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Rotten posts and selected fuel: Charcoal analysis of the first Middle Neolithic village identified in Provence (Cazan-Le Clos du Moulin, Vernègues, Bouches-du-Rhône, South of France)

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A B S T R A C T

“Cazan-Le clos du Moulin” is an open-air Middle Neolithic site located in the South of France near the village of Vernègues. The excavation of this site has, for the first time in the area, allowed us to reconstruct up to a dozen domestic buildings from the late Chassey culture (4100–3800 BCE), arranged around an area occupied by heated stone combustion structures. Because of the partial erosion of the archaeological horizons, artefacts and ecofacts related to the Neolithic occupation were only found in the fills of structures. Charcoal analysis was carried out on samples from the postholes, the heated-stone hearths and a well.

The anthracological results show a selection of natural resources depending on the use of the wood: timber or fuel. The size required for the posts can restrict the scope of the species suitable for timber: oak seems to be preferred for that purpose. On the contrary, the choice of fuel wood seems to be less constrained by technical limitations. Nevertheless, one particular species, *Arbutus unedo*, accounts for the bulk of the wood gathered for fuel supply, however it was certainly not the only woody resource available during the Middle Neolithic. Overall, charcoal analysis at Cazan-Le Clos du Moulin shows that wood harvesting - as recorded in the fills of structures - is selective. This selection could be imposed by purely technical requirements that we can only partly perceive or by cultural necessity which remains beyond our understanding, but, beyond this, the choices are probably guided by land and vegetation resource management in order to permit the coexistence of various wood-consuming activities in a single territory and to favor the exploitation of easily accessible fuel.

1. Introduction

The Middle Neolithic in southern France is identified as the period when the impact of agro-pastoral activities on the Mediterranean forest begins being recorded in charcoal assemblages, in the form of an increase of species from evergreen formations (evergreen *Quercus*, *Buxus sempervirens*, *Phillyrea* sp./*Rhamnus alaternus*...) to the detriment of the mixed deciduous oak forests species (Heinz and Thiébaud, 1998; Brochier et al., 1998; Thiébaud, 1997, 2001; Battentier et al., 2015). This pattern is based on data

from stratified sites where the sampling of dispersed charcoal was possible, i.e. caves or shelters often used for pastoral activities. Hence, it mainly reflects the vegetation changes and the management of wood in the karstic areas, which represent only a part of the socio-economic practices and territory. In the middle Rhône valley, charcoal recovered from “natural” deposits (i.e. outside archaeological horizons) and from archaeological structures, together with other data (phytolith, molluscs, pedology) provide a different image which has allowed us to propose the hypothesis of a multi-purpose management of the resources resulting in the “domestication” of the woodland (Delhon et al., 2009). Recently, several Middle Neolithic open-air sites have been excavated in Provence (South of France), among which Cazan-Le Clos du Moulin which provides, for the first time, clear evidence of persistent

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structured habitat. These recent advances in the understanding of the organization of middle Neolithic dwellings sheds new light on the everyday life of these populations, including wood gathering, for fuel or timber, which is one of the most persistent activities.

2. Cazan-le clos du moulin in its regional setting

“Cazan-le Clos du Moulin” is an open-air Middle Neolithic site located in the South of France, 60 km north-west from Marseille and the Mediterranean Sea, in the village of Vernègues (Fig. 1). The excavation by Archeodunum® in 2013 brought to light numerous postholes which, for the first time in the area, allows us to reconstruct several domestic buildings from the middle Neolithic (late Chassey culture, 4100–3800 BCE), arranged around an area occupied by heated stone combustion features (Moreau et al., 2014) (Fig. 2).

The site is located within a small valley (1 × 5 km, at 170 asl, aligned NE-SW) which forms part of the drainage basin of the river Durance. A few hundred meters to the north of the site, a series of small water courses join, before flowing northwards to the Durance. The valley forms an interruption between the Massif de Vernègues (385 m) and the Chaîne des Cotes (430 m), which is located halfway between the massif of the Petit Luberon (727 m) and the étang de Berre (coastal lagune). The vegetation is typical of the mesomediterranean belt on calcareous substrata, characterized by sclerophyllous formations with evergreen oak (*Quercus ilex* and *Q. coccifera*) on stony substrata and mixed forests dominated by deciduous oak (*Quercus pubescens*) on the deepest soils. Present-day vegetation bears the scars of long-term human's impact: *garrigue* and sclerophyllous stands cover ancient extensive pastures or burnt areas on skeletal soils formed upon Cretaceous

limestones, and Aleppo pine (*Pinus halepensis*) is well represented throughout on hillsides. Deciduous oak stands are restricted to deep and fresh soils developed upon Oligocene marly limestone, Miocene calcareous sandstone and Quaternary deposits, although *Q. pubescens* now expands practically everywhere due to a dramatic decrease of sheep grazing. River sides are occupied by stands of poplar (mainly *Populus alba*) and alder (*Alnus glutinosa*) mixed with various other riparian species (Ozenda et al., 1970; Molinier et al., 1976). Cultivated plots (and particularly vineyards) cover an important part of the plains extending to the bottom of the hillsides.

The archaeological value of the small valley of Cazan has been known for a long time thanks to archaeological prospection and preceding excavations, but it has been more recently confirmed after several development led excavations. Le Clos du Moulin is located in the core of a 3 km long area characterized by discontinuous but abundant Middle Neolithic remains (Fig. 1). The site itself proved to be of major importance as it revealed the plans of 10 houses and 3 complex buildings. It was a long anticipated discovery for the Chassey culture, for which dwelling structures were very sparsely documented.

The archaeological material is typical of the local Middle Neolithic (late Chassey culture) and radiocarbon dates range from 5240 ± 30 BP (4227–3971 cal. BC) to 5010 ± 30 BP (3942–3706 cal. BC) (Table 1). The very careful excavation in the field and a multi-disciplinary analysis of the archaeological data revealed that the site was occupied and abandoned at least three times in probably less than 300 years during the late Chassey culture (Moreau et al., 2015) and that the time span between two occupations was short enough to prevent the total destruction or burying of the previous structures, which were scrupulously avoided for the construction of

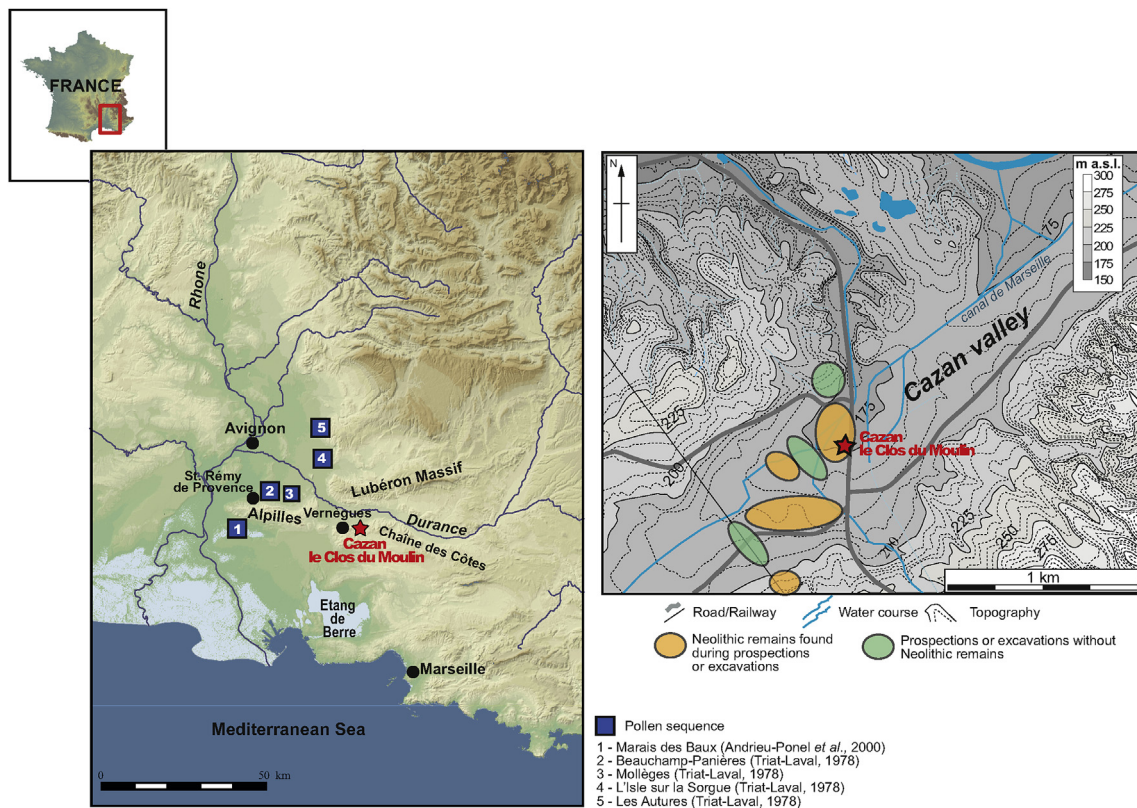


Fig. 1. Location maps. Left: location of the site (Cazan – Le Clos du Moulin) and of the pollen sequences referenced in the text in Southern France. Right: location of the site and of the other principal Neolithic discoveries in the Cazan valley.

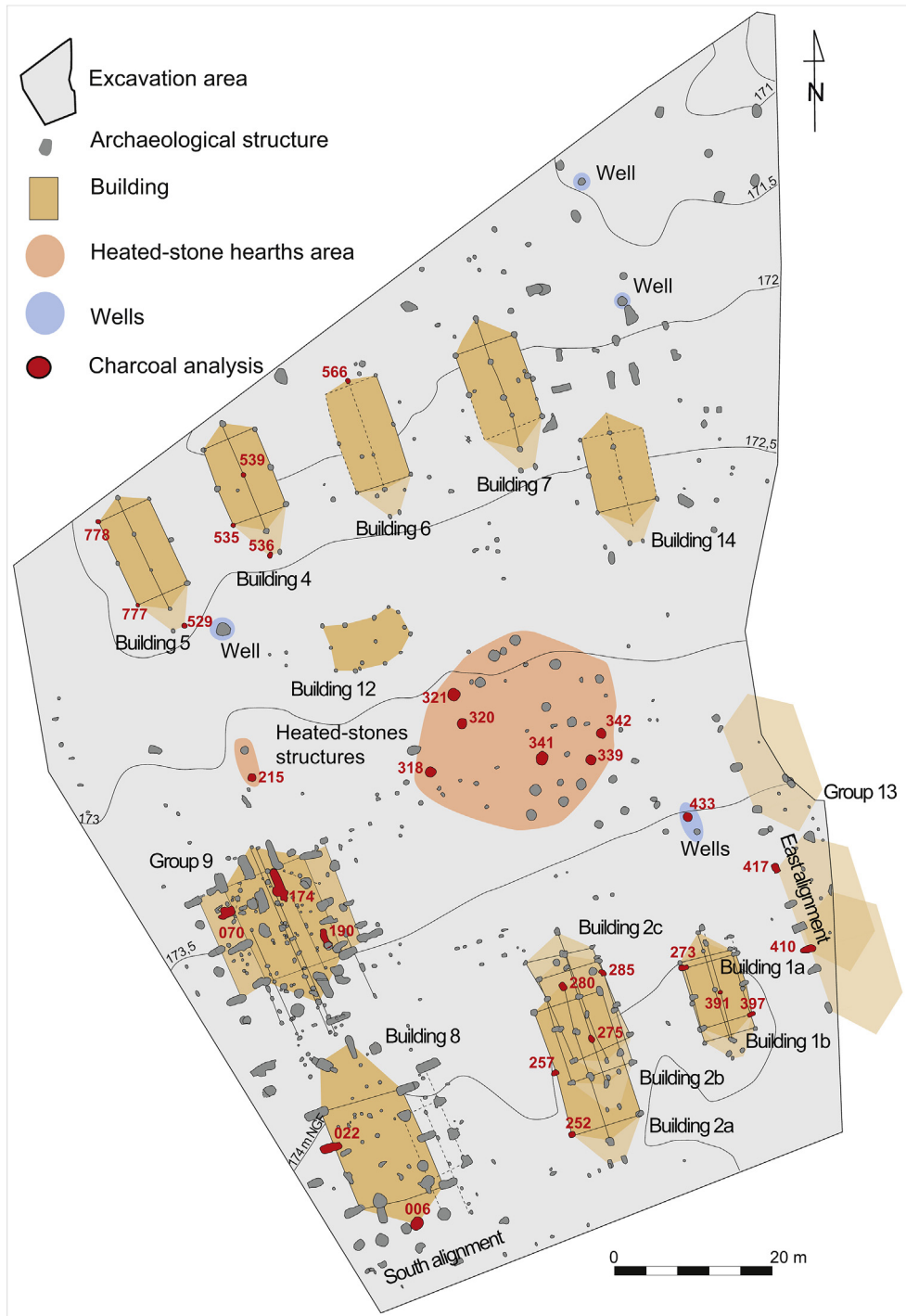


Fig. 2. Plan of the archaeological site showing the excavated structures and the sample locations (red – with structure number). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the new buildings. It is likely that the hearths belong to various occupation phases despite it has not been possible to determine which ones correspond to each phase.

The fills in the postholes are sometimes homogeneous, but several buildings show multiple phases of deposition infilling that could indicate the extraction of the post (buildings 1a, 2a, 2b). Some structures contain reddish clay which could result from wood decomposition (buildings 2a, 2b, 4) and some have been closed with large blocks (buildings 1a, 2a, 4, 5, 6). All these features tend to

suggest the abandonment of the related buildings and thus their precedence over the others. The foundation pits are large structures (up to 2 m deep) interpreted as holes for big posts. They are rectangular in plan with an unsymmetrically U-shaped profile: there is a soft slope on the external side (which allows an easy insertion of a large piece of timber), while the internal pit wall, against which the post finally stand, is vertical. As the profiles of opposite pits in a same building mirror each other, transversal beams probably connected the posts.

Table 1
Radiocarbon dates from Cazan-Le Clos du Moulin.

ID	Nb. Structure	Stratigraphic unit	Type of structure	Type/Taxa	Results	calibrated date BC (2 sigmas)
Beta-387513	F.433	908	Well	<i>Charcoal/Pinus</i>	5240 ± 30 BP	4230–3970
Beta-387510	F.252	1650	Posthole (Building 2a)	<i>Charcoal/Fraxinus</i>	5200 ± 30 BP	4050–3960
Beta-387508	F.135	594	Pit (Building 8)	<i>Charcoal/Arbutus</i>	5110 ± 30 BP	3975–3800
Beta-387514	F.433	916	Well	Burnt cereal seed	5100 ± 30 BP	3970–3800
Beta-387509	F.174	1385	Foundation pit (Building 9)	<i>Charcoal/Arbutus</i> (twig)	5060 ± 30 BP	3950–3790
Beta-387511	F.339	767	Heated-stones hearths	<i>Charcoal/Pinus</i>	5050 ± 30 BP	3950–3780
Beta-387515	F.536	1467	Posthole (Building 4)	<i>Charcoal/Pinus</i>	5050 ± 30 BP	3950–3780
Beta-387507	F.070	1423	Foundation pit (Building 9)	<i>Charcoal/Pop./Salix</i>	5010 ± 30 BP	3940–3700

3. Charcoal sampling and identification

As the archaeological horizons were truncated, the archaeological and bioarchaeological material was only available in the fills of the structures. Charcoal was thus sampled from 15 postholes from 7 houses, 6 foundation pits from 3 buildings, 7 heated-stone hearths and 11 sediment fills of a well. (Figs. 2 and 3). The stratified fill of the well provided two dates: the deepest one is the oldest

obtained on the site (4227–3971 cal. BC) and the one at mid-depth is of 5100 ± 30 BP (3968–3800 cal. BC). Therefore, the charcoal sampled according to the well's stratigraphy potentially constitutes a continuous “long-term” record of the fuel used on the site, contrarily to those from the other structures which are all suspected to be more or less punctual charcoal accumulations.

Admittedly, charcoal “concentrations”- principally in the form of primary deposits such as hearths - are often considered as poor

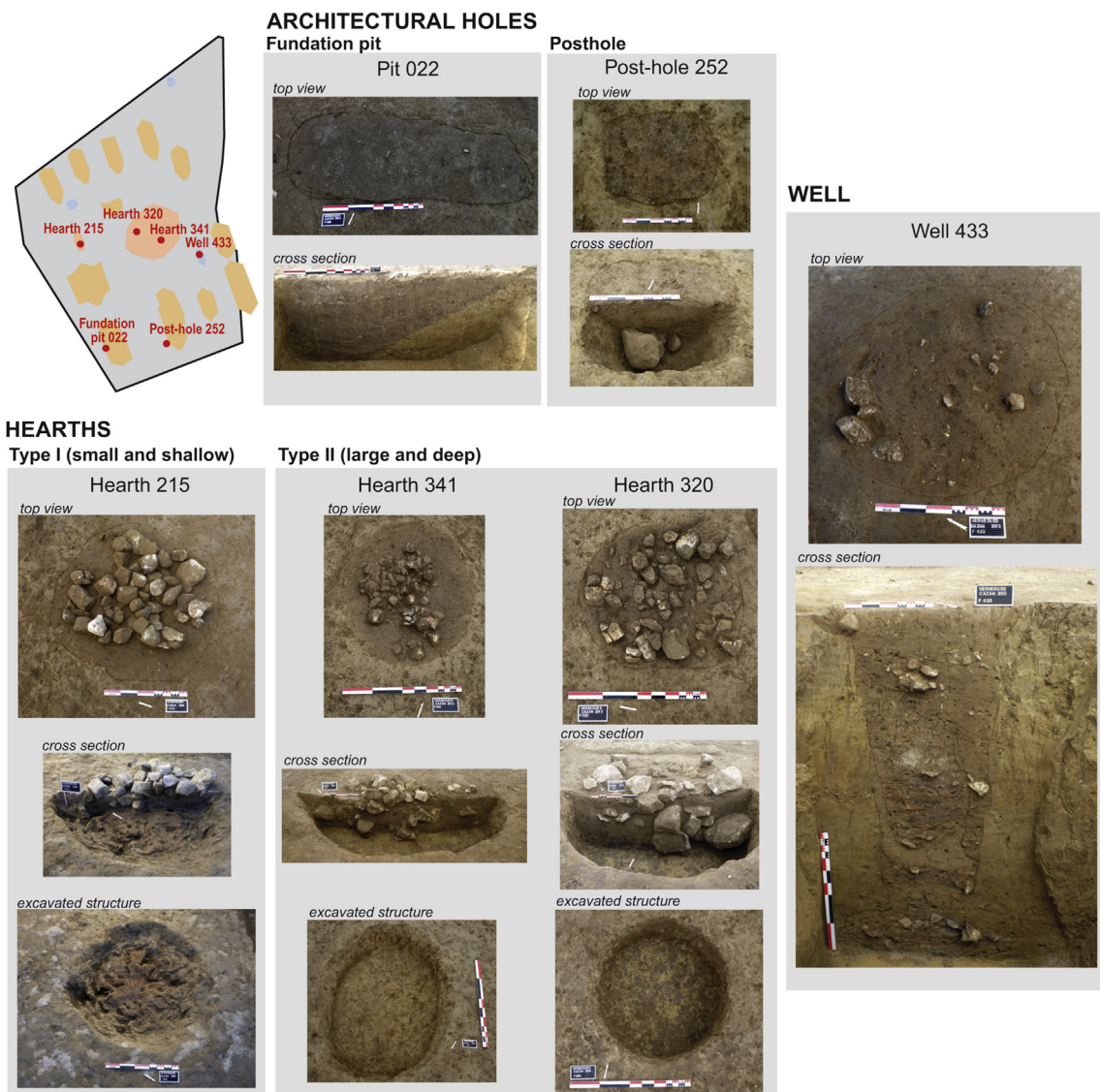


Fig. 3. Examples of structures excavated at Cazan-Le Clos du Moulin.

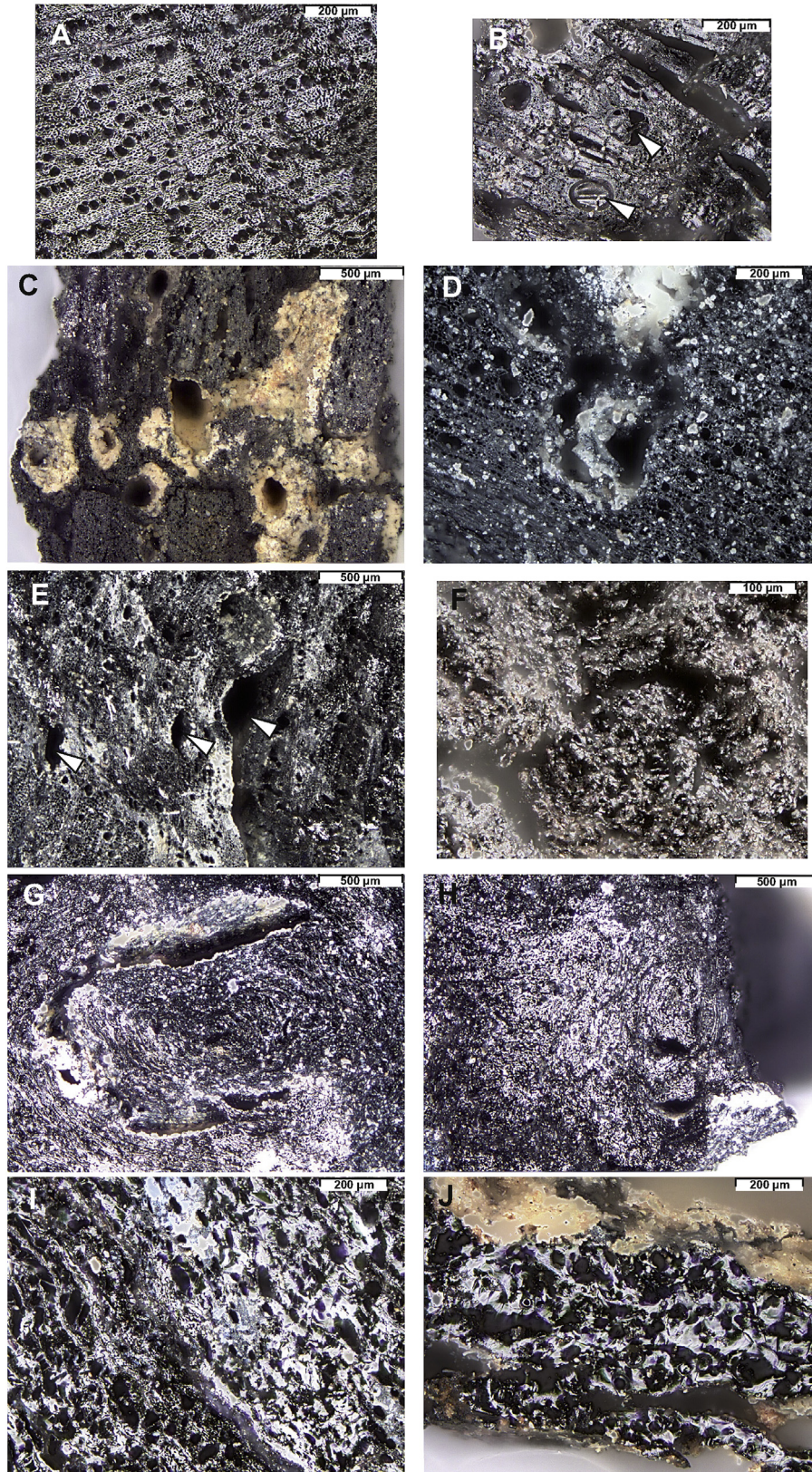


Fig. 4. Light microscope photographs of anatomical features and alterations of the charcoal fragments from Cazan-Le Clos du Moulin (z-reconstruction made by LAS software). A: *Arbutus unedo*, transversal plane (foundation pit 174); B: deciduous *Quercus*, transversal plane showing tyloses (white arrows) in the vessels (posthole 273); C: deciduous *Quercus*, transversal plane showing enlarged pores, probably due to woodborers, with calcite deposits (foundation pit 022); D: deciduous *Quercus*, transversal plane showing a hole probable due to woodborers (foundation pit 190); E: cf. *Arbutus*, transversal plane showing radial cracks (white arrows) (hearth 341); F: non-identified fragment, altered cell-walls and chewed aspect (foundation pit 410); G & H: *Arbutus unedo*, knots (hearth 318); I: cf. *Arbutus*, transversal plane, vitrification (hearth 320); J: non-identified dicotyledon, transversal plane, strong vitrification (hearth 321).

Table 2
Results of the charcoal analysis from Cazan-Le Clos du Moulin.

Vernègues 2013 Cazan Clos du Moulin MIDDLE NEOLITHIC (Late Chassey)	type of structure group nb. structure stratigraphic unit sample	WELL													HEATED-STONE HEARTH													POSTHOLES (B: building)													FOUNDATION PITS (B: building; A: alignment)												
		433	433	433	433	433	433	433	433	433	433	433	433	433	318	339	321	320	215	341	341	342	341	B1	B2a	B2b	B2c	B4	B5	B6	B8	B9	South A	East A	B1	B2a	B2b	B2c	B4	B5	B6	B8	B9	South A	East A								
		number of fragments													number of fragments													number of fragments													number of fragments												
		Hs (sp.) %													Hs (sp.) %													Hs (sp.) %													Hs (sp.) %												
TAXA																																																					
<i>Acer</i> sp.		1													1													2													1												
<i>Arbutus unedo</i> + cf. <i>Arbutus</i>		14 2 18 43 58 13													1													1													1												
<i>Buxus sempervirens</i>		1													1													1													1												
<i>Corylus avellana</i>		1													1													1													1												
cf. <i>Erica</i> sp.		1													1													1													1												
<i>Fraxinus</i> sp.		1													1													1													1												
<i>Juniperus</i> sp.		1													1													1													1												
<i>Phillyrea</i> sp./ <i>Rhamnus alaternus</i> + cf. <i>Phillyrea/Rhamnus</i>		3 3 1 1													3													1													1												
<i>Pinus</i> cf. <i>halepensis/pinaster/pinea</i> + <i>Pinus</i> sp. + cf. <i>Pinus</i> sp.		1 30 6 2 21 3 1													1 1													2													1												
<i>Populus</i> sp./ <i>Salix</i> sp.		3													3													1													1												
<i>Prunus</i> sp. + cf. <i>Prunus</i> sp.		1													1													1													1												
<i>Quercus</i> deciduous + <i>Quercus</i> sp. + cf. <i>Quercus</i>		12 31 2 4 3 7 2													5 6 5 6													8 1													8 1												
Rosaceae Maloideae + cf. Rosaceae Maloideae		1 6													7													1													1												
Total (identified fragments)		13 79 22 28 68 70 16													5 11 6 6													150 100													190 100												
non-identifiable dicot		1 11 11 7 17 32 5													1 3													1 88													1 95												
non-identifiable gymnosperm		5 1 3 2													1													1 101													1 1												
non-identifiable		1 6 5 3 3 1													1													1 19													1 1												
Total (observed fragments)		15 101 38 39 89 103 23													6 14 6 7													441													294												
notes		WELL													HEATED-STONE HEARTH													POSTHOLES													FOUNDATION PITS												
cross-section data BP		1340130													1350130													1320130													1310130												
reference data: BS (2 segments)		4317-1071													1649-1650													1652-1717													1664-1708												

records not only of the vegetation but also of human choices (Smart and Hoffman, 1988; Chabal, 1997; Heinz, 1990; Asouti and Austin, 2005). In such cases, there is a high probability that the abundance of one species corresponds to its last use (or to a single fire-event in cases of stratified deposits) and is not representative of its abundance in the vegetation nor of the usual practices of the inhabitants. Considering that the distortion of the data can however be mitigated by analyzing several “punctual” deposits (Battentier et al., 2016a), 7 hearths were analyzed at Cazan. They are circular and belong to the two different types identified on the field: small ones (diameter < 130 cm/depth < 30 cm), weakly reddened, and larger ones (diameter > 120 cm/30 < depth >70 cm), more reddened and containing more heated-stone.

Charcoal was recovered in most cases by wet sieving (2 and 1 mm mesh) of the sediment. In some layers where charcoal was very abundant, the sieving stage was skipped and charcoal fragments were directly picked from the raw sediment for the identification. More rarely, a single charcoal fragment was hand-picked in the field. The 2 mm fraction only was studied (except for sample F433-US 908: 2 mm and 1 mm). Depending on the available number of fragments and on the diversity of each assemblage, the samples were exhaustively or only partly studied. Efforts have been made to identify at least 30 fragments per sample. However, in cases of clearly re-fragmented pieces, of extremely poor preservation of the anatomical features (unidentifiable fragments), or where only a small quantity of fragments was available, this number was not attained.

The anatomical identification of the charcoal fragments was carried out with a reflected light bright field/dark field microscope (X50 to X500). Charcoal fragments were hand-broken in order to allow the observation of the three anatomical sections of wood (transverse, longitudinal-tangential and longitudinal-radial). The observed structures were compared to those described in the atlases of wood anatomy (Schweingruber, 1990; Vernet et al., 2001) and to an extensive reference collection of present-day burnt woods.

Besides the taxonomical information, several other parameters concerning the state of the wood before or after combustion (rotting features, vitrification) were also noted.

4. Results and interpretations

Charcoal fragments are sometimes large and abundant, but the preservation of the anatomical features is globally poor. Vitrification, radial cracks, biological degradation such as insect galleries and cell wall collapses - attributed to fungal or bacterial activity (Théry-Parisot, 2001; Théry-Parisot and Texier, 2006) - and

anatomical oddities due to the presence of knots are abundant, leading to a low amount of identification (Fig. 4). Knots correspond to the branching of a lateral axis on the trunk or on a bigger branch. At their level, the anatomy is altered and the usual identification criteria (size and abundance of rays, pore size and arrangement) may vary from the standards of the taxon, making the identification problematical. It is not unusual that a single fragment bears several kinds of alteration (knot, vitrification and cracks in particular are often found together), which explains the low rate of identification (23% of unidentified fragments) and some imprecise determinations (dicotyledon vs gymnosperms). Due to the very similar anatomy of several species, it has not been possible to identify further the *Pinus* fragments. They all show rather small pinoid (non-fenestriiform) cross-fields pits, characteristic of Mediterranean species (*P. halepensis*, *P. pinaster*, *P. pinea*, excluding *P. sylvestris*).

The total taxonomic diversity of the site is rather low (Table 2), with only 13 different taxa, among which only 3 are present in several different assemblages (*Arbutus unedo*, deciduous *Quercus* and a Mediterranean pine). *Phillyrea* sp./*Rhamnus alaternus* is present in few samples from the well and has been observed once in a hearth. All the other taxa appeared in only one or two different samples.

All the taxa refer to mesomediterranean plant formations: the deciduous oak forest (deciduous *Quercus*, *Acer* sp., *Prunus* sp., Maloideae, *Corylus avellana* pro parte, *Buxus sempervirens* pro parte, *Fraxinus* sp. pro parte), evergreen communities (*Arbutus unedo*, *Buxus sempervirens* pro parte, cf. *Erica* sp., *Juniperus* sp. pro parte, *Phillyrea* sp./*Rhamnus alaternus*), pine woods (*Pinus* sp., *Juniperus* sp. pro parte) and a riparian formation (*Populus* sp./*Salix* sp., *Corylus avellana* pro parte, *Fraxinus* sp. pro parte).

4.1. Postholes and foundation pits (Fig. 5)

Charcoal from architectural structures (postholes and foundation pits) consists in small assemblages of rather big fragments (from circa 1 to several cm.) and proved to be predominantly monospecific. In the cases where several fragments were available, a single taxon has nearly always been identified (excepted for 1 posthole and 1 foundation pit), and charcoal pieces show anatomical similarities making it probable that they were originally part of the same fragment. In most of the cases, deciduous oak (deciduous *Quercus*) was identified. In two samples, oak was found together with another taxon: ash (*Fraxinus* sp.) in the posthole 252 and poplar or willow (*Populus* sp./*Salix* sp.) in the foundation pit 70. Only 3 samples did not provide oak; they proved to be monospecific and consist of pine (*Pinus* sp.), strawberry tree (*Arbutus*

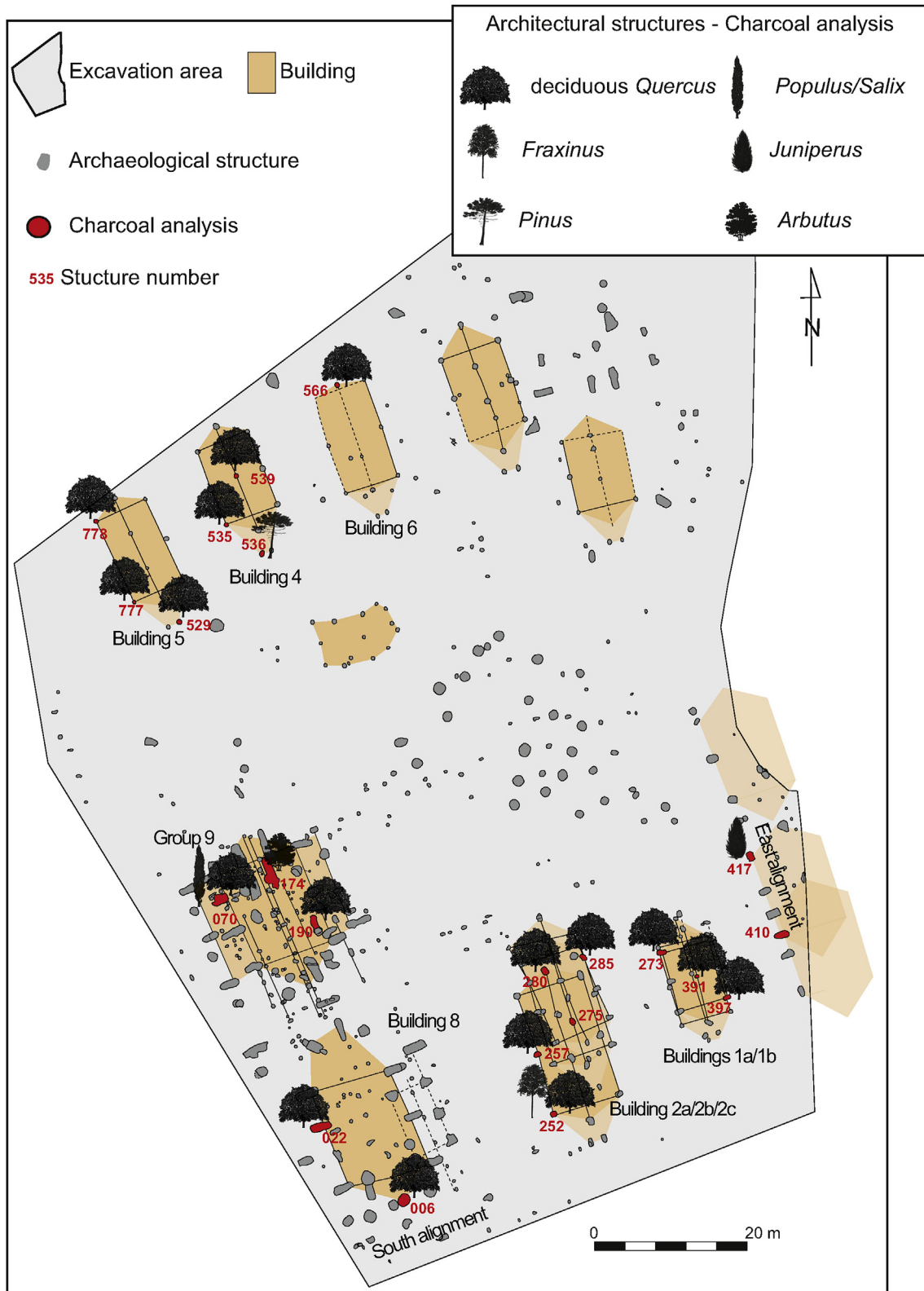


Fig. 5. Results of the identification of the charcoal fragments from the architectural structures (post-holes and foundation pits).

unedo) and juniper (*Juniperus* sp.). Tyloses are frequent in the vessels of oak charcoal from the architectural features. Although it may be pathological, the formation of tyloses in the vessels is normal and generalized during the ageing process of certain

species (Bakour, 2003) and allows the transformation of sapwood into heartwood (duraminization). The heartwood, impregnated with tannins, is much more resistant to biological degradation than functional sapwood which explains it is the only part workable for

timber. In oak trees, heartwood takes 20 years to appear, but tyloses form as soon as in the second or third growth ring (Ghazil, 2010). If the occurrence of tyloses is not a compelling evidence of old wood, the proportion of vessels clogged with tyloses in deciduous oak increases from the outermost rings (i.e. the youngest ones) to the most internal ones (i.e. the oldest ones) and nearly reaches 100% in the heartwood (Bakour, 2003). The high abundance of tyloses suggests that charcoal is from heartwood, either because that part was chosen *per se* or just because it is always present in large diameter pieces of oak. Oak heartwood offers the best durability among all the woody resources in Europe (Centre Technique du Bois et de l'Ameublement, 1992; Association des ingénieurs de l'école supérieure du bois, 2013), making it the most suitable building material, but also the part the less subject to decay if it is used without distinction with sapwood.

Because the assemblages are mainly constituted by one single species, because this species is the same in most of the cases (deciduous oak), and because the remains evoke the material (deciduous oak heartwood) the most suitable for timber (Centre Technique du Bois et de l'Ameublement, 1992; Association des ingénieurs de l'école supérieure du bois, 2013), it is likely that the charcoal fragments are the remains of the posts themselves rather than intrusive particles. Hence, in order to propose a quantification of the relative abundance of the taxa in the charcoal assemblages from these structures, we chose to consider all the fragments from a same taxon found in a same pit as a single original fragment. The total proportions (percentages) of the taxa among the architectural features are then calculated on the basis of the occurrences (Delhon, 2016). It must be noted that the sum of the occurrences is low (22), thus the relative proportions are just a point of information and must be cautiously used.

Oak represents around 77% of the occurrences (Table 2) and is present in more than 84% of the pits (17 over the 20 pits which provided identifiable charcoal) in which determinable charcoal was

found. Thus, the Neolithic people from Cazan would have chosen oak among the available trees for the construction of their buildings during the successive occupations.

Despite the great durability of oak heartwood, rotting features are very abundant, in the form of insects' galleries and cell walls collapses attributed to fungal or bacterial attacks (Théry-Parisot, 2001), suggesting that the posts may have begun to decay before being charred.

4.2. Heated-stone hearths

The hearths provided large quantities of large fragments but the amount of identifiable charcoal is lower than expected (less than 65%). The spectra is quite different from that of the postholes (Table 2 and Fig. 6A and B): oak is only present in two samples and represents only 4% of the fragments, while *Arbutus* is present in all the samples except for one (which only gave 3 fragments of pine). It nearly accounts for 92% of the identifications. Mediterranean pine was present in 3 different assemblages, the other taxa (*Phillyrea* sp./*Rhamnus alaternus* and *Populus* sp./*Salix* sp.) appeared only once each.

The important amount of non-identified fragments is in part due to the advanced stage of vitrification of most of them and to the abundance of knots whose anatomy is often too atypical to allow a reliable identification. However, the few preserved anatomical features (in particular typical spiral thickenings) were often compatible with that of *Arbutus*. This could indicate that this tree, although already dominating the assemblages, is underestimated in our results. Notwithstanding this, a potential taphonomical bias in favor of *Arbutus* should also be taken into account. Knots and vitrification are frequent on *Arbutus* fragments. If vitrification makes charcoal less crumbly and if the absence of orientation of the wood grain makes knots less sensitive to fragmentation, differential preservation could have affected the charcoal record, to the benefit

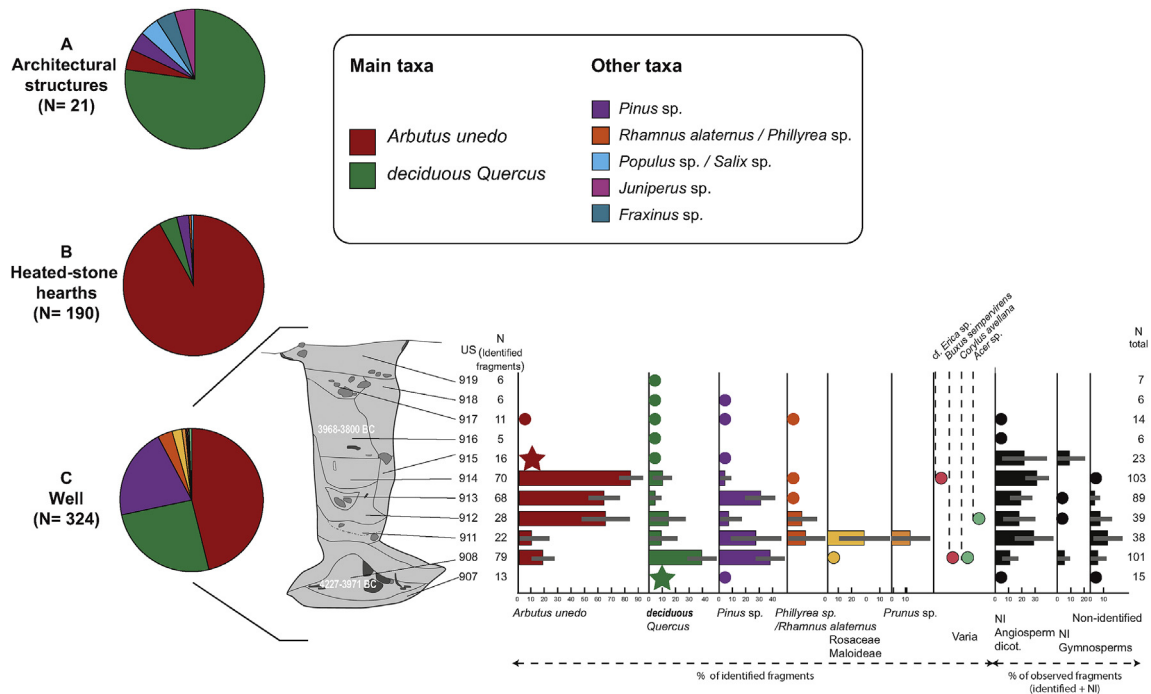


Fig. 6. Results of the charcoal analysis of the different kinds of structures. A: architectural structures (post-holes and foundation pits): percentages of the occurrences. B: Heated-stones hearths: percentages of the identified fragments. C: well, global results (left): percentages of the identified fragments and results for each sample (right): percentages of the identified fragments. Grey bars: confidence intervals. The percentages have not been calculated for the samples with less than 20 fragments or number of fragments of the taxon = 1; star: dominant taxon in assemblages of less than 20 fragments. Dot: assemblage of less than 20 fragments.

of gnarled and vitrified *Arbutus* fragments. Nevertheless, the preservation of knots or vitrified charcoal comparatively to normal and not vitrified wood has not been tested so far, and it would not detract from the fact that *Arbutus* is nearly the only taxon identified in fuel remains.

Even if they did not all functioned during the same period and they were not abandoned synchronously, seven out of the eight hearths studied provided nearly only *Arbutus* charcoal (in the eighth charcoal was not abundant: only three fragments of pine were identified). If we consider that the harvest of wood was made randomly in the available ligneous biomass, the low biodiversity of charcoal assemblages must be linked to the exploitation of pure *Arbutus* stands, except if the operators of the fire randomly chose *Arbutus* logs to feed the fire just before the hearth was abandoned. As the results are so similar, in seven cases out of eight, mere coincidence seems their least likely explanation. We should therefore investigate the possibility that *Arbutus* has been preponderant in the surrounding ligneous vegetation during the Middle Neolithic, which is not currently the case.

Arbutus grows in Mediterranean scrublands. It prefers acid substrata but it can be found on more or less decarbonated soils in limestone areas (Aubert, 1977). It can be favored by disturbances such as fire, grazing or frequent cutting. *Arbutus*-dominated formations are reported on crystalline substrata, in ravines from the Maures massif (Eastern Provence) (Rameau et al., 2008) and considered as a potential climax in humid or sub-humid bioclimates in Corsica (Panaiotis, 1995). They are also mentioned on the pelites (Permian sandstones) in the surroundings of the lake Salagou in Languedoc (at Carlenças, L. Liottier, pers. com.) and even in the calcareous hinterlands of Montpellier at La Boissière (L. Chabal, pers. com.). Nevertheless, this species very rarely forms dense and pure stands. It is usually found in the form of scattered trees, in formations dominated by evergreen oak *garrigue*, Mediterranean pine *pinède* or *Erica arborea maquis*, more rarely in deciduous oak forests (Aubert, 1977). With the exception of siliceous or extensively decarbonated soils, it is mostly a secondary element of retrogressive open woody formations (mid-successional according to Mesléard and Lepart, 1991) which tolerates dry and shallow soils. Currently, the geological and pedological context of Cazan seems unfavorable to the settlement of *Arbutus*-dominated *maquis*, even if isolated trees are scattered on the Chaîne des Costes. Several pollen diagrams are available for the lower Rhône/Durance area (Fig. 1). The closest from Cazan were sampled at 25/30 km from the site on both bank of the Durance river and date back to the end of the 1970's (Triat-Laval, 1978). More recently, two well-dated pollen cores were studied in the Marais des Baux (Andrieu-Ponel et al., 2000), around 30 km west from the site, in an area quite similar, edaphically and botanically speaking. In Triat-Laval's study, the Ericaceae - not identified to the genus level - show a sub-continuous curve (but never exceed 5% of the identified pollen grains) since the end of the Boreal at Beauchamp-Panières and Mollèges and appear sporadically at Les Autures but are not recorded at L'Isle-sur-la-Sorgue. The evergreen oak curve is more or less synchronous, showing somewhat higher values (but always below 10%), and increases more at the top of the diagrams (in particular at Mollèges). The more recent analyses from the Marais des Baux allowed most of the time identifying the Ericaceae, which proved to be mainly represented by *Erica arborea* whose curve seems again to accompany - although remaining more modest - that of evergreen oak. *Arbutus* is listed as a "rare taxon" in one of the profiles (2 pollen grains identified in a single sample whose pollen sum is 378), and totally absent from the other one, where non-identified Ericaceae gather 36 pollen grains from 5 samples (representing together a pollen sum of more than 1800). The representation of *Arbutus* in pollen spectra is not always representative of its

abundance in the vegetation ("poor pollen producer": Reille, 1992), and seems to have mainly a local significance (Díaz Fernández, 1994). Even if the spatial and chronological accuracy of these data are not representative of the locally exploited vegetation during the decades when the site of Cazan was occupied, they do not indicate the existence of extended *Arbutus*-dominated associations in the region during the Middle Neolithic.

Very dense stands of *Arbutus* are not documented in the past and are currently unknown in the surrounding nor - to our knowledge - in any climatically or edaphically comparable location. Therefore, the charcoal spectra from the hearths do not seem to have been formed through a random sampling of the vegetation. The species usually found together with *Arbutus* in present-day associations (*Erica arborea*, evergreen *Quercus*, *Phillyrea* sp., *Cistus* sp., *Pinus*) are absent or very weakly represented (one fragment of *Phillyrea* sp./*Rhamnus alaternus* and five of Mediterranean *Pinus* out of 190 identified fragments). Based on these observations, the hypothesis that *Arbutus* was specifically selected for fuel in the heated-stone hearths seems the most plausible explanation. Assuming this hypothesis, the reproducibility of the results from one combustion structure to another would suggest that the use of *Arbutus* could have been a standard practice reiterated during the successive occupations. Equally, it does not preclude a wider or denser Neolithic distribution of *Arbutus* in the area, on more evolved and decarbonated soils than currently encountered, but in the present state of our knowledge no data supports that hypothesis.

4.3. The well

As a long-lasting, secondary deposit, not directly linked to a single charcoal producing activity, the well was expected to propose a reliable record of the ligneous diversity of the site. Instead, the diversity remains low, with only 10 taxa, of which 5 are present only in one sample each (*Prunus* sp., cf. *Erica*, *Corylus avellana*, *Buxus sempervirens* and *Acer* sp.) and the list of taxa does not really provide new information compared to that of the other structures. *Arbutus* and oak are well represented (46 and 25.6% of the identified fragments), even if the bad state of charcoal probably leads again to an under-estimation of *Arbutus*. Only the representation of pine (20.4%) is better than it was in the other structures. Despite the infilling of the well, which is clearly formed by 3 successive phases, no variation is indicated by the charcoal spectra. As the well is located in the immediate vicinity of the hearths, and considering the abundance of *Arbutus*, it is possible that charcoal remains have been discarded in this structure after cleaning of the fireplaces.

5. Discussion

5.1. Low overall taxonomic diversity: bias of the archaeological record or wood selection?

The global biodiversity perceived through charcoal analysis at Cazan is low. Nevertheless, the recorded plants potentially refer to several different kinds of vegetation: seral stages of the deciduous oak forest, evergreen or mixed mesomediterranean formations (*garrigue/maquis*), pine formations and riparian forests (or at least an alluvial facies of the deciduous oak forest). However, the charcoal spectrum seems incomplete and fails to reflect the whole spectrum of the ligneous biodiversity of these associations. With three taxa (oak, *Arbutus* and pine) that supply more than 90% of the fragments, the charcoal assemblage is obviously only a partial record of the available vegetation.

Taphonomic processes may have affected the formation or the preservation of the charcoal record and be responsible for the

incompleteness of the spectra. Given the lack of a preserved occupation soil, charcoal was recovered from the sediment-traps the negative structures are, which casts doubts as to its reliability as an indicator of the whole diversity of the wood used on the site throughout the entire period of occupation (Chabal, 1997). Nevertheless, the charcoal accumulation in the well can be considered as continuous and long lasting (3 phases of deposition can be distinguished and the ^{14}C dates cover the whole span of the Late Chassey culture occupation) and is not directly linked to a single specific charcoal-producing activity (secondary deposit). Yet, the range of biodiversity displayed in the deposits, despite being wider than the heated-stone structures or of the postholes, remains limited (10 taxa, among which 3 represent 92% of the fragments) and brings only few taxa different from those identified in these specialized structures (*Acer* sp., *Buxus sempervirens*, *Corylus avellana*, cf. *Erica* sp., *Prunus* sp., Maloideae), while the two most abundant remain the same (*Arbutus unedo* and deciduous oak). Moreover, the architectural features on the one hand and the heated-stone hearths on the other hand gave very similar results from one sample to another, in the same kind of structure, and very different results between one type of structure to another: the hearths are dominated by *Arbutus* (91.6% of the fragments), while the postholes and foundation pits mainly provided deciduous oak (76.2% of the occurrences).

All of these observations support the hypothesis that harvests of timber and fuel are dissociate activities carried out either in two distinct targeted zones consisting of different vegetations, or possibly in the same area but involving two different taxa. Based on our data, it seems difficult to determine the level where the selection is done. The decision may intervene when choosing either (i) where to gather the woody resources or (ii) what to gather among the woody resources. In the first case, it corresponds to an opportunistic random harvest, among the available wood in the plots of land visited for specific activities - timber collection, fuel procurement - or during any other activity associated to one of them (it is well documented that fuel gathering often goes together with other daily tasks: Dufraisse et al., 2007; Salavert and Dufraisse, 2014; Henry et al., 2009). In the second case, it corresponds to a targeted search for a particular species, leading to the exploitation of the plot of land where that species grows.

We support that the significant lack of diversity in charcoal assemblages produced through specialized activities and the reproducibility of the results from one architectural feature to another and from a combustion structure to another is better in favor of a selection of the species. Oak seems to be preferred for making posts and avoided as a fuel for collective heated-stone hearths; *Arbutus* seems to be preferred for that purpose. The facts that these choices appear repeatedly - in several buildings for the use of oak, in several hearths for the use of *Arbutus* - and that these two species remain the most abundant throughout the stratigraphy of the well seem to confirm that the targeted harvests of these taxa are not unique events but persisting practices.

5.2. Contribution of charcoal analysis to the documentation of the buildings

The density of the features at Cazan presents, for the first time, a unique opportunity to reconstruct the form in plan of these « houses », built by the chassey culture. Based on these observations it was also possible to define a chronology for multiple phases of occupation and abandon. Various data concerning the arrangement of the postholes (they never recut older features and they form a standardized plan), the composition of their fills (evidence of post pullout prior to backfilling), the archaeological material they contain (possible foundation deposits, deposited or

dumped material) and radiocarbon dates show that the excavated area was occupied and abandoned at least three times, in probably less than three centuries (Moreau et al., 2015). Charcoal analysis from the postholes indicates that the posts were mostly made of deciduous oak. The preserved fragments show signs of duraminization. If the posts were made by large diameter logs, they could have originally included heartwood and sapwood. In that case, the complete decay of sapwood before carbonization would result in the preservation of heartwood only. Nevertheless, exclusive use of heartwood - especially of oak - is the only efficient way to ensure a durable wooden structure (sapwood is considered as unusable by present day carpenters) and seems more likely. Nor is the presence of ash (*Fraxinus*) and willow/poplar (*Populus/Salix*) surprising, as they can grow tall and provide relatively straight trunks or branches with sufficient diameters. Concerning the two finds of juniper and *Arbutus* in foundation pits, despite the smaller size of the charcoal fragments (compared to the average size of the fragments from postholes), their use as posts cannot be dismissed. If they are currently found in the form of small trees and coppices, both can reach several meters high and a diameter of several dozens of centimeters that can make them appropriate for making posts. However, in these two cases, intrusive charcoal is also possible.

The fact that oak fragments show signs evidences of duraminization as well as pre-combustion rotting features documents the chronology of the successive occupations. After the abandonment of the houses, the posts had time to partly decay, but were still present when the time for reconstruction came. Their remnants were then extracted and/or burnt, the holes were then backfilled with sediment and/or wastes and stone blocks; new holes were then dug for new posts. The durability of oak heartwood is of 15–25 years (Centre technique du bois et de l'ameublement, 1992; Association des ingénieurs de l'école supérieure du bois, 2013) which is an indication of the time-span between the building of the houses and the carbonization of the posts and thus between two successive occupations.

5.3. *Arbutus* as a fuel: a technical choice or the result of a larger landscape management?

The persistent use of *Arbutus* as fuel over the supposed 3 occupation phases is evidenced by its abundance in every hearth studied (except one structure which only provided 3 fragments of pine) and by the diachronic charcoal record of the well. The reproducibility of the results suggests that it would be too simplistic to ascribe the composition of the charcoal assemblages only to their being poorly representative of anything else other than the last combustion-event because they were recovered from combustion structures (Chabal, 1997). The charcoal analysis indicates that certain vegetal associations including *Arbutus* existed in the territory exploited by the Neolithic inhabitants of Cazan, but also, according to us, for a preference of that taxa for a specific use, as shown by a very poor quantitative and qualitative representation of the trees and shrubs which are usually associated with it (evergreen oak and tree heather are absent from the hearths; deciduous oak, *Phillyrea/Rhamnus* and pine represent together less than 8% of the identified fragments). Such a selection may be intended to satisfy cultural requirements that will remain unknown to us, but it could also fit technical or economical requirements.

Arbutus is still currently considered as a “good fuel” (Kühnholtz-Lordat, 1939, p.46; Lieutaghi, 2004) and has been used since the Iron Age to make charcoal (Fabre and Gervet, 1992; Acovitsióti-Hameau, 2001; Durand et al., 2010) of high calorific value, used in particular in forges in Western Spain until recent times (González et al., 2013). Unfortunately, it is not possible, in the present state

of charcoal analysis techniques, to distinguish charcoal produced by the use of wood as fuel from charcoal remaining from a second burning of already charred wood (Britton et al., 2007). To our knowledge, there is no report yet of Neolithic structures which could be linked to the deliberate production of wood charcoal. As a consequence, we tend to interpret charcoal spectra pre-dating iron metallurgy as the result of the combustion of wood, but the possibility of the use of charcoal - either produced for this purpose or recovered from previous fires - should be kept in mind. Whatever the form used (fresh wood or charred wood), it is possible that *Arbutus* was considered by the people living at Cazan as the best for the heated-stone hearths, either because of its intrinsic properties or, if used fresh, just because of the size of its branches. Nevertheless, the size alone is not a sufficient criteria as many other species could offer similar dimensions. Heated-stone structures are a particular type of hearth, typical of the Chassey culture for the Neolithic period. Despite improvements in recording and sampling of these features, due to a special attention given to them during field excavations and post-excavation analyses and recent experimental work (Muller-Pelletier, 2006), their functioning is not completely understood yet. Nevertheless, it seems widely accepted that “the objective is not the flame but the heat” (Muller-Pelletier and Pelletier, 2010): fire is used to start the heat-transfer process which is then mostly realized by the hot stones. Charcoal analyses of such Neolithic structures are not frequent to our knowledge (Cabanis, 2006; Marchand et al., 2009; Morin in Thirault, 2011, Figueiral, 2016), partly because they do not always provide charcoal. Comparisons are made difficult due to the reduced number of studies and the wide biogeographical range they concern. The taxonomic diversity and the identified taxa vary a lot from one site to another. In Languedoc (South of France), in the middle Neolithic hearths from the sites of Peras and Cadoules, most of the charcoal identifications points to *Erica* sp. (Figueiral, 2016), which belongs to the same family as *Arbutus* (Ericaceae), shows some ecological and biological similarities with it and has also been widely used to produce charcoal during middle ages (Durand et al., 2010). All the studies point to a high rate of vitrification (Cabanis, 2006; Marchand et al., 2009; Morin in Thirault, 2011, Figueiral, 2016), sometimes interpreted as an evidence of green wood (Cabanis, 2006) or of anaerobic combustion (Marchand et al., 2009). The process by which the cell walls melt is not well understood and none of the parameter which have been tested experimentally (which are: species, temperature, kinetics, green/seasoned wood, moisture) proved to be sufficient (Théry-Parisot, 2001; McParland et al., 2009; McParland et al., 2010). The only variable not sufficiently tested to our knowledge is combustion in a reducing atmosphere. Successful experimental reproductions of the phenomenon have only been reported in charcoal kilns (Fabre, 1996) and in fire mining using green wood (Py and Ancel, 2006). The lack of oxygen during combustion should be investigated, not only as a mean to explain vitrification but to also improve our understanding of the function of the heated-stone hearths. We reported numerous radial cracks in *Arbutus* charcoal, whose accurate quantification could give information on the phenological state of the wood (Théry-Parisot and Henry, 2012). Unfortunately, *Arbutus* charcoal often displays a poorly readable transversal section (knots, vitrification), making such analysis difficult to achieve.

However, even if the kinetics of combustion of *Arbutus* is suitable for use in the heated-stone structures, other reasons may also explain its use for fuel. Plant resources management depends on the behavior of plants. *Arbutus* has a rapid juvenile growth, and, when brunt or cut, it produces clump shoots, ensuring a quick regeneration of the resource after harvesting. As a component of the scrublands, it is found in disturbed areas, like pasturelands or previously burnt zones (Kuhnholz-Lordat, 1939). We thus can

imagine that the specific exploitation of *Arbutus* is part of a land management system in which the scrublands are used both as grazing areas and as fuel supplies. As a feed-back, *Arbutus* could be to some extent favored by such management and gain importance in the vegetation compared to less competitive species. Meanwhile, oak timbers are preserved for use in construction. As shown by the charcoal from the well, pine is also exploited, although its use is not directly recorded. This could be because its primary deposits were not preserved (due to the truncation of the archaeological horizon) or alternatively because it was processed outside the excavation area.

6. Conclusion

Despite the absence of a preserved occupation soil and the restriction of charcoal remains availability to negative structures only, the site of Vernègues, Cazan – Le Clos du Moulin provides precious information not only about the vegetation cover around the site during the Middle Neolithic – which still needs to be better understood – but also about the socio-economic system. The study of assemblages from different types of structures linked to different activities grants opportunity to reconstruct some aspects of a specialized use of woody species. Posts are made of oak. Once rotten, they are cleared by fire, but oak is not used as a fuel in community hearths: *Arbutus* seems specifically chosen for that purpose, despite multiple sources of evidence which suggest it was not the most abundant species in the surrounding vegetation. The Neolithic population of Cazan practiced other charcoal-producing activities, including at least one that used the pine wood and that excavations did not revealed. If the size required for the posts and the need for a durable material can restrict the scope of the species suitable for timber, the choice of fuel seems to be less constrained by technical limitations. Nevertheless, a clear selection persists throughout the occupation of the site; it may be intended to satisfy cultural requirements that will remain unknown to us, but it could also fit technical or economical requirements.

The harvesting and the management of ligneous resources seem to be governed by socio-economic rules that must be linked to a broad exploitation of the landscape diversity, in particular for agro-pastoral purposes. The connection between agro-pastoral practices and firewood gathering according to a principle of land-management optimization has already been proposed for the Neolithic (Delhon et al., 2009; Salavert and Dufraisse, 2014; Battenier et al., 2016b). The charcoal analysis of Cazan allowed us to reconstruct the organization of wood-consuming activities in details, which echoes the strict organization of the habitat that has been demonstrated the first time at Cazan, but also the complex socio-economical organization of Chassey culture communities described by several authors at the regional scale (Beeching et al., 2000; Bréhard et al., 2010; Beeching, 2011; Beeching and Léa, 2015). The specific exploitation of *Arbutus* could then be a part of a land management system in which the scrublands are used both as grazing areas and as fuel supplies.

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