Geoarchaeology and chronostratigraphy of the Lac du Puy intraurban protohistoric wetland, Corent, France

Alfredo Mayoral, Jean-Luc Peiry, Jean-François Berger, Paul Ledger, Bruno Depreux, François-Xavier Simon, Pierre-Yves Milcent, Matthieu Poux, Franck Vautier, Yannick Miras

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Geoarchaeology and chronostratigraphy of the *Lac du Puy* intra-urban protohistoric wetland, Corent, France

A. MAYORAL (1), J-L PEIRY (1, 2), J-F BERGER (3), P. M. LEDGER (4), B.DEPREUX (5), F-X. SIMON (6), P-Y. MILCENT(7), M. POUX (5), F. VAUTIER (6), Y. MIRAS (1,8)

(1) Université Clermont Auvergne, CNRS, GEOLAB, F-63000 CLERMONT-FERRAND, FRANCE; (2) CNRS, UMI 3189, « Environnement, Santé, Sociétés », Faculté de Médecine, Université Cheikh Anta Diop, BP 5005, Dakar-Fann, Sénégal; (3) CNRS, UMR 5600, EVS-IRG & Université Lyon 2, 5 avenue Pierre Mendès-France, F- 69676 BRON Cedex ; (4) Department of Archaeology, School of Geosciences, University of Aberdeen, Elphinstone Road, Aberdeen AB24 3UF, UK; (5) CNRS, UMR 5138, Laboratoire Archéométrie et Archéologie & Université Lyon 2, MSH Maison de l'Orient et de la Méditerranée, 7 rue Raulin, F-69365 LYON cedex 07; (6) Université Clermont Auvergne, CNRS, Maison des Sciences de l'Homme, F-63000 CLERMONT-FERRAND, France ; (7) CNRS, UMR5608, TRACES & Université de Toulouse 2 Jean Jaurès, Maison de la Recherche Bât 26 Laboratoire 5, allée Antonio Machado F-31058 TOULOUSE Cedex 9; (8) CNRS, UMR 7194, Histoire Naturelle de l'Homme Préhistorique, Département de Préhistoire, Muséum National d'Histoire Naturelle, Institut de Paléontologie Humaine, Paris, France.

ABSTRACT

This paper presents the first results of the geoarchaeological study of an unusual hilltop wetland, located within the protohistoric proto-urban site of Corent (France). This small depression offers an exceptionally local sedimentary record which provided valuable data on long term human-environment interactions, as well as proto-urbanization of the first millennium B.C.E. Field survey revealed a major archaeological discovery: a large ensemble of 114 Iron Age storage pits excavated in clayey deposits. The geoarchaeological analysis of stratigraphic logs and cross-sections completed by geophysical maps and radiocarbon dating allowed us to refine the chronology of these structures. Here we suggest these structures are probably contemporary with the Hallstatt occupation of the site (600-425 B.C.E.), consistent with the emergence at Corent of a short-lived proto-urban environment during this period. These investigations also allowed us to characterize the main evolution phases of the basin and the diversity of human impacts from first disturbance in the Early Neolithic to its final destruction in the Roman period. These findings highlight the non-linear nature of the socio-environmental interactions and the definitive shift to an anthroposystem as a consequence of major disturbance in the first Iron Age, centuries before the development of urban settlements in the *oppida* period.

1. INTRODUCTION

The prehistoric impact of humans on the environment, especially vegetation and soils, has been widely documented throughout western and central Europe since the Neolithic (Dotterweich, 2013; Ellis et al., 2013). Late Holocene climatic oscillations in Western and Mediterranean Europe such as the 4.2 event, late Iron Age-Roman Period climatic optimum, or the Little Ice Age are now well known (Magny, 2004; Martin-Puertas et al., 2008; Wanner et al., 2008). However these events are often considered as minor influences on geomorphological processes when compared to increasing human impacts (e.g. Lavrieux et al., 2013). Rather, the progressive anthropogenic forcing of natural systems is highly correlated with the development of agriculture and urbanization processes (Lang, Niller, & Rind, 2003; Notebaert, Berger, & Brochier, 2014). The latter has often been considered to be restricted to Mediterranean Europe, but is now known to have begun in Central and Western Europe during the late Bronze Age (LBA) and the Iron Age (Milcent, 2007, 2012; Fernández-götz, Wendling, & Winger, 2014). The environmental impacts of these proto-urbanization processes are still poorly understood at a local scale, as few geoarchaeological and palaeoenvironmental studies have specifically focused on these questions. This is mainly a result of palaeoenvironmental studies typically being pursued in areas suitable for sedimentary record preservation like lakes, floodplains or peatlands. While such studies provide remarkable results at landscape-scale they frequently lack sensitivity to local signals (Ledger, Edwards, & Schofield, 2015). Geoarchaeology has typically been concerned with intra-site studies focusing on specific archaeological challenges, for example, stratigraphic records and post-depositional processes in human structures, analysis of lithic materials or specific deposits like dark earths, and the study of specialist structures such as ramparts or agricultural terraces (Butzer, 2008). However, in suitable contexts, such as intra-urban, or urban-connected wetlands, integrated palaeoenvironmental and geoarchaeological approaches can provide valuable information on human-environment interaction and characterize the environmental impact of the proto-urbanization processes in key periods such as the Iron Age (e.g. Ledger et al., 2015). These human influenced environments, frequently studied in rural areas (e.g. Bernigaud et al., 2014), are a rare and valuable place to develop integrated palaeoenvironmental and geoarchaeological approaches, but are rarely studied in connection with proto-urbanization processes in Western Europe, with some remarkable exceptions (Mele et al., 2013). This paper presents the first geoarchaeological results, including context of site formation and post-depositional processes, of a wider palaeoenvironmental study begun in 2014. A highly local approach, using an intra-urban wetland, has been developed to investigate the long-term palaeoenvironmental impacts of proto-urban human settlement episodes of the first millennium B.C.E.

2. STUDY AREA AND OBJECTIVES

Located in the French Massif Central, 20 km south of Clermont-Ferrand, the Puy de Corent is a volcanic plateau located in a key position controlling the north-south axis of the valley of the River Allier (Fig. 1A and B). The summit (621 m.a.s.l.), located in the southwest of the plateau, is a Pliocene (circa 3 Ma B.P.) monogenetic scoria cone (Greffier & Restituito, 1980; Nehlig et al., 2003). Differential erosion of marls and basalts since the late Pliocene caused the gradual raising of the plateau above the marl lowlands by relief inversion. The central and northwestern sectors are characterized by gentle topography and are situated on a basaltic lava flow deposited over 200 m thick Oligocene sedimentary rocks (limestone and marl with occasional gypsum). The Corent plateau is a major regional archaeological site and several human occupations, from the Middle Neolithic to the Roman period, have been documented. These include two major settlement phases with proto-urban features in the LBA 3 (950-800 B.C.E.) and the late Hallstatt D1 (600-550 B.C.E.) (Milcent, Poux, et al., 2014), and a vast oppidum (La Tène D1-2, 125-25 B.C.E.) with monumental and planned urban characteristics, which is considered as the possible capital of the *Arverni* (Poux, 2012). Corent is therefore an excellent site to study long-term human-environment interactions, and more specifically the highly-localized palaeoenvironmental impacts of proto-urbanization and urbanization processes during the 1st millennium B.C.E.

Unfortunately, the plateau is afflicted by severe soil erosion and truncation of deposits, a process which probably began in the Mid-Neolithic, when the first palynological evidence of forest clearance and agriculture appears (Ledger et al., 2015). In some instances this has resulted in a poor preservation of archaeological sediments, especially those preceding the La Tène D period (Poux et al., 2016). The Lac-du-Puy, an ancient pond located in the lowest part of the plateau within the extension zone of the LBA 3 and La Tène settlements, offers a well-preserved intra-urban sedimentary record (Fig. 1C). It appears as a small sub-circular natural depression (of approximately 2 Ha) in the surface of the basaltic rock, similar to others known on neighboring volcanic plateaus also situated above a sedimentary basement. These small basins are quite common in the region (e.g. Lacs de la Pénide, Lac de Pardines) and are usually interpreted as pseudo-sinkholes (Bureau de Recherches Géologiques et Minières, 2015). The modern pool is small (surface area of c. 300 m^2) and mainly fed by occasional runoff and subsurface water flow from the summit of the plateau. Hydraulic traces and historical maps indicate evidence of recent management, probably in the 19th century. However, the palaeobasin represents a much larger area (0.5 Ha) as evidenced by aerial imagery and maps from 1820 (Fig. 1D and F). Small-scale archaeological survey explored this depression for the first time in the early 1990s, confirming the sedimentary nature of accumulation in the center of the depression (approximately 2 m deep) and therefore its palaeoenvironmental interest (Guichard, 1991). The Lac-du-Puy was then neglected until 2012 when, under the AYPONA project framework (*Paysages et visages d'une agglomération Arverne: approche intégrée et diachronique de l'occupation de l'oppidum de Corent,* dir. Y. Miras & F. Vautier), a sediment coring allowed a palynological analysis. The result of this study (Ledger et al., 2015) confirmed that the Lac-du-Puy offers an exceptional sedimentary record within a protohistoric intra-urban context. This excellent palaeoenvironmental potential encouraged a more extensive geoarchaeological survey in the summer of 2015. The objective of this paper is to present the initial results of this survey and to use them to build a robust chronostratigraphic framework as a basis for the forthcoming multi-proxy palaeoenvironmental research of this complex pedosedimentary site. The detailed archaeological analysis of the structures excavated during the geoarchaeological survey of the basin is beyond the scope of this work and will be undertaken in further studies.

3. MATERIALS AND METHODS

Ten 2 m wide trenches were excavated to survey sedimentary deposits and their stratigraphy across the Lac-du-Puy (Fig 1D). Trenches 1, 2 and 4 served to define the geomorphological context, while trenches 3 and 5-10 delineated the lateral extent of archaeological structures within the depression. The archaeological work involved manual excavation, description and photography of structures. The geomorphological element comprised pedosedimentary description of stratigraphic logs (Table 1) and photography, supported by topographic survey at a centimetric precision (Leica DGPS system 500). Sediment samples were taken for multi-proxy analysis (grain size analysis, geochemistry and micromorphology), which will be exploited in further studies.

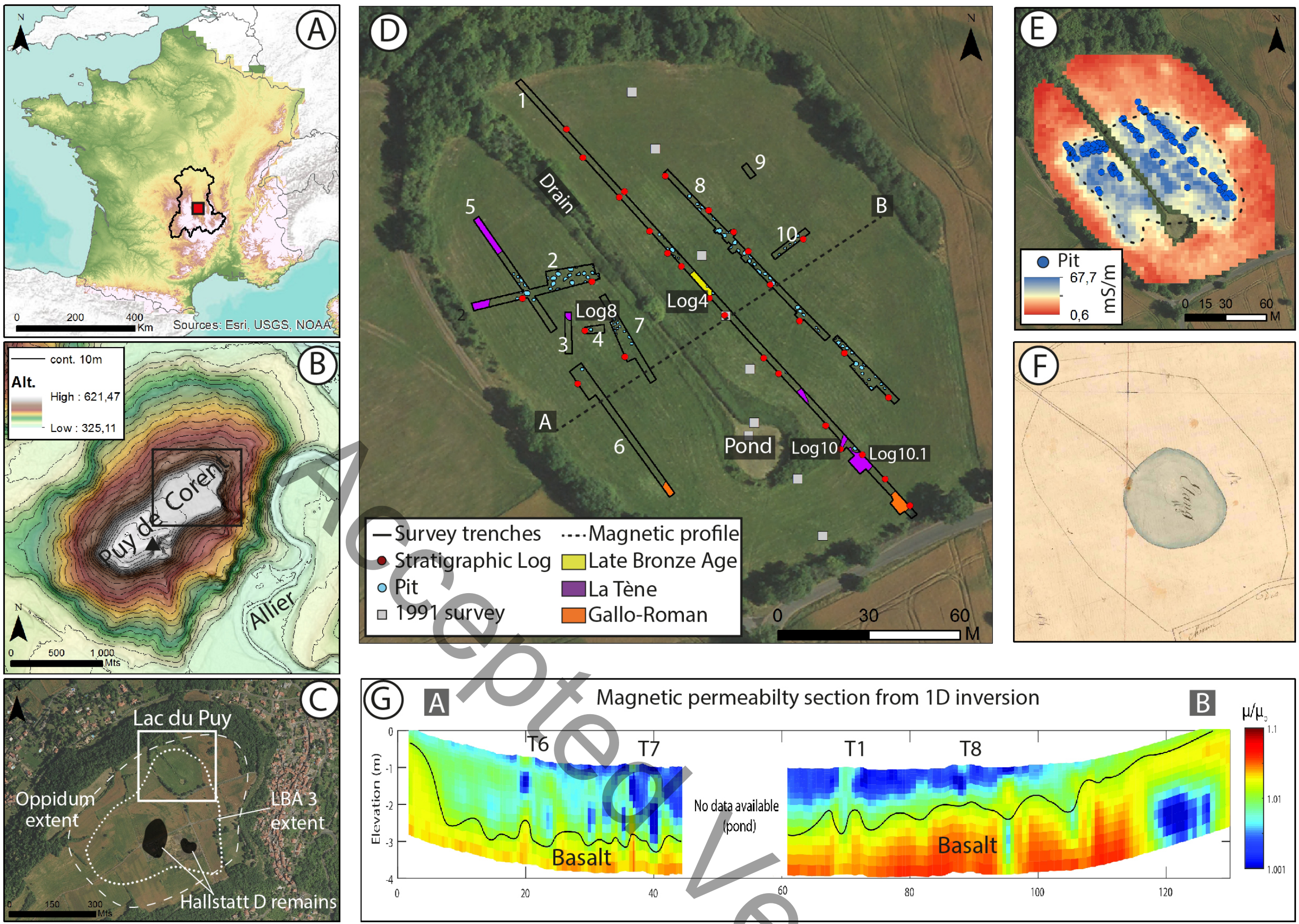

Figure 1. A, B and C: Study area location and approximate extent of the main phases of settlement (C). D: Map of the geoarchaeological survey trenches, with location of the studied stratigraphic logs and the archaeological finds. E: electrical conductivity map and pit distributions (red: low values, blue: high values). F: Early 19th century map of the Lac-du-Puy (Napoleonic land register). G: EMI tomography (magnetic permeability section) along the A-B transect illustrated in D. Blue: low values, red: high values (adapted from Guillemoteau et al., 2016).

AMS ^{14}C dating was undertaken on macrocharcoal, microcharcoal and bulk sediment samples from stratigraphic logs and archaeological structures (see Table 1). For charcoal samples, the sediment was deflocculated in a solution of sodium hexametaphosphate and sieved at 500µm and 100µm. Macro- or micro-charcoal were manually concentrated using a binocular microscope. Twelve samples were submitted to Beta Analytic, Florida, with a thirteenth being sent to the Poznan Radiocarbon Laboratory. ^{14}C dates were calibrated using CALIB V7.04 and IntCal13 calibration curve (Reimer et al., 2013). The results of six previous radiocarbon dates, from the 2012 core and used to establish a first chronology (Ledger et al., 2015), were used to assess the potential reservoir effect associated to the bulk sediment and micro-charcoal. Since the locations of most trenches were widely linked to archaeological objectives and their number conditioned by the resources devoted to excavation, information on sedimentary structures and geometry of the sedimentary infilling was incomplete. To overcome this limitation we obtained additional information by using non-destructive techniques such as geophysics. Several methods were implemented within the Lac-du-Puy depression, including electromagnetic induction (EMI) using various devices with different investigation depth (EMP400, EM31, DualEM21S), and also electrical resistivity using Abem Terrameter. Electromagnetic measurements delivered valuable results and are therefore presented, including a map of apparent electrical conductivity undertaken using the EMP400 in Horizontal Coplanar (HCP) geometry (Fig. 1E). An EMI tomography resulting from the development of an experimental protocol (Guillemoteau et al., 2016) from DualEM21S provided a magnetic permeability (or magnetic susceptibility) pseudo-section (Fig. 1G).

4. RESULTS

Archaeological Finds

Older structures are mainly scattered remains of an archaeological soil without pottery fragments and are stratigraphically correlated to Early/Middle Neolithic levels of the 2012 core (Ledger et al., 2015). The LBA 3 is represented by an archaeological soil level with abundant basalt pebbles and pottery, located in the central part of the basin (see Fig 1D and Fig 2b). La Tène D1-2 is the best represented period, with abundant structures (mainly pavements) especially in the peripheral south and west areas of the depression (Fig 1D), characterized by the presence of frequent fragments of *amphorae* type Dressel 1 (Guichard, 1997). Gallo-Roman structures (pavements and small buildings foundations) are present in the south of trenches 1 and 6. Modern drainage works are also present in all surveyed trenches. As a major archaeological discovery, 114 protohistoric pits were found covering all the central part of the depression (Fig 1D and 2a). Excavated in the clayey sediment, these pits have diameters between 70 and 120 cm, a maximal depth around 130 cm, variated shapes (pear-shaped, bottle-shaped, bell-shaped etc.) with a more or less truncated narrower top, and a dark probably organic thin lining in their walls and bottom (Fig 2a and 2c). The sedimentary fill of the pits is a massive and homogeneous dark grey clay presumably the result of deliberate infilling when they were decommissioned. All of the structures are carefully and closely distributed (sometimes only separated by 10 cm) without any coalescence (Fig 2a), with the exception of 3 pits (within the 37 fully excavated) where a partial overlapping of two structures was observed. Attending to these characteristics the structures can be interpreted as storage pits (Sigaut, 1978; Reynolds, 1988; Miret i Mestre, 2009, 2015).

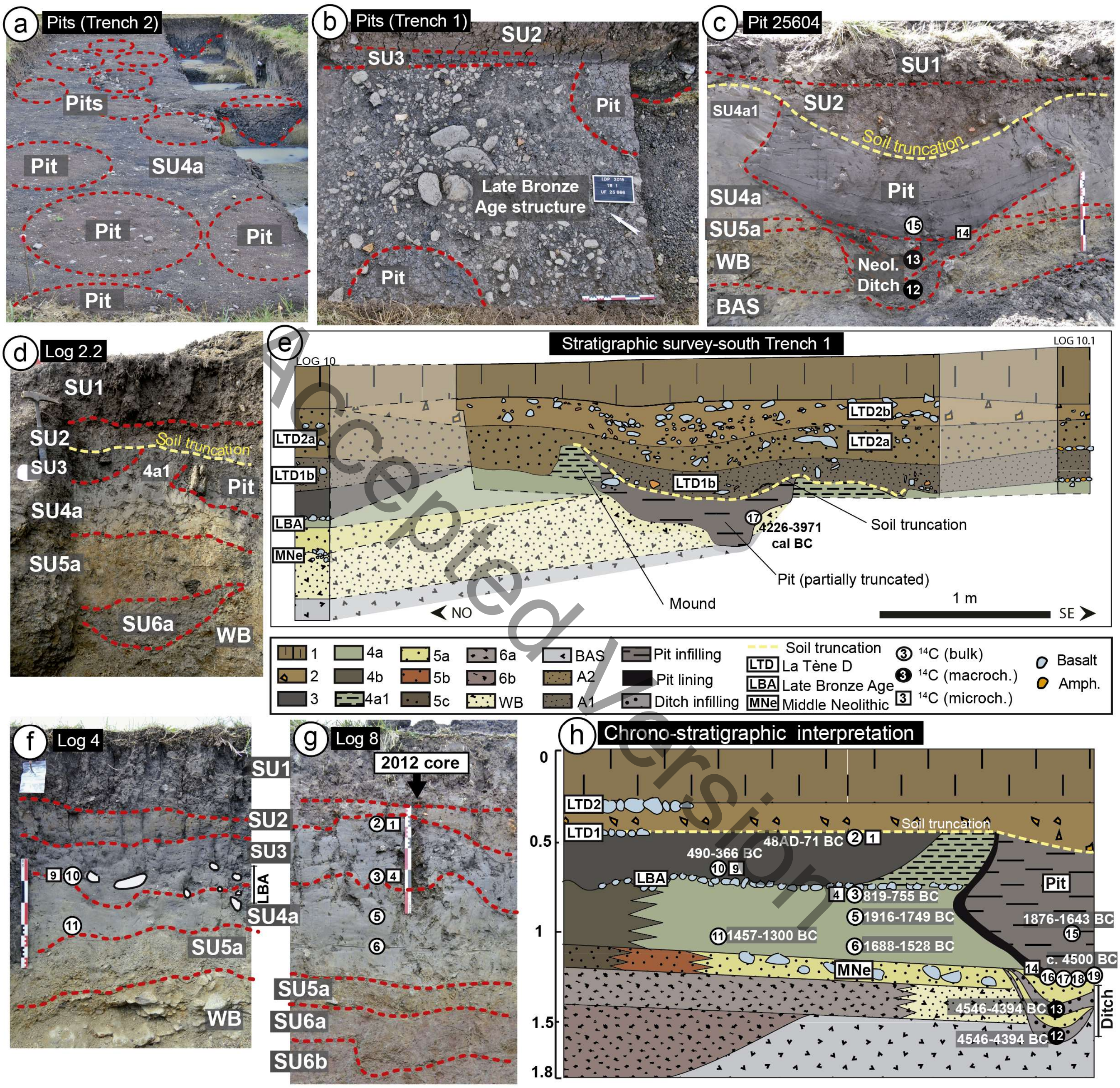

Figure 2. a) Closely distributed pits in trench 2. b) Pits cross-cutting a LBA archaeological soil in trench 1. c) Pit 25604 and underlying Neolithic structure. d) Log 2.2 including a pit and SU 4a1. e) Stratigraphic survey of the south of trench 1. f) Log 4. g) Log 8. h) Synthetic interpretation of chrono-stratigraphic relationships between pits, natural stratigraphy and well-dated archaeological remains. See Table 2 for SU codes.

Unfortunately typological dating was impossible: the presence of occasional pottery sherds in the top of the structures' infilling provide only a *Terminus Ante Quem* (TAQ) age of the abandonment. Their small number and their systematic proximity to a Stratigraphic Unit (SU) considered as backfill (SU 2, see Table 2), suggests a post-depositional origin related to this SU.

No sherds were found in the bottom of the structures. Moreover the absence of organic macro-remains or charred material in pits, likely a result of taphonomic processes due to frequent water level fluctuations in the basin (Ledger et al., 2015), necessitated the predominant use of bulk samples for dating, which are susceptible to vertisolization processes and possible reservoir effect and complicate interpretation of the results.

Radiocarbon Dates

The AMS radiocarbon database of the Lac-du-Puy is summarized in Table 1: the six first (nº1 to 6) dates come from a core drilled in a natural sequence (Log 8, Fig 2g) and were previously published (Ledger et al., 2015). Five additional radiocarbon dates were performed in Log 4 (nº7 to 11, see Fig 2f) to complete the natural chronological framework. Three of these dates (nº9 to 11) are coherent with previous dates and archaeological evidence. Dates nº9 and 10 confirm previous observations (Ledger et al., 2015) of a small reservoir effect on micro-charcoal compared to bulk sediment. Therefore dates from bulk sediment were preferred for chronological interpretation of the natural stratigraphy. The last ones, taken close to the top of the sequence in the SU 2 (nº7 and 8), were rejected because their ages are not compatible with the well-established archaeological dating of this unit, probably because of its anthropogenic origin and consequent mixing effects (see Table 2, SU2).

On archaeological structures, two dates were obtained on centimetre size macro-charcoal from two levels of the small excavated structure in the SU 5a, under the pit 25604 (see Fig 2c), both provided the same Early/Middle Neolithic age (nº12 and 13). The bulk from the base of the pit 25604 (dark lining), partially excavated into the summit of the underlying Neolithic structure, provided a similar age (nº14). A bulk sediment date on the fill of this structure taken 10 cm above the base (nº15) provided a more recent date (see Fig 2c). A further four samples (nº 16 to 19), from similar contexts (dark lining at the base of the structures) in other pits also provided Early/Middle Neolithic ages. These dates are surprisingly old, especially when compared with similar settlements in Western Europe with abundant storage pits such as *Ensérune*

(France), *Mas Castellar de Pontós* (Spain) or *Danebury Ring* (U.K.) (Cunliffe, 1984; Cunliffe & Poole, 1991; Pons, 2002). Therefore, we sought to further investigate the age of these archaeological structures through an in-depth analysis of the stratigraphy and its links with the archaeological data.

Table 1. Radiocarbon data base from Lac-du-Puy trenches and logs; dates n°1 to 6 were previously published in Ledger et al. (2015). Dates have been placed in their stratigraphic context on Fig 2f, 2g and 2h; dates in *italic* were rejected on a stratigraphic basis.

№	Localization	Depth(cm)/position	Lab. code	Material	14C yr. BP	Cal BC/AD (2σ)
1	Core/Log L8	54-57 (SU3-top)	Beta-379416	Microcharcoal	2240 ± 30	390-205 BC
2	Core/Log L8	54-57 (SU3-top)	Beta-379417	Bulk sed.	1990 ± 30	48 BC-AD 71
3	Core/Log L8	71-72 (SU4-top)	Beta-377232	Bulk sed.	2590 ± 30	819-755 BC
4	Core/Log L8	71-73 (SU4-top)	Beta-379418	Pollen	2750 ± 30	944-823 BC
5	Core/Log L8	87-88 (SU4-middle)	Beta-375785	Bulk sed.	3510 ± 30	1916-1749 BC
6	Core/Log L8	102-103 (SU4-bottom)	Beta-379419	Bulk sed.	3330 ± 30	1688-1528 BC
7	*Log L4*	*43-47 (SU2-bottom)*	*Beta-434187*	*Microcharcoal*	*5550 ± 40*	*4457-4339 BC*
8	*Log L4*	*43-47 (SU2-bottom)*	*Beta-430610*	*Bulk sed.*	*1430 ± 30*	*575-657 AD*
9	Log L4	59-63 (SU3-bottom)	Beta-434188	Microcharcoal	2390 ± 30	542-397 BC
10	Log L4	59-63 (SU3-bottom)	Beta-430611	Bulk sed.	2340 ± 30	490-366 BC
11	Log L4	87-91 (SU4-bottom)	Beta-430612	Bulk sed.	3130 ± 30	1457-1300 BC
12	Excav. Struct.	Base	Beta-418695	Macrocharcoal	5650 ± 30	4546-4394 BC
13	Excav. Struct.	Middle	Beta-418694	Macrocharcoal	5650 ± 30	4546-4394 BC
14	Pit 25604	Lining-Base	Poz-74925	Microcharcoal	5520 ± 40	4453-4327 BC
15	Pit 25604	Fill	Beta-425790	Bulk sed.	3430 ± 30	1876-1643 BC
16	Pit 25677	Lining-Base	Beta-425426	Bulk sed.	6130 ± 30	5208-4992 BC
17	Pit 25703	Lining-Base	Beta-425787	Bulk sed.	5240 ± 30	4226-3971 BC
18	Pit 25699	Lining-Base	Beta-425788	Bulk sed.	4780 ± 30	3641-3519 BC
19	Pit 25610	Lining-Base	Beta-425789	Bulk sed.	5640 ± 30	4541-4372 BC

Geomorphology And Stratigraphy

The electrical conductivity map provided information regarding the extent and thickness of clayey sediment in the basin, revealing that it is limited to a sub-circular irregular 100 m radius depression (blue and yellow areas in Fig 1E), and that some scattered spots in the central area have thicker clay accumulation (dark blue areas). The magnetic pseudo-section provides a good indication of the shape of the sedimentary infill and the underlying basaltic bedrock, showing an irregular and dissymmetric bottom of the basin, with a maximum depth reaching 2 m (Fig 1G). The 29 stratigraphic logs distributed in the surveyed trenches (Fig 1D) allowed a detailed characterization of the sedimentary infilling of the depression, which was divided into 12 Stratigraphic Units (Table 2). The more complete sequences were Log 8 (equivalent to the published core extracted in 2012) and Log 4 (Fig 2f and 2g) and hence these were the subject of the highest resolution dating. An additional 15 logs from trench 1 were used to document a 195 m long stratigraphic section which crosses the depression center, including only key archaeological structures for reasons of stratigraphic clarity (Fig 3).

Table 2. Synthetic natural and archaeological stratigraphy of the Lac-du-Puy excavation area. Depths in cm are indicative.

<table>
<tr><th>Stratigraphic Unit (SU)</th><th>Depth (cm)</th><th>Pedo/
Lithofacies</th><th colspan="6">Description</th></tr>
<tr><td>SU1</td><td>0-30</td><td>Modern topsoil/Plow zone</td><td colspan="6">Dark brown (10 YR 3/2) clay loam distributed over all the excavation area with constant thickness around 30 cm. Scattered basaltic fragments from granules to coarse gravels. Frequent pottery fragments (mainly amphorae type Dressel 1). Blocky to prismatic structure, sometimes crumbly. Surficial cracks in summer dry periods.</td></tr>
<tr><td colspan="9">La Tène D2B to Gallo-Roman (50/40-30 BC) archaeological structures</td></tr>
<tr><td>SU2</td><td>30-45</td><td>General anthropogenic backfill</td><td colspan="6">Dark brown clay loam (10 YR 3/2) distributed all over the excavation area with constant thickness around 15 cm. Scattered basaltic particles from granules to coarse gravels. Many amphorae fragments (Dressel 1). Blocky/prismatic structure, sometimes crumbly. Frequent brown-orange oxidation mottles.</td></tr>
<tr><td colspan="9">La Tène D2A (80/70-50/40 BC)archaeological structures</td></tr>
<tr><td>SU A1-A2</td><td>Variable</td><td>Local anthropogenic backfill</td><td colspan="6">Mainly dark brown (10 YR 3/1 to 2/1) clay loam with common heterometric basaltic inclusions from granules to small blocks, macrocharcoals and scattered pottery (La Tène D). Granular to blocky, sometimes prismatic structure. Present mainly in peripheral areas of the depression (south and west).</td></tr>
<tr><td colspan="9">La Tène D1B (100/90-80/70 BC) archaeological structures</td></tr>
<tr><td>SU3</td><td>45-70 approx.</td><td>Palaeo-vertisol type</td><td colspan="6">Very dark grey to black (10 YR 2,5/1) clay, including basaltic particles from fine sand to granules, rarely gravels, and prismatic structure with slickensides-like features. No archaeological material. Very irregular distribution and thickness (0-20 cm) within the depression, lacking lateral continuity. The unit has probably its upper part truncated before SU2 deposition.</td></tr>
<tr><td colspan="9">Late Bronze Age 3 archaeological structures (950-800 BC)</td></tr>
<tr><td rowspan="2">SU4a, 4a1, 4b</td><td rowspan="2">70-115
approx.</td><td rowspan="2">Palaeo-gleysol</td><td colspan="3">4a/4a1-center of the depression</td><td colspan="3">4b-peripheral areas</td></tr>
<tr><td colspan="3">Olive grey (5 Y 4/2) massive heavy clay, few small orange oxydation mottles at the top. Rarely quartz gravels. Homogeneous distribution within the lowest part of the depression, in lateral transition with 4b. Bioturbation (roots) and irregular palaeotopography with small mounds (4a1)</td><td colspan="3">Dark grey to brown (2,5 Y 3/2 to 3/1) clay loam, with few basaltic granules to gravels, scattered pottery fragments (Late Bronze Age) and few small orange oxydation mottles. Replaces laterally 4a in peripheral parts of the depression. Massive to blocky structure. Irregular palaeotopography.</td></tr>
<tr><td colspan="9">Early/Middle Neolithic scattered remains</td></tr>
<tr><td rowspan="2">SU5a, 5b, 5c</td><td rowspan="2">115-130
approx.</td><td rowspan="2">Palaeo-regosol</td><td colspan="2">5a-center of the depression</td><td colspan="2">5b-peripheral areas</td><td colspan="2">5c-external areas</td></tr>
<tr><td colspan="2">Greyish to greenish brown (10 YR 3/1 to 2,5 Y 3,5/2) sandy clay, with abundant weathered subrounded basaltic granules (white mottles or orange oxydation mottles), few gravels and small blocks, sometimes quartz gravels. Bioturbation (rootlets).</td><td colspan="2">Grayish brown (10 YR 3/1,5) sandy loam, with many sub-rounded basaltic granules and some angular basaltic gravels. Few rounded quartz gravel. Very abundant orange oxydation mottles. Replaces laterally 5a.</td><td colspan="2">Dark brown (10 YR 3/1 to 3/2) sandy loam, with many basaltic sub-rounded granules and sparse angular gravels. Some orange oxydation mottles. Replaces laterally 5b.</td></tr>
<tr><td>SU6a</td><td>130-145
approx.</td><td>Grey clay with scoria</td><td colspan="6">Dark grey (10 YR 4,5/1) clayey silt with many sub-rounded inclusions of scoria (sand to gravels, 10 R 3/3) more or less disaggregated. Appears in discontinuous areas in central and peripheral parts of the depression.</td></tr>
<tr><td>6b</td><td>145-?</td><td>Scoria breccia with interstitial clay</td><td colspan="6">Dark grey (10 YR 4,5/1) clayey silt, with abundant sub-rounded and heterometric inclusions of scoria (gravels to cobbles, 10 YR 3/3) more or less disaggregated and increasing to the bottom, until forming a scoriaceous breccia with hardened clay matrix. Appears in discontinuous areas, in the lower parts of the bedrock in central parts of the depression.</td></tr>
<tr><td>Weathered Basaltic rock (WB)</td><td>Variable</td><td>Alteration front</td><td colspan="6">More or less weathered bedrock, from unaltered basalt in external areas, to well-developed and thick alteration front in central areas of the depression.</td></tr>
<tr><td>Basaltic Bedrock (BAS)</td><td>Variable</td><td>Massive basaltic bedrock</td><td colspan="6">Solid basaltic rock (basanite) representing the top of a lava flow with columnar disjunction.</td></tr>
</table>

The fill is generally clayey, and ranges in thickness from 30-40 cm at the periphery to 2 m in the deeper sectors of the central part of the basin; the lateral variability is pronounced and sharp due to the undulating bedrock bottom. In the NW sector the natural stratigraphy is well preserved, whereas in the SE sector several successive backfill layers separated by La Tène archaeological levels appear directly in contact with the bedrock. The sedimentary sequence systematically thins from the inner to external parts of the depression (Table 2, Fig 3) and is accompanied by a very gradual lateral change of facies (SU 4 and 5), likely related to the frequency of palaeoflooding and the resulting hydromorphic gradient.

Focusing on stratigraphic particularities, results mainly concern the relationship between SU4, SU3 and pits. First, elevations of the top of SU 4a and 4b are higher around each pit or group of pits (forming small mounds surrounding pits, SU 4a1) than in inter-pits zones, which can only be the result of an irregularity in the palaeosurface that is probably anthropogenic in nature (Fig 2d and 2e). Second, there is a complete lack of stratigraphic contact between SU3 and pits filling: SU3 never covers pits and is never cross-cut by the pits (Table 2, Fig 2c, 2d, 2e). Furthermore, SU3 is predominately found in low-areas of the very irregular top SU4 topographic surface (Fig 2d, 2e). Third, SU4 and SU3 are both clayey sediment, but SU3 can be differentiated on the basis of its sand and gravel content, vertic characteristics and extremely irregular distribution and thickness. This indicates increased detritism, seasonal shrink-swell processes and probable truncation of the top of SU3 (Table 2). Finally, SU3, SU4 and the pits are systematically truncated suggesting that a phase of erosion or levelling works occurred before SU2 was deposited (Fig 2c, 2d, 2e).

5. DISCUSSION

The archaeological, radiocarbon and stratigraphic data allowed the construction of a robust chronostratigraphic framework for the natural stratigraphy. SU 6b and 6a are not directly dated, but on the basis of their stratigraphic position and their pollen assemblages (Ledger et al., 2015), they likely date from the Early Neolithic (c. 5000 B.C.E.) . Units 5a, b and c are dated to the Early/Middle Neolithic transition by two radiocarbon dates from the archaeological structure (Table 1 dates nº12 and 13, 4545-4394 cal. B.C.E.). Units 4a and b cover at least the period from approximately the Early Bronze Age (c. 1900-1600 cal. B.C.E.) to the end of the LBA (c. 800 cal. B.C.E.). SU 3 deposition takes place from between 490-366 cal. B.C.E. to between

50-40 cal. B.C.E. Finally, SU 2 is dated by archaeological artefacts (ceramic) between 50 and 30 B.C.E. The pedo-sedimentary characteristics and the generally low sedimentation rate of the sequence suggest that it is a succession of more or less cumulic hydromorphic palaeo-soils, including archaeological levels and phases of low sedimentation (or maybe hiatuses), rather than a classical lacustrine sedimentary sequence (Table 1).

With regards to archaeological structures, surveyed trenches and geophysical maps show that a quasi perfect correlation exists between the pits implantation and the spatial extent of the clay basin (Fig 1E). Archeological and ethnographic studies suggest that storage pits are often placed in function of the presence of loose and thick sediment, with a preference for impermeable clays which offer important storage advantages, in spite of the associated humid conditions (Sigaut, 1978; Hill, Lacey, & Reynolds, 1983; Reynolds, 1988; Miret i Mestre, 2009). On the basis of the spatial pattern of the pit distributions, which was visible in surveyed trenches after topsoil stripping (see Fig 2a), we estimate there are likely to be several hundreds, maybe a thousand, across the Lac-du-Puy basin. The narrow arrangement of the pits with rare overlap between them suggests a high degree of synchronicity and their probable excavation in a relatively short length of time, perhaps decades.

The five dates from the dark lining at the base of the pits provided Early/Middle Neolithic ages, and are clearly too ancient to be consistent with stratigraphic evidence and age of the fill (see Fig 2b, 2c, 2d, 2e and Table 1 date nº15). This is probably because the bases of pits were systematically excavated through SU 5 before reaching bedrock or SU 6a/b, and therefore the bulk or micro-charcoal samples from the dark lining at the base of pits date the age of SU 5. ^{14}C assays on macro-charcoals from the small excavated structure opened in SU 5 stratigraphically below a pit (Table 1 date nº12 and nº13, Fig 2c) provided the same Neolithic age as the pits. However this structure cannot be contemporaneous with the pits, as the only date obtained from the pit fill provides a much younger age (Table 1 date n°15, Fig 2c). This date is also inconsistent with stratigraphic evidence (Fig 2b), but could be explained by the fact that this kind of structure was usually backfilled when a new neighbouring structure was excavated. Sediments from the new pit were then likely used to fill the abandoned pit, and logically provide a bulk age sensibly similar to the obtained dates from SU 4 sediments in logs 4 and 8 (see Fig 2c, 2f, and 2g).

These results make it clear that the pits, in absence of pottery or charred material at the base, cannot be directly dated by radiocarbon on bulk samples. This prevents their dating more precisely than the TPQ and TAQ provided by archaeostratigraphic evidence: pits are excavated through a well-dated LBA 3 archaeological soil (950-800 B.C.E., Fig 2b) and are all covered by structures or archaeological soils from La Tène D2b to Gallo-Roman (SU2, 50/40-30 B.C.E., Fig 2c and 2d), except in a single instance where a pit is covered by a La Tène D1B archaeological soil (100/90-80/70 B.C.E., Fig 2e).

Given the site size and the archaeological importance of this group of pit structures, we attempted to further refine the relative chronology of the pits on the basis of stratigraphic evidence in order to associate them with one of the archaeological occupations of the site. The discontinuous nature of the log-based stratigraphic data and the lack of a unique exposure containing all the archaeological and stratigraphic information required us to construct a stratigraphic synthesis (Fig 2h). This synthesis led us to the chrono-stratigraphic interpretation presented below as the most likely. The well-dated SUs (4a and 3) were used to achieve this, despite the lack of direct stratigraphic relationships between SU 3 and pits, which is interpreted as a consequence of subsequent soil truncation. The very uneven palaeotopography of the top of SU 4a, with small mounds (SU 4a1) around each pit and depressions between them, suggests that these mounds are minor earthworks constructed immediately after the excavation of pits in the clayey SU4 layer (Fig 2c, 2d and 2e). This microrelief (SU 4a1) could be interpreted as the truncated remains of a rim or a "neck" around the upper part of the pits (Fig 2c, 2d, 2e and 2h), probably built using the clay extracted during the excavation of the pits (SU 4a). This morphology was observed in approximately 10% of the pits – despite their truncation and post-depositional erosion – and has been documented in storage pits in anthropological studies (Sigaut, 1978; Miret i Mestre, 2009) and on archaeological sites such as *Danebury Ring* (U.K.), which were also systematically truncated (Cunliffe, 1984, 2013; Cunliffe & Poole, 1991). As a consequence the excavation of the pits can, with some certainty, be assumed to have been contemporary with the surface of SU 4a or slightly posterior, but in any case prior to SU 3 which fossilized this palaeotopography after the structures were abandoned (Fig 2h). SU3 deposition occurred across the basin, but preferentially in the lower areas of SU 4 palaeotopography between pits. Finally, after a general truncation of the top of SU3 and the majority of the pits necks, SU2 deposition occurred across the entire basin (Fig 2h). Therefore, the pits were likely excavated sometime between the dates n°3 (819-755 cal. B.C.E.) and n°10 (490-366 cal. B.C.E.). On the basis of the existing archaeological chronology for Corent the only two periods of major settlement within this timeframe are a LBA settlement and a Hallstatt settlement (Milcent, Chassan, et al., 2014; Milcent, Poux, et al., 2014). However the hypothesis of a LBA 3 age is unlikely because of the stratigraphic evidence of pits excavated through the LBA levels and the complete lack of ceramic remains in the base of the pits, while they are frequent in neighbouring Late Bronze Age archaeological levels. For this reason the excavation of the pits is probably related to the Hallstatt D1-2 agglomerated settlement attested on the volcanic plateau at ~600-550 B.C.E. (Milcent, Poux, et al., 2014), albeit an association with a little occupation of the Hallstatt D3-La Tène A1 (510-425 B.C.E.) is also possible. The absence of ceramic material in the base of the pits is also more coherent with a medium-size and distant occupation (Hallstatt D settlements) than with bigger and material-rich occupations surrounding the basin, such as the LBA 3 and La Tène D2 occupations (Fig 1C). This Hallstatt chronological hypothesis is not surprising considering that this kind of storage techniques was commonplace in this period (Gransar, 2000) as attested by examples in Western Europe, especially in or near hillforts (e.g. Pons, 2002; Cunliffe, 2013). This unusually large grouping of storage pits in an open area, close to a relatively important Hallstatt proto-urban settlement (Milcent, Poux, et al., 2014) implies an increased storage capacity suggesting agricultural surplus. This pattern has sometimes been interpreted as a consequence of a short climatic optimum during the First Iron Age, but is more likely linked to socio-economic changes. Increasing centralization, long distance commerce and proto-urbanization is also observed in other sites in central France (Gransar, 2000; Milcent, 2012), alongside evidence of contact with Mediterranean world (Milcent, 2013) where similar patterns are noted for the period (Buxô & Pons, 1999; Pons, 2002). The abundant storage pits at Corent can therefore be interpreted as a marker of the emergence of proto-urban activity outside of the Mediterranean world, aborted towards the end of the first Iron Age.

On the basis of chronostratigraphic evidence, we propose the following reconstruction of the main evolution phases of the basin from the Early Neolithic to Late Antiquity and modern period (Figure 3), that is coherent with the palynological data (Ledger et al., 2015) : (1) In the oldest sedimentary phase, probably during the Early Neolithic, the basin was irregular with some sparse pools where sedimentary inputs concentrated in more or less intense runoff episodes, carrying scoria and clays from the volcanic cone. (2) In the transition from Early to Middle Neolithic (c. 4500 cal. B.C.E.) detrital inputs leveled the bottom of the basin and were probably associated with an oscillating water table as suggested by the lateral facies change between SU 5a, b and c. This increased erosion could be connected with the Neolithic forest clearing on the plateau suggested in palynological data (Ledger et al., 2015). Scattered archaeological remains at the top of this level are indicative of human activity and soils stability at the end of this phase, probably related to the Middle Neolithic occupation of Corent (fortified settlement). (3) The period between the middle Neolithic and the Early Bronze Age is difficult to interpret due to the low chronological resolution of this part of the sedimentary sequence. This may be related to a declining sedimentation rate or even a sedimentary hiatus. Palynological data clearly illustrate continuity in the vegetation dynamics for this period, suggesting a slow sedimentation rate rather than a long hiatus (Ledger et al., 2015). In the Early Bronze Age (after c. 1900-1600 cal. B.C.E.) a new sedimentary phase began, associated with low-energy inputs and a permanently high water table (gleysol development). This phase was interrupted c. 800 cal. B.C.E., where an archaeological soil in the depression shows human occupation associated with the Corent LBA 3 settlement. Between c. 800 cal. B.C.E. and 5th c. B.C.E. (dates 3 and 9-10 on Table 2) sedimentation ceased.

This sedimentary *hiatus* could be related to a contemporary stability and soil genesis phase in the plateau well documented in annual excavations (Milcent, Poux, et al., 2014). (4) Probably between 600 and 425 cal. B.C.E. a large number of storage pits were excavated in the basin with consequent relief and surface disturbance. (5) After the abandonment and filling of pits, external sedimentary inputs occurred again during ephemeral and episodic flooding, partially or totally fossilizing the previous topography and causing a vertisol-type functioning. These processes can be interpreted as the hydro-sedimentary reaction to the previous anthropogenic disturbance of the basin. (6) Between 100/90 B.C.E. and 50/40 B.C.E. at least two phases of soil levelling, backfill and occupation occurred in the southern part of the basin, whereas SU3 was still in deposition in central parts of the depression. (7) Between 50/40 and 30 B.C.E. (from La Tène D2B to Gallo-Roman period) the whole basin was levelled, backfilled and probably drained, partly truncating and fossilizing the pre-existing vertisol. (8) Finally, from Antiquity to Modern Period, a slow sedimentation gradually covered the antique backfill forming a topsoil with incipient vertic characteristics, and drainage works were performed in undetermined recent period.

Figure 3. Main pedo-sedimentary phases of the Lac-du-Puy evolution between early Neolithic and modern period. For SU colors, see Fig 2.

This reconstruction provides an insight to the evolution of socio-environmental interactions from the Early Neolithic to the Late Antiquity in an unusual intra-urban context. These interactions are characterized by different land uses, resources exploitation and impacts in the palustrine system, and appear to be the main driver of changing conditions in the basin. Neolithic sedimentary impacts, linked to a typical pattern of forest clearance and cultivation, are followed by a long period of low-energy hydrosedimentary dynamics. This phase can be interpreted as a system recovery, suggesting a non-linear but nevertheless progressive anthropogenic forcing. Major impacts in the systems evolution occur from as early as the first Iron Age in association with proto-urbanization, represented by the excavation of around 1,000 storage pits in the basin that resulted in major changes on its hydrosedimentary dynamics. These changes caused the shift of the Lac du Puy to an anthroposystem well before the impacts of the Late Iron Age Gallic oppidum.

6. CONCLUSION

This work presented the initial results of a geoarchaeological survey of the Lac-du-Puy basin, an unusual intra-urban wetland with a valuable sedimentary record covering 5000 years of human activity including settlements and proto-urban episodes of the first millennium B.C.E. Despite a complex, discontinuous and sometimes highly disturbed or even absent stratigraphy, the sedimentary archives allowed us to build a robust chronostratigraphic framework and to reconstruct the main evolution phases of this small depression from the Early Neolithic to the Gallo-Roman period. The unexpected find of a large number of Iron Age pits probably used for storage was a major discovery but complicated interpretation, owing to difficulties associated with direct dating and wide time-range provided by the stratigraphy. Nevertheless, the chronostratigraphical approach developed in this work allowed the identification and dating of the effects of post-depositional processes on these Iron Age pit structures and associated sediments. This detailed analysis led us to confidently propose, on the basis of the available data, that these structures are associated with the Early Iron Age Hallstatt D settlements of Corent (600-425 B.C.E.). Moreover, these abundant storage pits are also a local evidence of a short and early phase of socio-economic changes and emerging proto-urbanization processes outside the Mediterranean world, centuries before the well known *oppida* period at the end of the

Iron Age, providing a new insight into the diffusion of proto-urbanization in Western Europe during the first millennium B.C.E.

This geoarchaeological study was also the first attempt to document the human-environment interactions which were likely the main driver of changing pedo-sedimentary and hydrological conditions during the last 5 millennia in the Lac-du-Puy basin. Especially in the first millennium B.C.E., the geoarchaeological data suggest abruptly changing conditions in this wetland in response to changes of use and growing anthropogenic impact linked to storage pits excavation, and more generally proto-urbanization, culminating with its total backfill in the Gallo-roman period.

These preliminary interpretations will be followed by additional investigations and analysis such as grain-size analysis, micromorphology or geochemistry, to truly understand the complex trajectory of the human-environment interaction in this intra-urban wetland, a privileged mirror of the proto-urbanization processes and the associated anthropogenic forcing on soils during the first millennium B.C.E.

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8. REFERENCES

B.R.G.M. (2015). Carte Géologique de la France à 1:50000, feuille 765 (Massiac).

Bernigaud, N., Berger, J.-F., Bouby, L., Delhon, C., & Latour-Argant, C. (2014). Ancient canals in the valley of Bourgoin-La Verpillière (France, Isère): morphological and geoarchaeological studies of irrigation systems from the Iron Age to the Early Middle Ages (8th century bc–6th century ad). Water History, 6, 73–93.

Butzer, K. W. (2008). Challenges for a cross-disciplinary geoarchaeology: The intersection between environmental history and geomorphology. Geomorphology, 101, 402–411.

Buxô, R., & Pons, E. (1999). Els productes alimentaris d'origen vegetal a l'adat del ferro de l'Europa occidental : de la producció al consum. Girona: Museo d'Arqueologia de Catalunya.

Cunliffe, B. (1984). Danebury an Iron Age Hillfort in Hampshire Vol1 the excavations 1969-1978: the site. CBA research report n° 52a. London: Council for British Archaeology.

Cunliffe, B. (2013). Iron Age Grain Storage Pits – Danebury Ring Hillfort.

Cunliffe, B., & Poole, C. (1991). Danebury an Iron Age Hillfort in Hampshire Vol 4 The excavations 1979-1988: the finds. CBA Research Report n° 73a. London: Council for British Archaeology.

Dotterweich, M. (2013). The history of human-induced soil erosion: Geomorphic legacies, early descriptions and research, and the development of soil conservation—A global synopsis. Geomorphology, 201, 1–34.

Ellis, E. C., Kaplan, J. O., Fuller, D. Q., Vavrus, S., Klein Goldewijk, K., & Verburg, P. H. (2013). Used planet: A global history. Proceedings of the National Academy of Sciences, 110, 7978–7985.

Fernández-götz, M., Wendling, H., & Winger, K. (2014). Paths to complexity. Centralisation and Urbanisation in Iron Age Europe. Oxford & Philadelphia: Oxbow Books.

Gransar, F. (2000). Le stockage alimentaire sur les établissements ruraux de l'âge du Fer en France septentrionale : complémentarité des structures et tendances évolutives. In Les installations agricoles de l'âge du Fer en France septentrionale, Études d'Histoire et d'Archéologie (Vol. 6, pp. 277–297).

Greffier, G., & Restituito, J. (1980). Aspects géomorphologiques et stabilité des versants au sud de Clermont-Ferrand. Bulletin de liaison du Laboratoire des Ponts et Chaussées, 107, 17–26.

Guichard, V. (1991). Puy de Corent (Puy-de-Dôme) rapport de prospection et sondages.

Guichard, V. (1997). Les amphores. Lavendhomme, Guichard. Rodumna, le village gaulois. Paris.

Guillemoteau, J., Simon, F.-X., Lück, E., & Tronicke, J. (2016). 1D sequential inversion of portable multi-configuration electromagnetic induction data. Near Surface Geophysics, 411–420.

Hill, R. ., Lacey, J., & Reynolds, P. J. (1983). Storage of barley grain in Iron Age type underground pits. J. stored Prod. Res., 19, 163–171.

Lang, A., Niller, H.-P., & Rind, M. M. (2003). Land degradation in Bronze Age Germany: Archaeological, pedological, and chronometrical evidence from a hilltop settlement on the Frauenberg, Niederbayern. Geoarchaeology, 18, 757–778.

Lavrieux, M., Disnar, J.-R., Chapron, E., Breheret, J.-G., Jacob, J., Miras, Y., Reyss, J.-L., Andrieu-Ponel, V., & Arnaud, F. (2013). 6700 yr sedimentary record of climatic and anthropogenic signals in Lake Aydat (French Massif Central). The Holocene, 23, 1317–1328.

Ledger, P. M., Edwards, K. J., & Schofield, J. E. (2015). Taphonomy or signal sensitivity in palaeoecological investigations of Norse landnam in Vatnahverfi, southern Greenland? Boreas, 44, 197–215.

Ledger, P. M., Miras, Y., Poux, M., & Milcent, P. Y. (2015). The palaeoenvironmental impact of prehistoric settlement and proto-historic urbanism: tracing the emergence of the oppidum of corent, auvergne, france. PloS one, 10, e0121517.

Magny, M. (2004). Holocene climate variability as reflected by mid-European lake-level fluctuations and its probable impact on prehistoric human settlements. Quaternary International, 113, 65–79.

Martin-Puertas, C., Valero-Garces, B. L., Pilar Mata, M., Gonzalez-Samperiz, P., Bao, R., Moreno, A., Stefanova, V., Martín-Puertas, C., Valero-Garcés, B. L., Mata, M. P., González-Sampériz, P., Bao, R., Moreno, A., & Stefanova, V. (2008). Arid and humid phases in southern Spain during the last 4000 years: The Zoñar Lake record, Córdoba. Holocene, 18, 907–921.

Mele, M., Cremaschi, M., Giudici, M., Lozej, A., Pizzi, C., & Bassi, A. (2013). The Terramare and the surrounding hydraulic structures: A geophysical survey of the Santa Rosa site at Poviglio (Bronze Age, northern Italy). Journal of Archaeological Science, 40, 4648–4662.

Milcent, P.-Y. (2007). Bourges-Avaricum, un centre proto-urbain celtique du Ve siècle av. J.-C. Les fouilles du quartier Saint-Martin-des-Champs et les découvertes des Etablissements militaires. (P.-Y. Milcent, Ed.) (Coll. Bitu.). Bourges: Service d'archéologie Municipal, UMR 5608.

Milcent, P.-Y. (2012). Résidences aristocratiques et expérience urbaine hallstattiennes en France (VIe–Ve siècle av.J.-C.). In La question de la proto-urbanisation à l' âge du Fer.

Milcent, P.-Y., Chassan, N., Mader, S., Saint-Sever, G., & Tramon, A. (2014). Les occupations de l'âge du Bronze du plateau de Corent (Auvergne, Puy-de-Dôme) : résultats des campagnes de fouille 2010-2013. Bulletin APRAB, 12, 89–94.

Milcent, P.-Y., Poux, M., Mader, S., Torres, M., & Tramon, A. (2014). Une agglomération de hauteur autour de 600 a.C. en Gaule centrale : Corent (Auvergne). Transalpinare, 181–204.

Milcent, P. Y. (2013). Présence de Gaulois du Midi en Auvergne vers 600 avant J.-C. : les fibules méditerranéennes de Corent. Collection Archéologie de Montpellier Agglomération, 398.

Miret i Mestre, J. (2009). Systèmes traditionnels de conservation des aliments dans fosses et silos. Une vision multidisciplinaire.

Miret i Mestre, J. (2015). Trous, Silos et autres. Catalogue des structures préhistoriques d'Europe.

Nehlig, P., Boivin, P., De Goër, A., Mergoil, J., Sustrac, G., & Thiéblemont, D. (2003). Les volcans du Massif central. Géologues (sp. issue), 1–41.

Notebaert, B., Berger, J.-F., & Brochier, J. L. (2014). Characterization and quantification of Holocene colluvial and alluvial sediments in the Valdaine Region (southern France). The Holocene, 24, 1320–1335.

Pons, E. (2002). Mas Castellar de Pontós (alt Empordá) Un complex arqueològic d'època ibèrica (Excavacions 1990-1998). (E. Pons, Ed.). Girona: Museo d'Arqueologia de Catalunya.

Poux, M. (2012). Corent, Voyage au coeur d'une ville gauloise. Paris: Editions Errance.

Poux, M., Milcent, P., Pranyies, A., Lauranson, R., Dubreu, N., Chorin, A., Evrard, M., Hemard, C., Mader, S., Philibeaux, R., Tramon, A., Valfort, P., Duchamp, H., Demierre, M., Crausza, A., & Gruel, K. (2016). Corent, Rapport de fouille programmée 2015.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Buck, C. E., Cheng, H., Edwards, R. L., Friedrich, M., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hatté, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M., & van der Plicht, J. (2013). IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0–50,000 Years cal BP. Radiocarbon, 55, 1869–1887.

Reynolds, P. J. (1988). Pit technology in the Iron Age. British Archaeology.

Sigaut, F. (1978). Les réserves de grains à long terme. Techniques de conservation et foncions sociales dans l'histoire. Lille III: Editions MSH.

Wanner, H., Beer, J., Bütikofer, J., Crowley, T. J., Cubasch, U., Flückiger, J., Goosse, H., Grosjean, M., Joos, F., Kaplan, J. O., Küttel, M., Müller, S. A., Prentice, I. C., Solomina, O., Stocker, T. F., Tarasov, P., Wagner, M., & Widmann, M. (2008). Mid- to Late Holocene climate change: an overview. Quaternary Science Reviews, 27, 1791–1828.