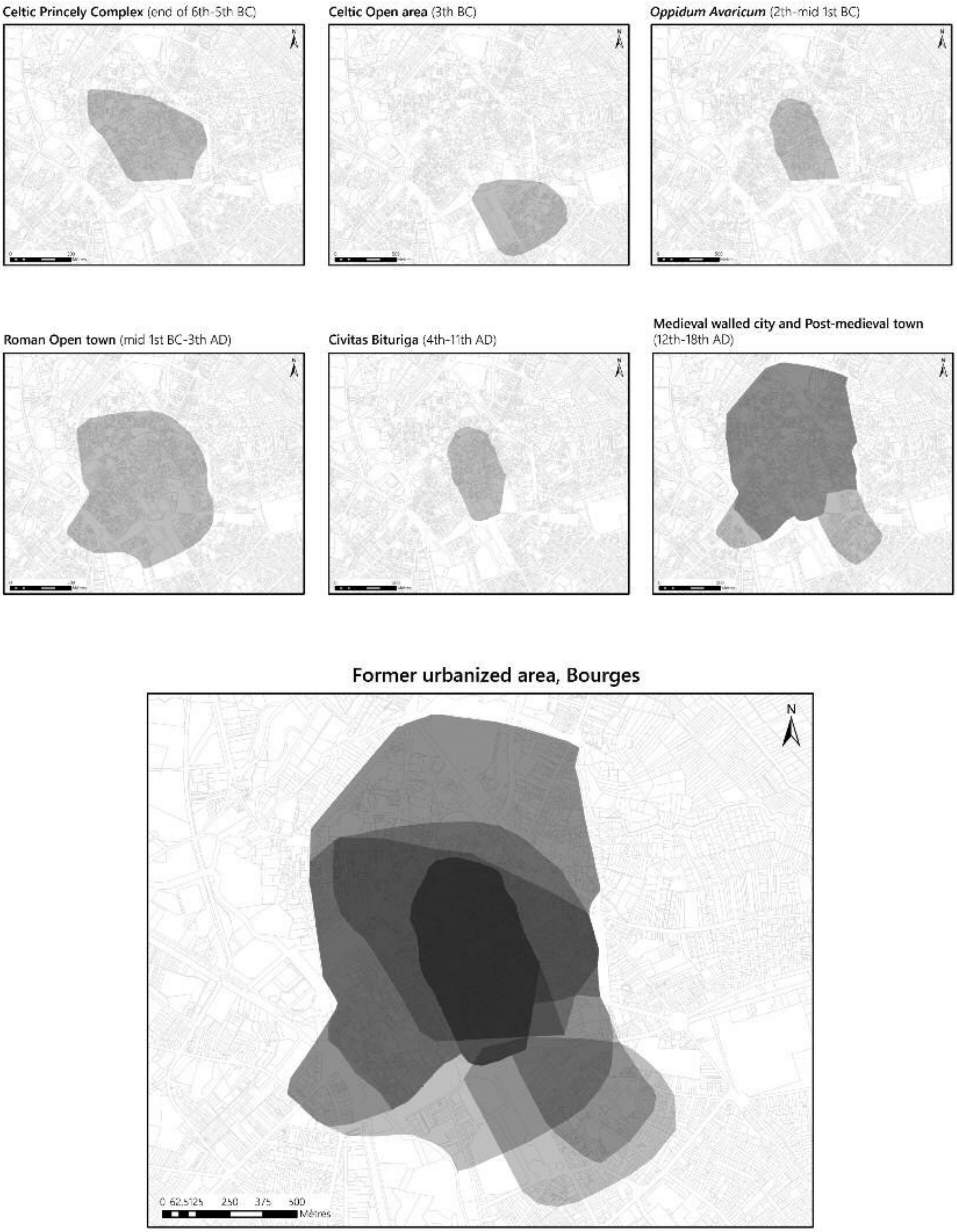


Fig. 10. Former urbanized area in Bourges.

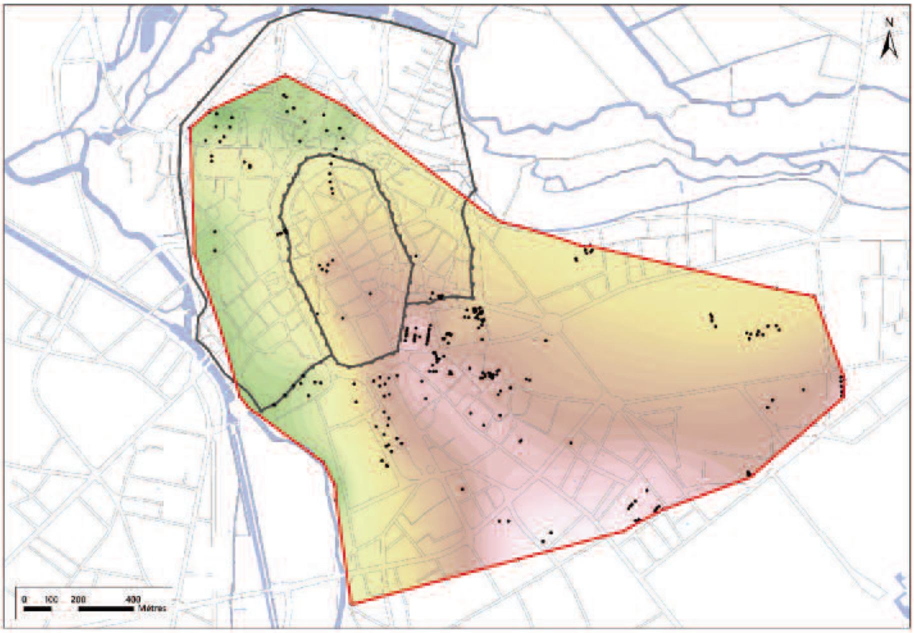


Fig. 11. Modeling of substratum roof in Bourges, using the interpolation Topo to raster (ESRI, Anudem program).

al. 2006) and Tours (see above, Laurent 2007; Morin *et al.* 2013), and in progress in Lyon, Paris and Orléans. This type of modelling could be used to create palaeo-digital terrain models (DTM), by representing the top stratification level or the volume of archaeological soil during different periods. In the short term, the objective is to acquire additional data for each large urban sector. Indeed, insofar as the Bourges site has a heterogeneous substratum and mixed relief (valleys, confluences, spurs, plateaus, slopes, ancient alluvial terraces), very different from that of Tours, it is essential to increase the number of observation points and to develop preliminary approaches at the local level (Fondrillon 2016, pp. 71-73).

4.3. Methods of characterising the urban soil at the site level: dark earth and brown earth at the Avaricum ZAC site

Three complementary approaches, geoarchaeological, artefactual, and archaeo-mechanical, have been applied to the archaeological stratification discovered at *Avaricum ZAC* (urban development site) site in Bourges, located in a marshy area at the bottom of the north slope of the Bourges spur. A preventive survey was carried out in 2009 and 2010, revealing that occupation of the site began in the 1st century AD and continued up to the present day. The urban stratification, approximately 4.5 m thick, includes sequences of brown and dark earth, providing evidence of occupation of the site between the 4th and 13th century. Numerous studies of the soil, organic material and archaeological objects were undertaken on these deposits to identify the processes of formation, alongside a stratigraphic survey carried out on a few sectors (Fondrillon, Marot 2013).

4.4. The geoarchaeological approach and microarchaeological analysis

In the north part of the excavated area, a large cut (section 205/206) across the whole of the archaeological stratification made it possible to study the formation processes at work in the stratigraphic sequence. The microarchaeological analysis, carried out alongside a micromorphological study (Pauly 2013; Vissac 2013), concerned the lower half of the stratification formed between the Early Middle Ages and the end of the modern period, with a thickness of 1.5 m (fig. 12). These two analyses revealed a stratigraphic pattern of six phases:

- the base of the cut is composed of dark earth from the Early Middle Ages (SU 20092), sealing the top of roman masonry; it provides evidence of outdoor human occupation, with significant quantities of domestic refuse (associated with meat consumption, and pottery); these rates should however be qualified, as there can be considerable residuality of this type of deposit; overlying this was a roadway (hardened agglomerates, numerous calcareous stones, highly fragmented components), probably built by the last quarter of the 12th century;
- the following phase (SU 20091 and 20089) shows several additions of coarse material to develop and maintain the road; it appears homogeneous, but slight variations indicate more or less massive deposition of construction elements;
- the upper levels (SU 20084, 20085, 20087 and 20088), formed at the start of the 15th century were very comparable to Late Antique or early medieval phases of dark earth; the accumulation of specific types of refuse (charcoal and domestic objects) indicates the densification of occupation and a functional transformation of space, interpreted as a sheltered zone (courtyard or occupation of an annexe); behind the apparent homogeneity of the deposit, the coarse assemblages reveal variations that indicate specialisation in the waste material. For example, traces of metallurgical activity can be found in the upper two strata (SU 20084 and 20085);

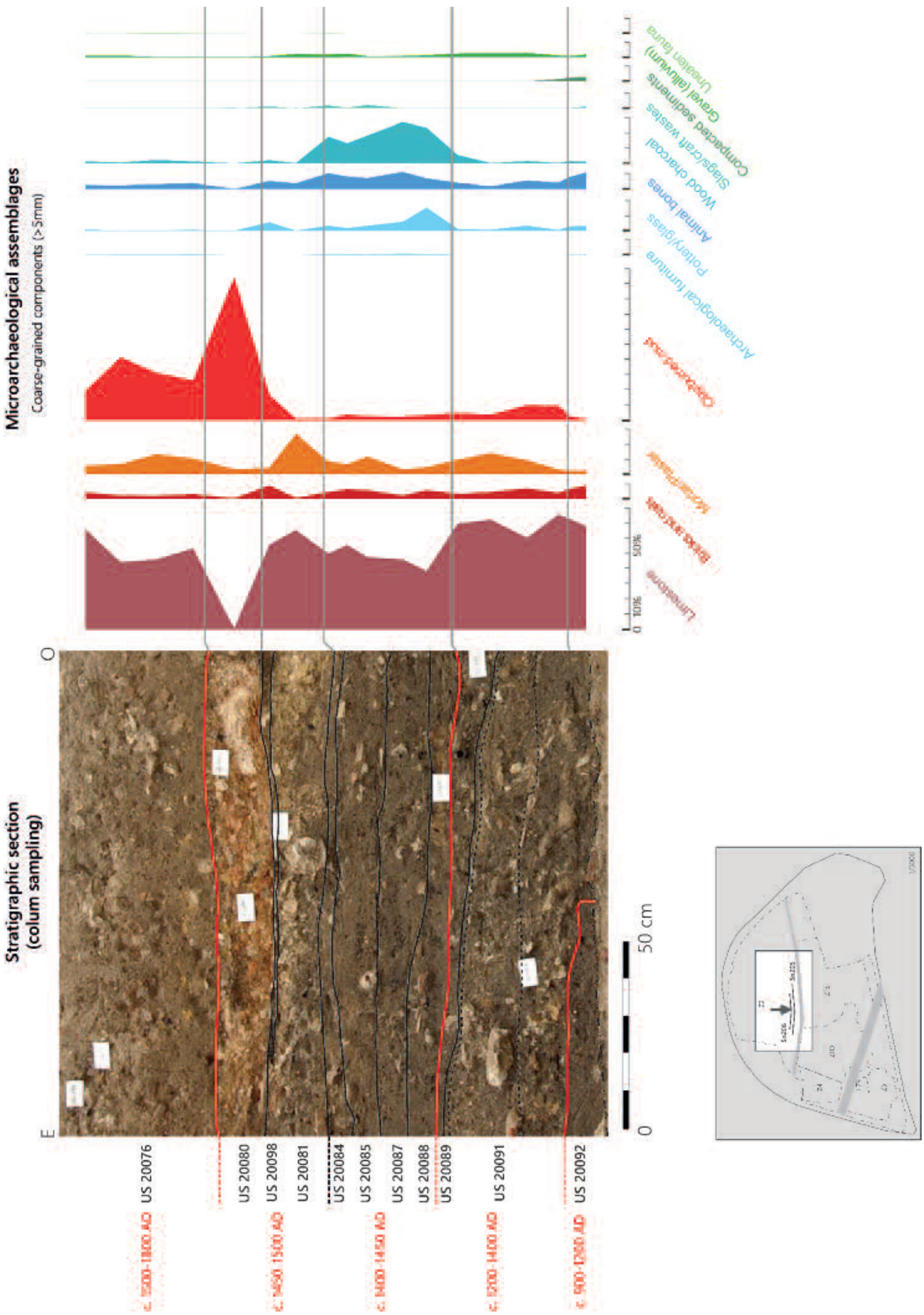


Fig. 12. Microarchaeological study of urban stratification, sections 205-206 of ZAC Avaricum site (Bourges).

- the overlying layer (SU 20081) yields evidence of massive deposits of rubble, probably used to back-fill the space for occupation of the layer above in the 15th century;
- the next layer (SU 20098) reflects indoor occupation, with a significant rate of domestic elements, excluding charcoal;
- the following phase provides evidence that the structure burnt down, marked by an almost exclusive assemblage of wattle and daub.

After the building was destroyed, the space was not occupied in the modern period, and shows a succession of exterior soils interspersed occasionally but regularly with domestic refuse, or with more massive deposition (SU 20072).

Like many archaeological and geoarchaeological studies of apparently homogeneous strata, the intrinsic analysis of archaeological layers, placed in the context of a stratigraphic sequence, reveals variations of sedimentary composition resulting mainly from the variety of human activities. However, in addition to the historical results of this type of study, methodological advances should be highlighted and encouraged. In particular, bringing together different methods is crucial to understanding dark earth, and current issues require the involvement of more traditional studies of archaeological artefacts, such as ceramics, in order to understand the chronology of the deposits.

4.5. Understanding the chronology of the deposits

In line with the sequence analyses carried out in Tours, the ceramic assemblages from the dark earth and related deposits at the *Avaricum ZAC* site were studied, using various dating methods alongside microarchaeological and micromorphological studies. In particular, in one cut made behind a medieval building in the south of the site (section 144), the use of different dating methods, together with geoarchaeological analyses (microarchaeology, micromorphology, organic chemistry and palynology), revealed how medieval dark earth and brown earth deposits were formed (fig. 13). The chronological approach involved both a traditional ceramological analysis for each stratigraphic unit and radiocarbon dating from charcoal retrieved from sifting. The objective was to test the degree of intrusion of charcoal micro-fragments in these regularly mixed sequences. As the preservation conditions were particularly good, large amounts of organic matter, notably pollen and varied domestic waste, had been preserved (Fondrillon, Marot 2013). The dating elements are all very consistent and indicate that this dark earth was formed between the end of the 11th century and the beginning of the 13th, confirming the very progressive character of these accumulations.

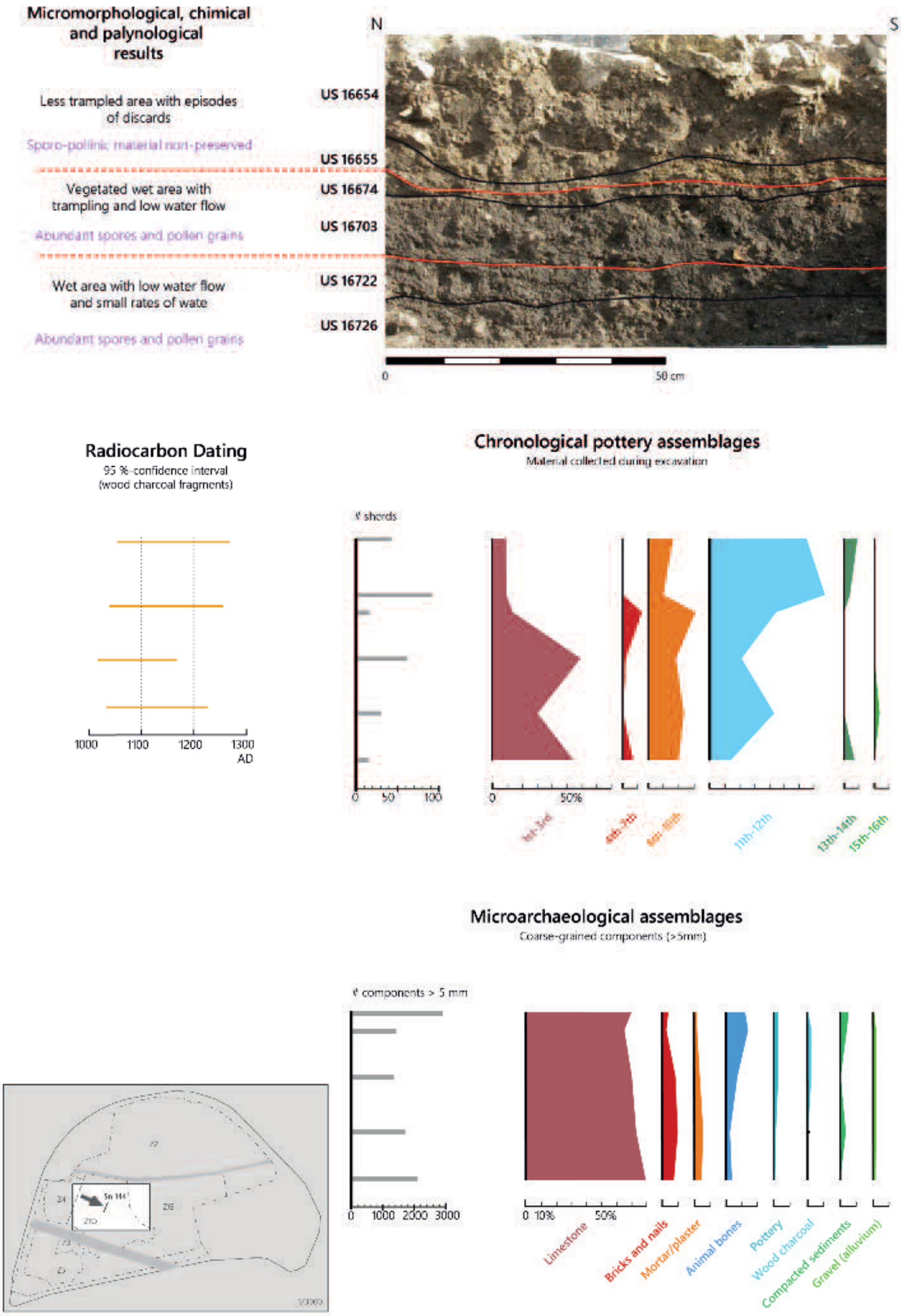


Fig. 13. Geoarchaeological and chronological study of medieval sequences in section 144, *Avaricum ZAC* site (from Borderie *et al.* 2012, p. 245, fig. 7).

4.6. The quantitative measure

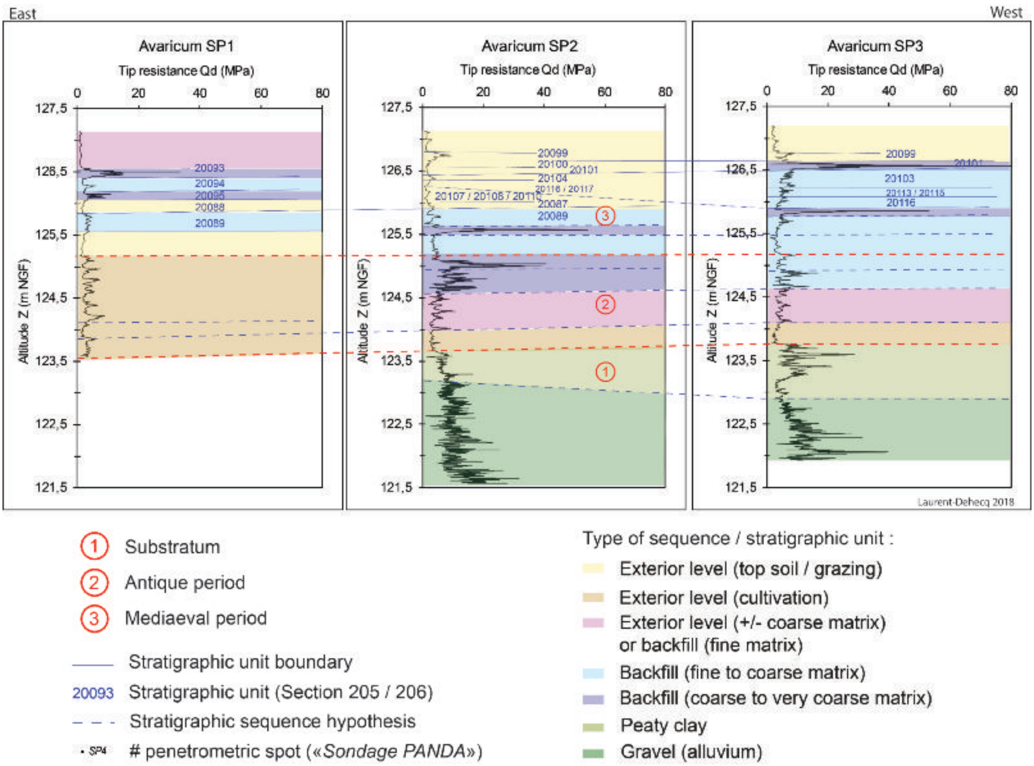
Another method was used across the whole of the *Avaricum ZAC* site to detect and characterise the sequences of dark earth or related deposits. This was the PANDA®, a geotechnical tool (mentioned above) that has the advantage of being cheap, easy to handle, and usable on all types of terrain (Laurent 2007, p. 58).

The study aimed to establish an archaeo-mechanical referential frame for each urban site. Although dark earth in different towns has common characteristics, the study required numerous comparison points for an urban space with a homogeneous substratum. For this reason, several surveys were carried out with the PANDA® during the archaeological investigations to develop this reference framework, linking mechanical properties to clearly defined archaeological layers (back-fill, interior and exterior occupation, masonry, etc.) as well as to clearly identified substrata (sand, clay, peat, limestone, etc.). The soundings were thus taken at the edge of the stratigraphic cut in order to observe the material the tool passed through.

To differentiate between the functional interpretations of the layers, several criteria were applied using statistical methods (Bayesian probability, factor analysis): mean resistance and internal variability of measures, the thickness of the layers and their stratigraphic position (Laurent, Fondrillon 2010, fig. 13). The results show that it is possible to distinguish between the archaeological deposit and natural formations, but they also particularly emphasise the heterogeneity of the mechanical properties of the archaeological functions. Nevertheless, it is possible to group types of archaeological deposit into broad categories.

The use of the PANDA® on the large reference cut in the southern part of the *Avaricum ZAC* site (sections 205/206) made it possible to correlate the penetrograms with field observations and geoarchaeological results (see above). The archaeo-mechanical analysis shows that the exterior occupation sequences (cultivation, pasture, garden) have weak to strong resistance values with low, and hence homogeneous, internal variability (fig. 14). The levels of dark earth identified on this site can be clearly distinguished from the underlying ancient layers, which are characterised by back-fill with a greater coarse fraction or by uses leading to higher resistance values and internal variability (significant heterogeneity), up to the impossibility of penetrating a layer composed of hard, compact material such as masonry.

Thus, the different analyses reveal that the variety of mean resistance values of dark earth or related deposits can be explained by the greater or lesser presence of coarse matter and the variety of assemblages of components. The homogeneous character of these levels, revealed by mi-



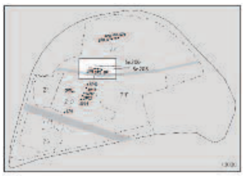


Fig. 14. Comparison of penetrograms and stratigraphic sequences, sections 205/206 of *Avaricum ZAC* site.

croarchaeological and micromorphological observations, can be clearly demonstrated by their varying mechanical properties. These encouraging initial results show the possibility of using the PANDA® in conjunction with analysis of soil components and their assemblages to characterise dark earth sequences and to detect them in other parts of the Bourges.

5. Conclusion

The use of different approaches led to a better understanding of the heterogeneous character of urban soil. Using a combination of methods is crucial in order to assess and characterise the full range of archaeological deposits. The particular attention paid to difficult-to-understand, apparently homogeneous sequences such as dark earth or related deposits, sheds new light on the large urban models. Whatever the nature and origin of the town, recent discoveries show that these levels provide evidence of the continuity of occupation since classical antiquity, but in different forms. This raises a cultural issue, leading to a need to rethink our image of the town of the Late Roman and Early Middle Ages, with new modes of construction, new ways of disposing of refuse, and new land uses. These analyses reveal the complexity of deposits generated by a wide range of human activities.

By following the different approaches to the study of dark earth presented in this paper, it is possible to propose a "tool box" with which to identify how, when and why such layers were formed. In this way, while recent research findings shed light on the urban landscape of the Early Middle Ages, they can also be used to characterise other puzzling sedimentary sequences such as the dark earth of the final Iron Age or the "garden soil" of the modern period in former town centres.

While every town has its own specific features, often inherited from a particular sedimentary base, and each requiring its own referential frame, these studies reveal trajectories that are common to all urban sites. These observations argue for the development of systemic approaches, in the form of representations of the urban phenomenon as a whole, and encourage the further development of tools and models that can be used in all urban contexts. The qualitative and quantitative measure of archaeological urban deposit thus requires continuous interaction between empirical and theoretical approaches, and constant feedback between the site and the town level (fig. 15).

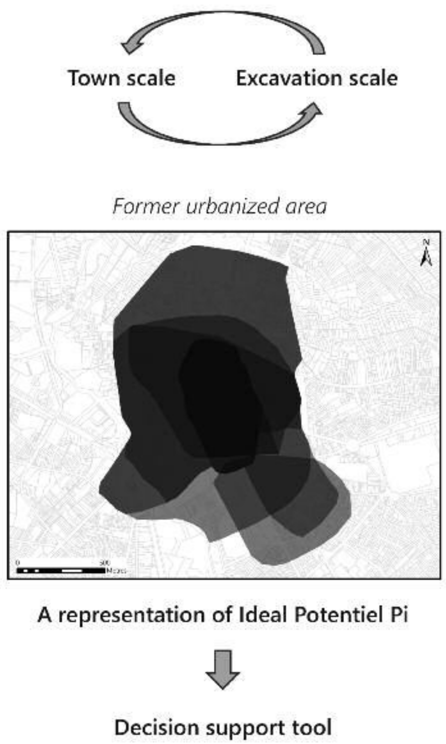


Fig. 15. Model of study scales in urban archaeology.

References

Archeologie Urbaine 1982, *Archéologie urbaine*, Actes du colloque international de Tours (17-20 novembre 1980), Paris.

L. Augier 2013, *Modélisation de la topographie de Bourges aux âges du Fer*, in S. Krausz, A. Colin, K. Gruel, I. Ralston, T. Dechezleprêtre, *L'Âge du Fer en Europe. Mélanges offerts à Olivier Buchsenschutz*, Pessac, pp. 181-186.

M. Biddle, D. Hudson, C. Heighway 1973, *The Future of the London Past. A Survey of the Archaeological Implication of Planning and Development in the Nation's Capital*, Worcester.

F. Blary, V. Durey-Blary 1994, *Château-Thierry (Aisne). Le château du comte de Champagne et ses antécédents*, in A. Renoux (ed), *Palais médiévaux (France, Belgique). 25 ans d'archéologie*, Le Mans, pp. 35-36.

C. Blin 1998, *Contribution à la géoarchéologie et la morphogenèse de la Loire dans le val de Tours. Constitution d'une base de données géologique*, Mémoire de maîtrise, Université d'Angers.

B. Boissavit-Camus, G. Djament, B. Dufay, H. Galinie, C. Grataloup, C. Guilloteau, X. Rodier 2005, *Chrono-chorématique urbaine: figurer l'espace/temps des villes,* in J.-F. Berger, F. Bertoncello, F. Braemer, G. Davtian, M. Gazenbeek, *Temps et espaces de l'Homme en société. Analyses et modèles spatiaux en Archéologie*, Actes des XXV[e] rencontres Internationales d'archéologie et d'histoire d'Antibes (21-23 octobre 2004), Antibes, pp. 67-80.

Q. Borderie, M. Fondrillon, C. Nicosia, Y. Devos, R.I. Macphail 2013, *Bilan des recherches et nouveaux éclairages sur les terres noires: des processus complexes de stratification aux modalités d'occupation des espaces urbains*, in E. Lorans, X. Rodier (eds), *Archéologie de l'espace urbain*, Tours, pp. 235-250.

D. Breysse, H. Niandou, X. Rodier, H. Galinie, A. Laurent 2002, *Le pénétromètre et l'hétérogénéité des sols archéologiques urbains*, "Revue Française de Géotechnique", 100, pp. 43-58.

C. Cammas, F. Champagne, C. David, B. Desachy, L. Guyard 1995, *Le problème des "terres noires" sur les sites urbains tardo-antiques et médiévaux: réflexions et propositions méthodologiques à partir de l'exemple du Collège de France à Paris*, "Les Nouvelles de l'Archéologie", 61, pp. 22-29.

CNAU (*Centre National d'Archeologie Urbaine*) 2004, *Informatisation des documents d'évaluation du patrimoine archéologique des villes de France – bilan d'étape 2002-2003*, Tours.

J. Delahaye 2012, *Synthèse archéologique urbaine: évaluation du potentiel archéologique de la ville du Mans*, Mémoire de master d'archéologie médiévale, Université de Paris 1.

B. Desachy 2000, *«Terres noires» du Collège de France (Paris): traitement par analyse factorielle des comptages en poids de fragments de matériaux de construction*, in *Terres noires*, Tours, pp. 77-82.

B. Desachy 2004, *Le sériographe EPPM: un outil informatisé de sériation graphique pour tableaux de comptages*, "Revue Archéologique de Picardie", 3-4, pp. 39-56.

D. Dubant 1989, *Site 021 (Rue de la Monnaie), sauvetage urgent*, Rapport de fouilles, Laboratoire d'Archéologie Urbaine de Tours.

B. Dufaÿ 2001, *Quel avenir pour la carte archéologique urbaine? Eléments de réflexion*, "Les Nouvelles de l'Archéologie", 85, pp. 37-49.

B. Dufaÿ 2002, *De la topographie à l'histoire: comprendre l'évolution des villes anciennes*, "Mappemonde", 67, pp. 32-37.

M. Fondrillon 2007, *La formation du sol urbain: étude archéologique des terres noires à Tours (4[e]-12[e] s.)*, PhD thesis, Université de Tours. Online in: http://tel.archives-ouvertes.fr (accessed 7 February 2018).

M. Fondrillon 2009, *À propos des recherches sur les terres noires urbaines: dépasser le concept d'attente*, "Archéologie Médiévale", 39, pp. 1-16.

M. Fondrillon 2012, *Formation des sols et usages sociaux: les terres noires urbaines en France*, in S. Archambault De Baune, H.-P. Francfort (eds), *L'archéologie à découvert*, Paris, pp. 144-151.

M. Fondrillon 2016, *Bourges: Jardins de l'Archevêché,* Rapport de prospection-inventaire campagne 2016, Service d'archéologie préventive de la Communauté d'agglomération de Bourges.

M. Fondrillon, L. Augier, A. Laurent, X. Rolland 2013, *Évaluation et modélisation du potentiel archéologique urbain à Bourges*, in E. Lorans, X. Rodier (eds), *Archéologie de l'espace urbain*, Tours, pp. 277-291.

M. Fondrillon, A. Laurent 2009, *Le sol urbain*, in C. Cammas (ed), *La Géologie: les sciences de la terre appliquées à l'archéologie,* Paris, pp. 80-84.

M. Fondrillon, E. Marot (eds) 2013, *Un quartier de frange urbaine à Bourges (Ier s. ap. J.-C.-XXe s.): les fouilles de la ZAC Avaricum. Volume 1: stratification et structures,* Bourges.

H. Galinié 1989, *Prévision et gestion archéologiques en milieu urbain*, in R. Brulet, *Archéologie et aménagement du territoire,* Actes du colloque (Louvain-la-Neuve, 14 octobre 1988), Liège, pp. 64-69.

H. Galinié 1992, *La gestion des archives du sol en ville*, "Nazioarteko Jardunaldiak Interbenzioarkeologia", pp. 137-162.

H. Galinié 1999, *L'appréhension archéologique du sol urbain*, in S. Barles, D. Breysse, A. Guillerme, C. Leyval*, Le sol urbain*, Paris, pp. 7-21.

H. Galinié 2002, *L'entre-deux: les terres noires des cités*, in B. Beaujard, *La naissance de la ville chrétienne*, Tours, pp. 97-105.

H. Galinié (ed) 2007, *Tours antique et médiéval: lieux de vie, temps de la ville, 40 ans d'archéologie urbaine,* Tours.

H. Galinié, J. Boucard 1980, *La gestion des archives du sol à Saintes, implications archéologiques de l'occupation des secteurs anciens,* Tours.

H. Galinié, E. Lorans 2007, *La cité et l'agrégation autour de Saint-Martin. L'espace urbain vers 800*, in Galinié 2007, pp. 45-46.

H. Galinié, E. Lorans, R. Macphail, J. Crowther, M. Fondrillon, A. Laurent, J. Seigne in press, *Archéologie urbaine à Tours: les fouilles du square Prosper Mérimée (site de Saint-Julien)*.

H. Galinié, B. Randoin 1979, *Les archives du sol à Tours: survie et avenir de l'archéologie de la ville*, Tours.

H. Galinié, X. Rodier 2002, *TOTOPI – Topographie de Tours Pré-Industriel*, "Les Petits Cahiers d'Anatole", 11. Online in: http://www.univ-tours.fr/lat/pdf/F2_11.pdf (accessed 7 February 2018).

H. Galinié, X. Rodier 2004, *La formalisation des données de la topographie historique*, in *Informatisation des documents d'evaluation du patrimoine archéologique des villes de France, bilan d'étape 2002-2003,* Tours, pp. 25-34.

P. Garmy 1994, *Pour une archéologie de la ville*, "Les Nouvelles de l'Archéologie", 55, pp. 5-6.

P. Garmy 1999, *France*, in *Rapport sur la situation de l'archéologie urbaine en Europe*, Strasbourg, pp. 91-102.

Y. Gratton 2002, *Le krigeage: la méthode optimale d'interpolation spatiale*, "Les Articles de l'Institut d'Analyse Géographique", 2002, pp. 1-4. Online in: http://www-ia.lip6.fr/~hnguyen/coursan/projets/krigeage/krigeage_juillet2002.pdf (accessed 8 February 2018).

J. Gravier 2012, *Synthèse archéologique urbaine: topographie historique de la ville de Noyon (Oise) du Ier s. après J.-C. au XIXe siècle*, Mémoire de master 2 d'archéologie médiévale, Université de Paris I.

L. Guyard (ed) 2003, *Le Collège de France (Paris). Du quartier gallo-romain au Quartier latin (Ier av. J.-C.-XIXe siècle)*, Paris.

D. Joly 1979, *Les archives du sol à Chartres, avenir et archéologie de la ville*, Mémoire de maîtrise, Université de Paris I.

C. Laurent 2004, *Etudes micro-archéologiques et carpologiques de sédiments sombres, à très sombres: arguments en faveur de l'extension chronologique de l'appellation «terre noire»*, in Verslype, Brulet 2004, pp. 56-74.

A. Laurent 2006, *Un outil de prospection géotechnique en milieu urbain: le PANDA*, in A. Ferdiére (ed), *La prospection*, Paris, pp. 220-222.

A. Laurent 2007, *Évaluation du potentiel archéologique du sol en milieu urbain*, Thèse de doctorat d'histoire, Université de Tours. Online in: http://tel.archives-ouvertes.fr (accessed 8 February 2018).

A. Laurent 2011, *Une méthode de modélisation par interpolation spatiale: le krigeage*, in X. Rodier (ed), *Information spatiale et archéologie*, Paris, pp. 166-170.

A. Laurent-Dehecq 2014, *L'évaluation du potentiel archéologique des villes, une nécessité pour concilier recherche scientifique et aménagement*, "Les Nouvelles de l'Archéologie", 136, pp. 10-14.

A. Laurent, M. Fondrillon 2010, *Mesurer la ville à travers l'évaluation et la caractérisation du sol urbain: l'exemple de Tours*, "Revue Archéologique du Centre de la France", 49. Online in: http://racf.revues.org/1485 (accessed 10 June 2014).

B. Lefebvre 2009, *La formation d'un tissu urbain dans la Cité de Tours: du site de l'amphitheâtre antique au quartier canonial (5e-18e s.)*, PhD thesis, Université de Tours. Online in: http://theses.fr (accessed 8 February 2018).

B. Lepetit, D. Pumain 1999, *Le temps des villes*, in B. Lepetit, D. Pumain (eds), *Temporalités urbaines*, Paris, pp. V-X.

E. Louis 2004, *«Terres noires» rurales: le cas de l'abbaye mérovingienne et carolingienne de Hamage (France, département du Nord)*, in Verslype, Brulet 2004, pp. 95-101.

G. Matheron 1970, *La théorie des variables régionalisées et ses applications*, Paris.

O. Marlet 2000, *Les paléochenaux dans la plaine alluviale de Tours*, Mémoire de maîtrise, Université de Tours.

E. Morin, X. Rodier, A. Laurent, J.-J. Macaire 2013, *Évolution morphologique et sédimentaire de la plaine alluviale d'un espace urbanisé (Tours, Indre-et-Loire, France),* "Revue Archéologique du Centre de la France", 52, pp. 367-400. Online in: http://journals.openedition.org/racf/1862 (accessed 8 February 2018).

E. Morin, X. Rodier, A. Laurent, J.-J. Macaire 2014, *Morphological and sedimentary evolution of an alluvial floodplain in an urban area: geoarchaeological approaches and applications (Tours, France)*, "Journal of Archaeological Science", 46, pp. 255-269. Abstract online: https://doi.org/10.1016/j.jas.2014.03.021 (accessed 1 May 2018).

H. Noizet 2003, *Pratiques spatiales, représentations de la ville, et fabrique urbaine de Tours du 9e au 13e siècle: chanoines, moines et laïcs à Saint-martin et Saint-Julien*, PhD thesis, Université de Tours.

S. Pauly 2013, *Étude microarchéologique et référentiel sédimentaire*, in M. Fondrillon, E. Marot, J. Troadec, *Bourges, ZAC Avaricum: évolution d'un quartier urbain de Bourges du 1er s. jusqu'à nos jours. Volume 3. Rapport final d'opération de fouille préventive,* Bourges, pp. 597-614.

A. Pinhede 2012, *Synthèse archéologique urbaine des quartiers Saint-Père et Bas-Bourgs de Chartres*, Mémoire de master 2 d'archéologie médiévale, Université Paris I.

S. Riquier 2007, *L'occupation gauloise vue à travers le mobilier céramique et quelques éléments singuliers*, in Galinié 2007, pp. 202-203.

M.B. Schiffer 1975, *Behavorial chain analysis: activities, organization, and the use of space*, "Fieldiana", 65, pp. 103-119.

M.B. Schiffer 1987, *Formation Processes of the Archaeological Record*, Albuquerque.

J.K Stein, P.A. Telster 1989, *Size distributions of artefacts classes: combining macro- and micro-fractions*, "Geoarchaeology", 4(1), pp. 620-628.

C. Taberly 1999, *Interprétation lithostratigraphique sur la fenêtre de Tours. Intégration des données géologiques, palynologiques et archéologiques*, Mémoire de maîtrise, Université d'Angers.

J. Troadec 1996, *Bourges: document d'évaluation du patrimoine archéologique urbain*, Paris.

J. Troadec 2014, *De l'usage contemporain de l'archéologie urbaine,* "Les Nouvelles de l'Archéologie", 136, pp. 5-8.

L. Verslype, R. Brulet (eds) 2004, *Terres noires. Dark Earth*, Louvain-la-Neuve.

C. Vissac 2013, *Etude géoarchéologique*, in M. Fondrillon, E. Marot, J. Troadec, *Bourges, ZAC Avaricum: évolution d'un quartier urbain de Bourges du 1er s. jusqu'à nos jours. Volume 3. Rapport final d'opération de fouille préventive,* Bourges, pp. 483-591.

J.-M. Zaninetti 2005, *Statistique spatiale, méthodes et applications géomatiques*, Paris.