



Phytoliths as a seasonality indicator? The example of the Neolithic site of Pendimoun, south-eastern France

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Abstract	<p>Pendimoun rock-shelter is among the oldest Neolithic sites known on the French littoral (Impressa culture, since ca. 5700 BCE). It was discontinuously occupied from the Mesolithic to the end of the Neolithic. During the Neolithic, it was used for pastoral purposes and domestic activities as well as for pottery production. Agriculture and cereal processing are clearly attested during the Impressa occupation (grains, husk and straw macroremains, grindstones) and become more less obvious in the overlying layers. Phytolith analysis concerned 1 Mesolithic sample (Sauveterrian culture) and 16 samples covering most of the 6th millennium BCE (Impressa, Cardial, and transition to Early Square Mouthed Pottery—SMP cultures). Significant amounts of grass phytoliths and the scarcity of dicot phytoliths suggest that the livestock, whose dung constitutes an important part of the sediment, mainly fed on wild grasses. Inflorescence bract phytoliths are well represented only in the Impressa levels, confirming that cereals were partly processed in situ only during the earliest stages of the Neolithic. Amounts of BILOBATE short cells proved to be higher than expected in an area where only a few panicoid species can grow. The three candidates for BILOBATE phytolith producers (<i>Setaria</i> spp., <i>Digitaria sanguinalis</i>, <i>Echinochloa crus-galli</i>) all have a short vegetation cycle that lies entirely between the end of spring and the beginning of autumn, suggesting that the shelter was mainly used during that period. The low amount of inflorescence bract phytoliths (except during the Impressa) seems to restrict that range to the period before the ears become mature, namely the end of spring or early summer.</p>	
Keywords (separated by '-')	Phytolith - Neolithic - South-eastern France - Seasonality - Panicoideae - Pastoralism	
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Phytoliths as a seasonality indicator? The example of the Neolithic site of Pendimoun, south-eastern France

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Abstract

Pendimoun rock-shelter is among the oldest Neolithic sites known on the French littoral (Impressa culture, since ca. 5700 BCE). It was discontinuously occupied from the Mesolithic to the end of the Neolithic. During the Neolithic, it was used for pastoral purposes and domestic activities as well as for pottery production. Agriculture and cereal processing are clearly attested during the Impressa occupation (grains, husk and straw macroremains, grindstones) and become more less obvious in the overlying layers. Phytolith analysis concerned 1 Mesolithic sample (Sauveterrian culture) and 16 samples covering most of the 6th millennium BCE (Impressa, Cardial, and transition to Early Square Mouthed Pottery—SMP cultures). Significant amounts of grass phytoliths and the scarcity of dicot phytoliths suggest that the livestock, whose dung constitutes an important part of the sediment, mainly fed on wild grasses. Inflorescence bract phytoliths are well represented only in the Impressa levels, confirming that cereals were partly processed in situ only during the earliest stages of the Neolithic. Amounts of BILOBATE short cells proved to be higher than expected in an area where only a few panicoid species can grow. The three candidates for BILOBATE phytolith producers (*Setaria* spp., *Digitaria sanguinalis*, *Echinochloa crus-galli*) all have a short vegetation cycle that lies entirely between the end of spring and the beginning of autumn, suggesting that the shelter was mainly used during that period. The low amount of inflorescence bract phytoliths (except during the Impressa) seems to restrict that range to the period before the ears become mature, namely the end of spring or early summer.

Keywords Phytolith · Neolithic · South-eastern France · Seasonality · Panicoideae · Pastoralism

Introduction

Pendimoun is a very important site for understanding of the Neolithic transition in the northwestern Mediterranean. Farming economies, which spread throughout the Near-East and the Aegean, reached southern Italy shortly after 6000 BCE (Binder et al. 2017). The Neolithic innovations were brought to the Western Mediterranean by groups of pioneers belonging to the Impresso-cardial cultural complex who arrived by sea from Italy. These groups settled close to the littoral, while parts of the hinterlands were still occupied by Late Mesolithic groups. These pioneer populations are

known thanks to a very small number of sites, scattered from Liguria in Italy to the south-eastern Languedoc in France. Pendimoun is one of these few key-sites documenting the very beginning of agro-pastoral economies in south-western Europe. With the spread of agriculture, questions arise concerning the ways prehistoric farmers exploited the territory and managed their resources. In particular, the mobility of the groups and the duration of the occupations, which seem to be linked to the kinds of activities carried out at the sites, remain difficult to assess accurately. Due to the scarcity of archaeological sites and to preservation hazards, plant and animal remains linked to human activities are rare. Therefore, as many as possible of the recovered remains need to be fully exploited and studies must extend beyond the most obvious macroremains. Phytolith analysis has proved to be an effective tool for obtaining reliable quantitative information concerning plant-related activities (and more specifically agriculture and farming), particularly in contexts where organic remains are poorly preserved or scarce (Harvey and Fuller 2005; Delhon et al. 2008; Cabanes et al. 2009;

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Lancelotti et al. 2014). In our study, phytolith analysis of Early Neolithic levels at Pendimoun shelter has been used as a means, among others (there are several ongoing studies concerning the same site which rely on a wide range of analytic approaches: see Binder et al. in press), of documenting agro-pastoral activities.

Archaeological background

Pendimoun is a rock-shelter located in south-eastern France, near the Italian border, just above the City of Menton (Fig. 1). Due to the steep topography, this can be considered to be both a coastal site (at less than 4 km from the sea as the crow flies) as well as a low mountain site (at an elevation of nearly 700 m). The site is currently on the ecotone between Meso- and Supramediterranean Vegetation Belts and the surrounding landscape is strongly characterized by pastoral exploitation. The site was first explored in the 1950s,

and more recent excavations carried out by Didier Binder between 1985 and 2006 have revealed a discontinuous occupation from the Mesolithic to the end of the Neolithic. The southern and northern sectors of the site are separated by a trench inherited from the old excavation, which unfortunately hinders any strict correlation between the two stratigraphies (Binder et al. 1993).

The oldest archaeological level is attributed to the Sauveterrian Mesolithic culture of the 9th millennium BCE and it is notably represented by an infant burial. Around 80 cm above this level, the Neolithic sequence stretches over a thickness of ca. 200 cm and records occupations from the Impressa Neolithic (Early 6th millennium BCE) to the Bell Beaker cultural complex (Late 3rd millennium BCE). Despite the fact that the two sectors of the site are now disconnected, it appears that the Impressa deposits from the southern sector predate those from the northern sector. The sequence also includes several archaeological discontinuities due to periods of abandonment of the site and/or to erosion. The

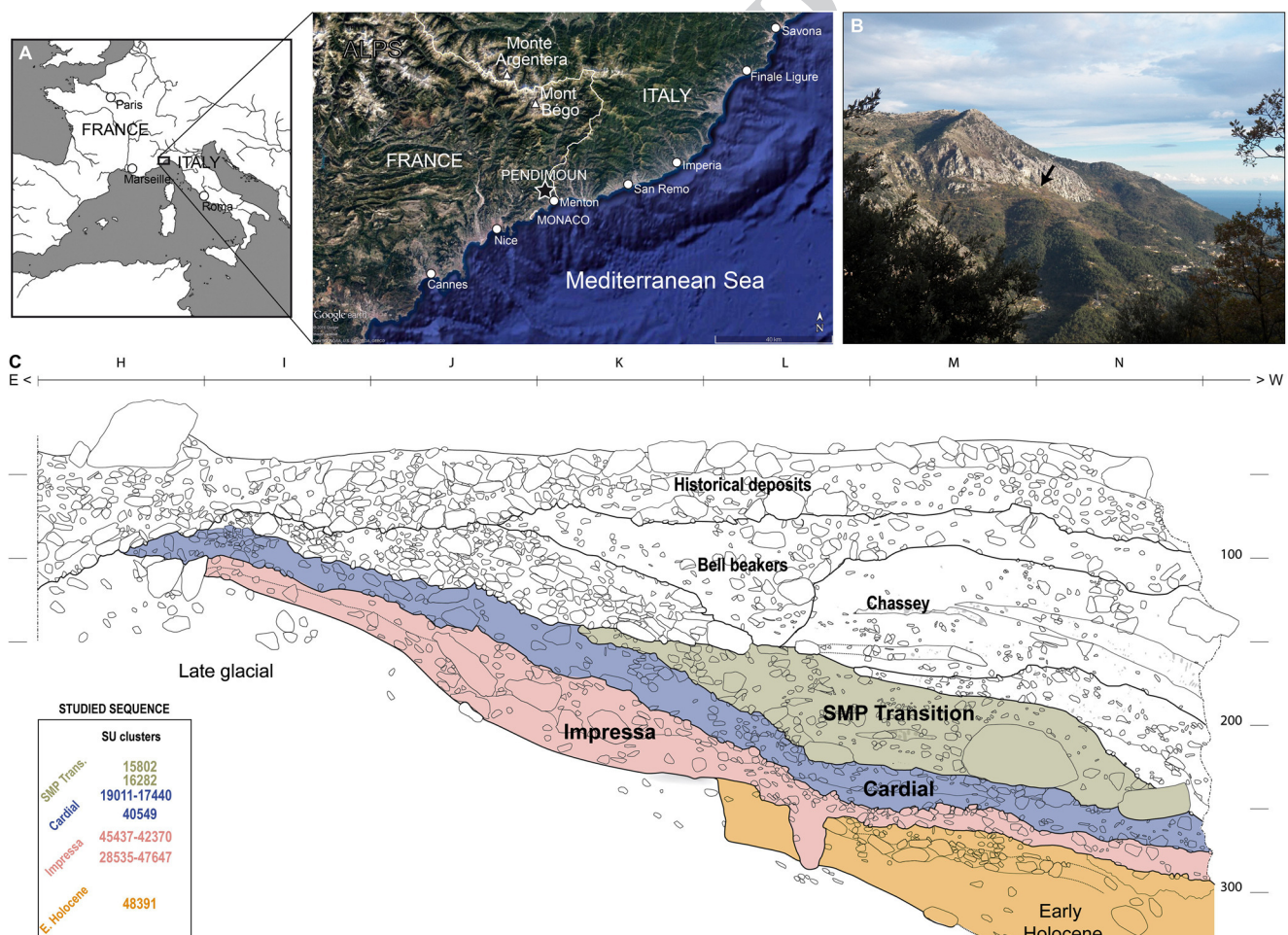


Fig. 1 Site location in south-eastern France (a), general overview of the shelter (b photograph JV Pradeau) and stratigraphic sequence of the northern sector (c east/west section)

identification of sheep bones and the composition of the sediment, partly made up of mineralized dung and rich in spherulites and ashes, indicate that the shelter was used for pastoral purposes since the earliest Neolithic occupation, but more intensively during the Chassey Neolithic (Late fifth–Early fourth millennium) (Binder et al. 1993, in press). Charcoal analysis has shown that the impact of pastoral practices on the vegetation remained low until the end of the fifth millennium but increased markedly during the 3rd millennium BCE. It also shows the exploitation of diverse patches of a mosaic vegetation, probably linked to a staged agro–sylvo–pastoral system based on the exploitation of the resources from various altitudes (Battentier et al. 2015). Several domestic activities also took place at the site, in particular an abundant and distinctive production of ceramic wares (Basso et al. 2006; Gomart et al. 2017). Numerous hearths and waste from everyday life suggest that the shelter was used as a dwelling by shepherd–potter groups. A set of burials has also been discovered in the Cardial levels (Mid-6th millennium BCE) (Zemour et al. 2016). Agriculture is attested since the earliest Neolithic by the presence of cereal grains in the Impressa levels, which are amongst the oldest in France (Binder et al. 1993; Guilaine et al. 2007), and various tools linked with agricultural activities or with grain processing, such as sickle blades or grindstones. Seashell gathering is also attested during the 6th millennium BCE.

The stratigraphy is particularly detailed from the 6th to the 5th millennia BCE (235 stratigraphic units grouped in 30 clusters). The present study focusses on this period, during which the shelter was used for diverse activities, sometimes successively and sometimes simultaneously. Phytolith analysis is part of a set of investigations implemented in order to hone our understanding of the chrono–stratigraphy and of the archaeological occupations. Despite the fact that ongoing studies have not as yet yielded all their results, the data currently available already provide us with a good picture not only of the activities carried out on the site but also of some aspects of the socio–economical organization through time (Binder et al. in press). Like most of these shelters and caves used during the Neolithic in such contexts, Pendimoun is considered to have been a seasonal settlement. The key challenge facing us in terms of the Neolithic in general, and this site in particular, is to understand the nature, periodicity and rhythm of the seasonal occupations, and consequently to understand the position of the site in the territory exploitation network. During the earliest Neolithic (Impressa), the site was inhabited by a group of farmers (Rowley-Conwy et al. 2013), who cultivated cereals and raised sheep. The activities that took place on the site were diverse and also included some hunting, gathering of plants (acorns) and of seashells as well as the manufacture of ceramics; these activities seem to have been conducted at different seasons of the year, during long-lasting occupations of the shelter.

Afterwards, during the Cardial Neolithic, the shelter seems to be used during briefer but repeated periods, although the spectrum of activities remains globally the same (livestock keeping, pottery production), with the noticeable exception of the use of the shelter to bury the dead. The importance of hunting in the economy is not clear, partly because of difficulties in the identification of *Suideae* (wild boar vs. domestic pig). During the transition phase to the Square Mouthed Pottery (SMP) culture, the shelter was used for the penning of herds, but also for various other domestic and craft activities, which suggest long-lasting occupations. A hiatus of several centuries isolates the first SMP settlement from the rest of the Neolithic sequence, which exhibits an increasing specialization of the site towards pastoral activities: during the Middle Neolithic, the occupation is typical of the *grottes-bergeries* (sheepfold caves) known elsewhere in the Alps and the northwestern Mediterranean area during that period (Delhon et al. 2008; Angelucci et al. 2009; Martin et al. 2011 and references therein); afterwards, during the Bell Beaker period, the pastoral economy switches to rearing cattle rather than small ruminants (Binder et al. 1993). Because Pendimoun is a reference site for the first stage of the Neolithic in the area and because the following levels (from mid-fifth to the end of 3rd millennia BCE) provided less artefacts and ecofacts, this paper focuses on the earliest Neolithic sequence, i.e. the Impressa first Neolithic, the Cardial Neolithic and the transition towards the SMP.

Materials and method

Phytoliths are microscopic opal silica particles produced in and between plant cells during the life of the plant. Due to their chemical composition, they are usually well preserved in various contexts, even when the organic plant remains are decomposed (Kibblewhite et al. 2015). Because of the high phytolith content of grasses (including cereals) and the specificity of the forms produced by the Poaceae, these bioremaines are appropriate for reconstructing agricultural practices, cereal processing and the diet of herbivores (including domesticated species). Seventeen stratigraphic units were sampled for phytolith analysis, in order to give clues to the relationships between the human groups that frequented the shelter during Prehistory and the surrounding vegetation. In particular, we aimed to gain a better understanding of the share of agriculture in the economy of the Early Neolithic societies by tracking cereal remains, and of the management of herds through the phytolith record of their diet. Focusing on the most promising archaeological levels, phytolith analysis was carried out on 1 sample from a Mesolithic burial and 16 samples covering most of the 6th millennium BCE (Impressa, Cardial, Early SMP). Our analysis targets chronological complexes for which sharply focused documentation

concerning the exploitation of vegetal resources is lacking, in particular the pioneer stages of the Neolithic (Impressa), but also the earliest stages of the establishment up of Middle Neolithic cultural complexes (SMP).

All of the samples come from sheltered zones of the site, where the sedimentary sequence was shown to have been protected from major erosion. Most of the samples come from the northern sector of the site and were analysed by C.D.; two samples recovered from the southern sector and previously analysed by P.V. are also included into the present study. A small number of samples originate from the fill of identified structures, while most are from the sedimentary matrix of the archaeological levels (Table 1).

Around 2 g of sediment from each sample were processed by A.M. at the CEPAM-CNRS Laboratory, following the laboratory's routine protocol for phytolith extraction. The sediment is sieved (200 μm) after soaking (12 h) in demineralized water for deflocculation of clays. The fine fraction is then treated first with concentrated hydrochloric acid and then with potassium hydroxide in an ultrasonic hot bath. After several rinses, phytoliths are concentrated by heavy liquid separation using a Thoulet solution ($d=2.35$). Once dried, the phytoliths are dispersed on a slide in a drop of immersion oil and protected by a cover-glass sealed with resin. Phytolith identification is carried out through a transmitted light microscope, at a magnification of $\times 1,000$. Where needed, polarizer/analyser devices are used to differentiate amorphous silica opal from potentially birefringent particles. The protocol used provides a very clean phytolith extract, but it does not allow the observation of spherulites. These are identified in the sediment through other analytic means (Brochier in Binder et al. 1993) and do not fall in the scope of the present study. Phytolith identification is based on a morphotypic classification prior to a taxonomic one, due to the multiplicity (a single species may produce various different morphotypes) and the redundancy (the same morphotype may be produced by various different species) of phytolith production (Rovner 1971; Brown 1984). As regards the terminology used for the description of the morphotypes, we endeavour to follow the latest recommendations of the International Committee for Phytolith Nomenclature (ICPN 2.0, ICPT in press). In order to guarantee the statistical reliability of the results, we ensured that more than 200 classified phytoliths were counted for each studied sample.

Results

All of the samples provided abundant and well preserved phytoliths (Table 1). It was not difficult to observe satisfactory quantities of significant forms on the slides, as phytoliths proved to be abundant and well preserved in

every sample. As a result, identifiable phytoliths counts vary between 167 and 409. Weathering and surface alteration (Fredlund and Tieszen 1997) were rarely observed. The phytoliths were nearly always represented by single-cell particles: connected silicified cells, also known as silica skeletons, were only rarely encountered in five different samples, mainly from the sedimentary matrix (Impressa, Cardial, SMP transitions levels) but also from one Impressa combustion structure. They account for 0.3 to 1.2% of the assemblages in which they have been observed, i.e. 1 to 4 individuals per sample. These multicelled phytoliths are mainly made up of grass epidermal cells, apart from one example of contiguous silicified grass bulliform cells. The observed morphotypes (Fig. 2) mainly relate to the Poaceae (grass) family. Phytoliths attributed to dicots are rare over all, but reach noticeable values in the southern area. They are represented by globular morphotypes (SPHEROID ORNATE) and by probable epidermal cells (tabular polygonal morphotype). Concerning grass phytoliths, the morphotypes produced in the vegetative parts of the plants (culm, leaves) are abundant. Among them, ELONGATE ENTIRE, ELONGATE SINUATE, ACUTE BULBOSUS are very common and cannot be taxonomically identified further. The silicified bulliform cells have also been allocated to the general grass family due to a lack of published descriptions and of modern comparison reference material for the area. They were represented by the BULLIFORM FLABELLATE and BLOCKY morphotypes. Although BLOCKY forms are not unequivocal (ICPT in press), the overall composition of the phytolith spectra, dominated by grass phytoliths, points to silicified bulliform cells. A silica skeleton made of articulated BLOCKY phytoliths, likely silicified bulliform cells, was observed. BULLIFORM FLABELLATE and BLOCKY morphotypes are subsumed into the BULLIFORM category in Table 1 and Fig. 3. On the other hand, short cells allow us to distinguish between several Poaceae sub-families (Twiss et al. 1969; Twiss 1992). CRENATE morphologies characterize the Pooideae subfamily, while RONDEL is more widespread, but, in a temperate context, can be interpreted as mainly originating from the Pooideae family too. BILOBATE morphotype, also previously known as "dumbbells", is mainly produced by the Panicoideae subfamily. SADDLE, only present in low amounts in Pendimoun sediment, is frequently used as a diagnostic the Chloridoideae, despite that it can be found in other related subfamilies (ICPT in press). Nearly all of the species of wild grasses from temperate Europe are Pooideae, as are the first cereals domesticated in the Middle East and then introduced into Europe (*Triticum* spp., *Hordeum* spp.). Panicoideae are only represented by a small number of genera in middle latitudes of Western Europe, particularly *Setaria* (wild millets), *Digitaria* and *Echinochloa*. Domesticated millets also belong to the Panicoideae subfamily.

Table 1 Results of the phytolith analysis of the Mesolithic and Early Neolithic levels of Pendimoun shelter (analyses C. Delhon)

Chronocultural attribution	Sauvet-errian	Impressa (base)	Cardial (base)		Cardial (mid.)	Cardial (top)	Cardial (top2)	SMP trans. (base)		SMP trans. (mid.)
			45,437	42,370				16,282	15,802	
SU Cluster	48,391	28,535	47,647		40,549	19,011	17,440	16,282	15,802	
Sample	48,413	28,936 ^a	48,238	47,884	47,442	40,317	41,859	40,048	19,879	15,539
Zone	North	South	North	North	North	North	North	North	North	North
Square	N22C	O13C	L21C	M22B	L21A	L21B	L22A	L20A	K21D	M22
Stratigraphic unit	48,391	28,890	47,803	47,800	47,647	43,661	19,909	19,908	19,011	14,999
Structure	Burial		Combustion		Posthole		Burial (sec. fill)			
Silica skeleton		2	3	1			1			4
ELONGATE ENTIRE	69	118	42	86	82	96	77	80	51	89
ELONGATE SINUATE			2		3	2	2	3		86
ELONGATE DENDRITIC	2	6	32	43	25	6	17	7	2	3
BULLIFORM	28	2	28	12	18	13	22	15	5	6
Articulated BLOCKY							3			17
ACUTE BULBOSUS	9	16	40	16	10	9	22	14	8	13
RONDEL	149	60	162	117	187	145	149	176	94	129
CRENATE	2	12	2	10	2	5	6	7	1	1
BILOBATE	4	18	26	5	6	5	8	8	5	7
SADDLE	2		1	2			1	1		10
PAPILLATE			1			1				15
SPHEROID ORNATE	18		6	3		4	5	3	1	2
Tabular polygonal	1	44								
Total no. classified phytoliths	284	276	396	287	333	264	305	313	167	254
		400				256	290	329		270

The samples are chronologically sorted and grouped in relevant stratigraphic unit clusters (SU cluster) based on field observation and Bayesian processing of the ¹⁴C dates (Binder, ongoing work)

^aAnalyses: P. Verdin

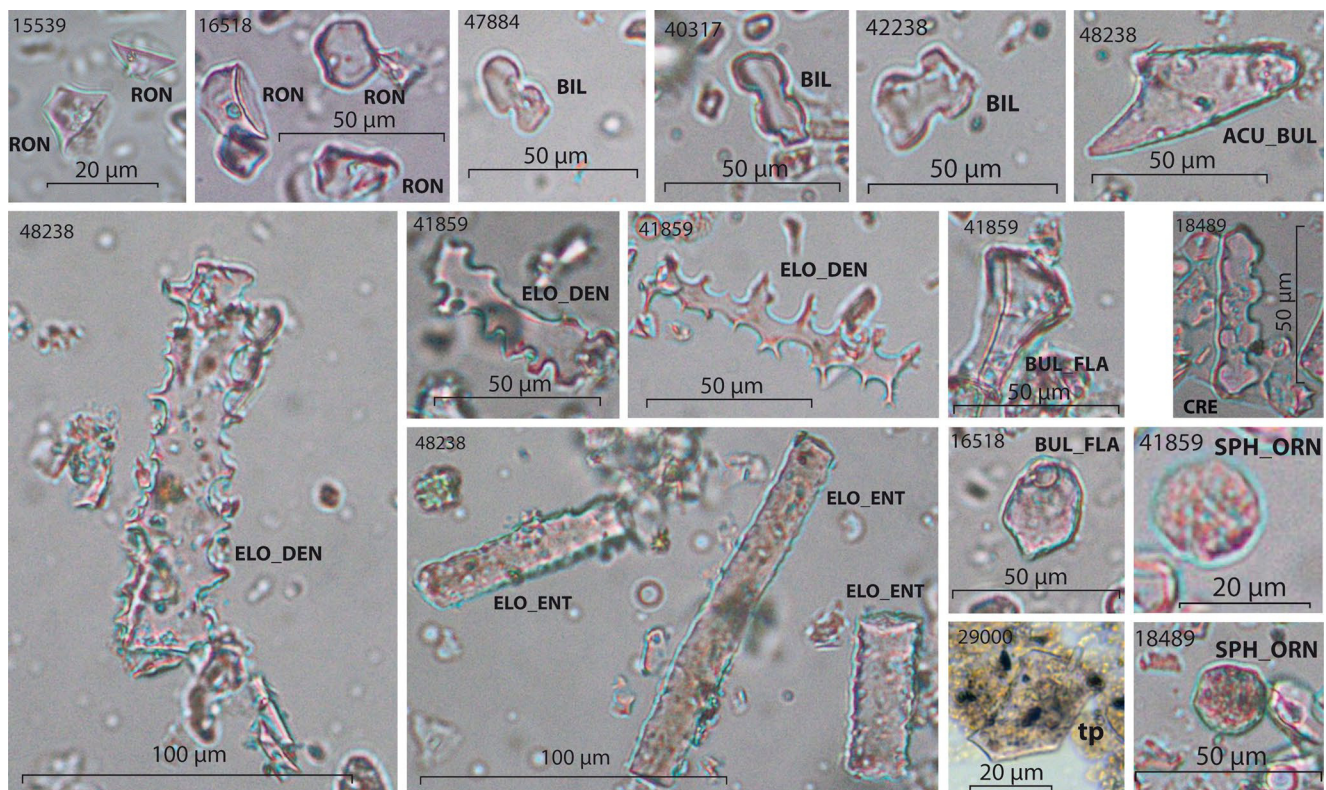


Fig. 2 Photographs of the main phytolith morphotypes found at Pendimoun: RONDEL (RON), BILOBATE (BIL), CRENATE (CRE), ELONGATE DENDRITIC (ELO_DEN), ELONGATE ENTIRE (ELO_ENT), BULLIFORM

FLABELLATE (BUL_FLA), ACUTE BULBOSUS (ACU_BUL), SPHEROID ORNATE (SPH_ORN), tabular polygonal (tp). The number in the left corner refers to the phytolith sample

Finally, the Chloridoideae subfamily is mainly distributed in intertropical areas, but it is nevertheless represented in southern France by *Cynodon dactylon* (Bermuda grass). The common reed, *Phragmites australis*, which belongs to the Arundinoideae subfamily, also produces saddle-shaped short cells (Ollendorf et al. 1988), but this species is restricted to wetlands, especially in Mediterranean areas. Morphotypes from grass inflorescence bracts have also been observed, in the form of ELONGATE DENDRITIC and scarce PAPILLATE (Parry and Smithson 1966; Rosen 1992).

Most of the spectra show a strong dominance of grass phytoliths (Fig. 3). In the Neolithic samples from the northern sector, dicot morphotypes show a discontinuous curve and only account for nil to 1.6% of the total. The pattern is completely different for the samples from the southern area, in which dicots phytoliths, in the form of tabular polygonal particles interpreted as leaf epidermal cells (tp in Fig. 2) have high values: 16.1 and 23.5%. The variability of the phytolith spectra might be linked to a spatial distribution of the activities inside the shelter, but more samples from the southern zone would have been necessary to assess the extent of the phenomenon and to propose further interpretations. The Sauveterrian burial, in the northern area, also exceeds the Neolithic levels in

this sector in terms of dicots, which represent 6.7% of its phytolith content.

Discussion

Livestock diet

In pastoral sites like Pendimoun, phytolith accumulation is thought to be mainly due to shepherds bringing vegetation into the cave as bedding or fodder for the livestock, and also, depending on the frequency and the duration of their presence in the shelter, to the transportation of plant material within the digestive systems of the animals. Nevertheless, it remains difficult to determine whether these microremains mainly stem from livestock alimentation or if they could also partly result from the use of plants for other purposes. Based on ethnoarchaeological observations, a significant presence of multi-cell phytoliths (also called silica-skeleton) is sometimes considered as a marker of dung accumulation (Portillo et al. 2014) or of the presence of bedding (Cabanes et al. 2009). Yet, these forms are rather rare in Pendimoun. Nevertheless, in some cases, like in La Grande Rivoire, the abundance of spherulites indicates that

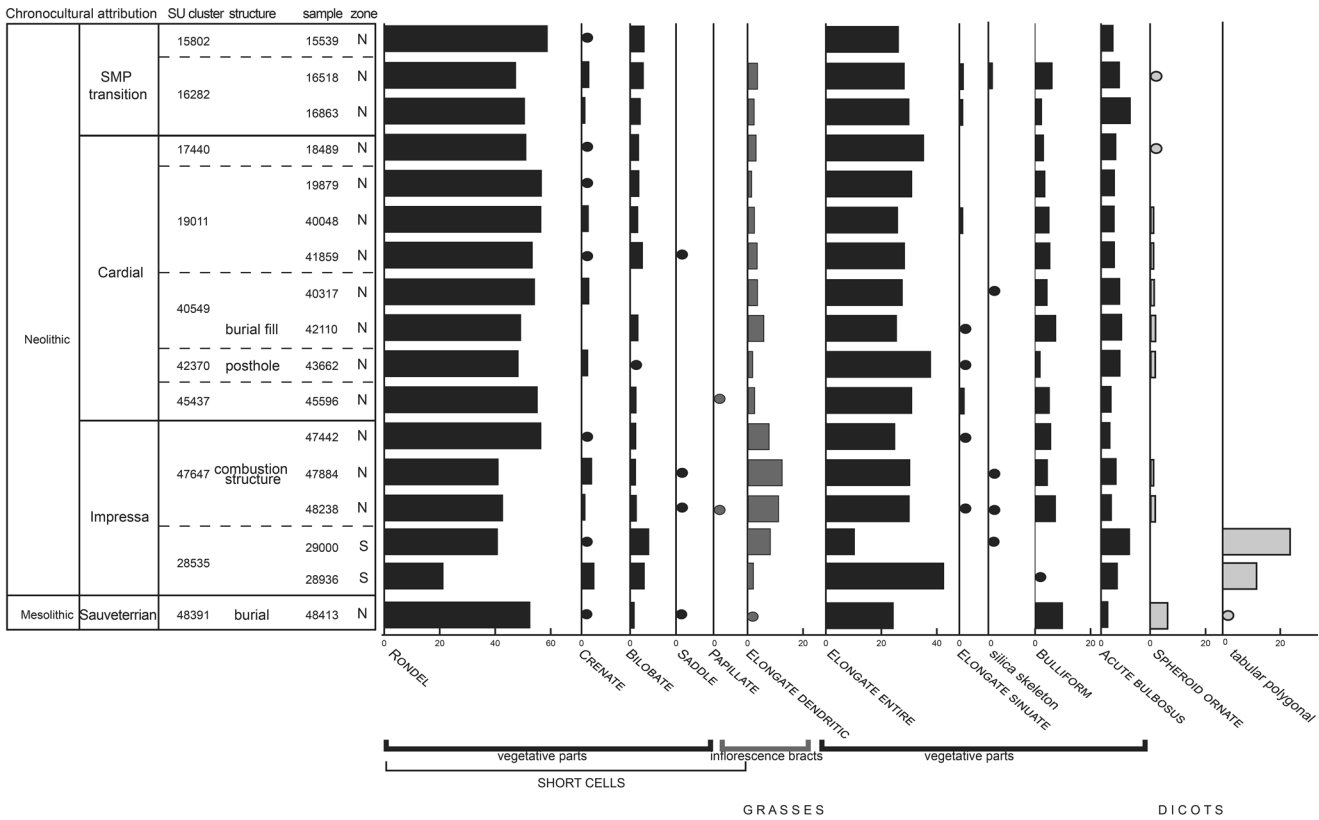


Fig. 3 Results of the phytolith analysis of the Mesolithic and Early Neolithic levels of the Pendimoun shelter

sediment mainly derives from dung, despite the fact that the abundance of grass multi-cell phytoliths remains low (from 0 to 6%, Delhon 2014). Taphonomical processes may enhance the breakage of these forms into single-cell particles. Moreover, depending on environmental factors and on the age of the vegetal tissues, multicelled phytoliths may not be present in the browsed grasses. Thus, the absence or scarcity of silica skeletons at Pendimoun is not sufficient to rule out the possibility that the phytolith assemblages derive from dung accumulation. Focusing on the northern zone, it thus seems that the livestock mainly fed on grasses, either brought into the shelter by the shepherds or grazed from the surrounding vegetation. Even though phytolith production is far more important in grass than in dicots (Delhon 2010), the presence of dicot phytoliths suggests that such plants were introduced into the shelter, albeit in smaller quantities compared to grasses. In dicots from temperate areas, phytolith production seems to be mainly concentrated in leaves (epidermal cells) and wood (globular morphotypes), although it remains very low in the latter (Scurfield et al. 1974; Kondo et al. 1994; Alexandre et al. 1997; Albert and Weiner 2001; Delhon 2010). Wood was used on the site, at least for fuel, as documented by the presence of scattered charcoal in all of the levels. Nevertheless, the scarcity of dicot phytoliths

indicates that branches and leaves were probably not used as bedding or for feeding animals.

These results are similar to those reported from two Ligurian sites (Italy). In the phytolith analysis of Riparo di Pian del Ciliegio shelter (transition to and early SMP: 5000–4800 to 4600–4300 BCE), only grass morphotypes are reported (Arobba and Caramiello 2009), while at the Arene Candide Cave there is a “sharp prevalence” of grass origin (Nisbet 1997). In contrast, the use of tree branches bearing leaves and/or flowers has been demonstrated on various other Neolithic shelters in southern France (*grottes-bergeries*) (Thiébaud 2005). At La Grande Rivoire (Isère, Vercors massif, Alps), the use of tree fodder is clearly indicated by very high proportions of dicot phytoliths (most of the time between 30 and 50%) throughout the Neolithic (Delhon et al. 2008). At Pendimoun, it seems that the livestock mainly fed on grasses, either freely browsed or brought for this purpose into the shelter by the shepherds. This is consistent with the data from charcoal analysis, which failed to identify any evidence of leaf-fodder either in the taxonomic spectra (Battentier et al. 2015) or in the diameter of the branches (absence of charcoal fragments characteristic of twig morphology) (Battentier 2018). Perhaps a climatic gradient might explain the need to gather tree fodder only at certain

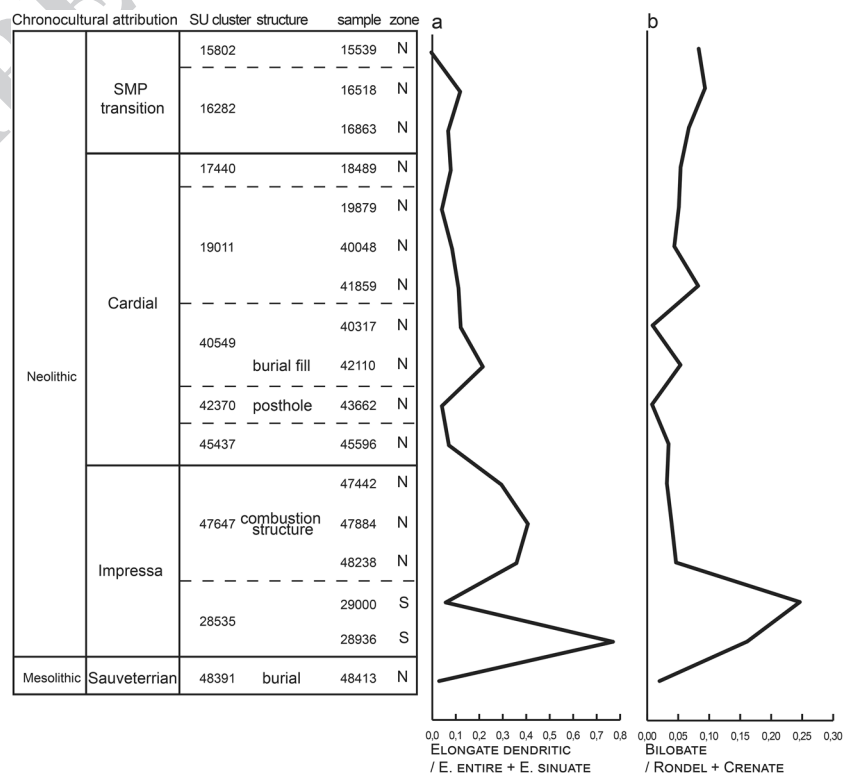
altitudes or latitudes (for example at La Grande Rivoire and not at Pendimoun) where it would have compensated for a lack of vegetation. However husbandry practices could also be involved, such as the duration of the period when the animals were stabled, the season during which the shelter was used as a sheepfold or the type of animals being kept (sheep and/or goats) and their proportions. Concerning the northern sector of Pendimoun, it is noteworthy that the only structure which is not linked with pastoral activity is also the one that provides the best evidence for the potential use of dicots: the phytolith spectra for the Sauveterrian (Mesolithic) burial contain 6.7% dicot phytoliths, including a fragment of silicified epidermis. Although we are dealing with a single sample, it is tempting to think that this result could be linked to Sauveterrian funerary practices.

Cereal processing on the site

Morphotypes from inflorescence bracts (ELONGATE DENDRITIC and PAPILLATE) are very rare among Pendimoun grass phytoliths (Fig. 4a), except in the Impressa levels where they reach 12% of the identified phytoliths. In the other levels, the only instance in which they attain frequencies higher than 3.3% is the sample from the Cardial burial (42,110), where they could originate from the Impressa levels. In fact, the funerary pit may have been filled using the surrounding sediment, including the layers deposited during the preceding Impressa period. In archaeological contexts, an

accumulation of inflorescence bract phytoliths is generally considered as a sign of an important contribution of cereals to the phytolith record. In cereals, fertile parts (ears) usually represent a greater part of the total biomass than is the case for most European wild grasses, and the increase of seed mass that characterizes domestic grasses could have led to an increase of glume silicification (Novello and Barboni 2015), both phenomena leading to higher amounts of inflorescence bract phytoliths than in wild species. Moreover, even when the archaeological record results from the accumulation of culm and leaves, cereals are most likely to have been harvested when ears were mature, which is not necessarily the case for wild grasses; this leads to the systematic occurrence of significant amounts of inflorescence bract phytoliths. The very Early Neolithic levels at Pendimoun also yielded preserved cereal grains (emmer wheat, einkorn and barley) and grindstones (Binder et al. 1993, in press). In the southern part of the site, one of the research team (P.V.) has identified two different types of ELONGATE DENDRITIC phytoliths (Fig. 5). Nevertheless, the range of intraspecific variation of ELONGATE DENDRITIC is considerable (Ball et al. 2017) and makes it hazardous to connect these forms to the cereal taxa identified through macro-remains analysis. Inflorescence bract phytoliths clearly do not occur in the same quantities as on later sites where cereal-related activities have been proved with certainty. For example, in the Bronze Age layers of El Mirador cave (Sierra de Atapuerca, Spain), inflorescence bract phytoliths reach 30% in an assemblage (*facies*

Fig. 4 Phytolith ratios. **a** Ratio of the proportions of ELONGATE DENDRITIC phytoliths (from inflorescence bracts) versus ELONGATE ENTIRE and E. SINUATE (from culms and leaves). **b** Ratio of BILOBATE short cells versus RONDEL and CRENATE short cells



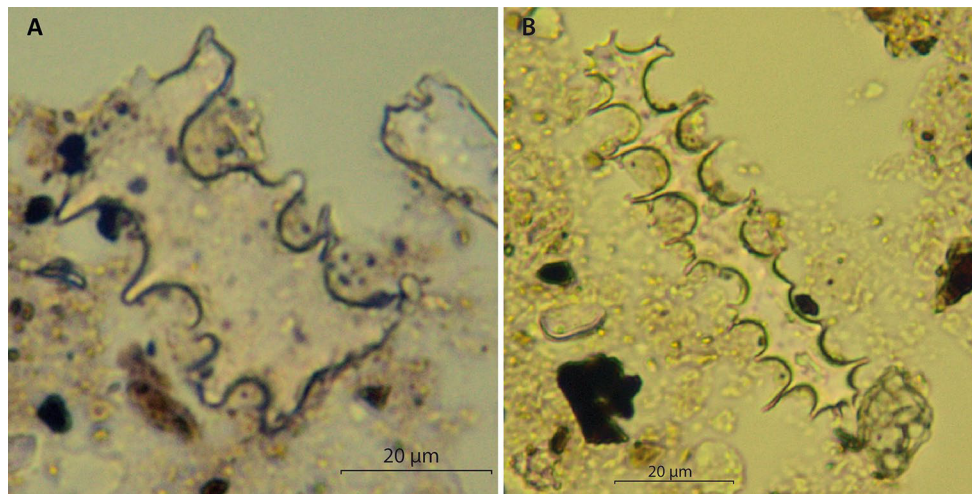


Fig. 5 Main types of ELONGATE DENDRITIC (a and b) distinguished by P.V. in Pendimoun phytolith assemblages

f) considered to be made up of crop-processing (threshing/ winnowing or milling/pounding) residues and also rich in cereal pollen (Cabanès et al. 2009). Nevertheless, our opinion is that the amount of inflorescence bract phytoliths found in the Impressa levels, which is not only high per se but is also significantly higher than what is observed in all of the other levels of the sequence, is evidence of an input of grass inflorescences in the shelter which could be linked to in situ processing of cereals during the earliest Neolithic.

With the exception of the Impressa levels, the very low presence of inflorescence bract phytoliths seems to indicate that no crop processing occurred at the site in other periods of occupation. Cereal macroremains were identified in the Cardial levels and in very low quantities in the SMP transition levels (Binder et al. in press). These cereals, presumably consumed by the shelter's inhabitants, seem to have been introduced onto the site in a dehusked form. At Els Trocs (Early and Middle Neolithic, Pyrenees, Spain, 1,564 m a.s.l., end of the sixth/beginning of the third millennia: Rojo Guerra et al. 2013), very low amounts of inflorescence bract phytoliths have been interpreted not only as suggesting an absence of cereal processing but also as a sign of a very low input of grass inflorescences, either domesticated or wild, at the site (Lancelotti et al. 2014). The authors suggest that the site was occupied before the complete formation and silicification of the inflorescence bracts, which is achieved at the end of the summer at the altitude which the site is located. Concerning the Cardial and SMP occupations of Pendimoun, the low but variable amount of inflorescence bract phytoliths could also be evidence for the grazing of young grasses, before they bear mature inflorescences, i.e. at an early stage of their life-cycle. Nevertheless, it is more difficult to connect it to a specific season of occupation because of the location of the site at a lower altitude (ca. 700 m a.s.l.)

in a Mediterranean context in which the favourable season for seed production may be longer.

Seasonality of pastoral activities as recorded by phytolith assemblages

Grass short cells are very abundant and mainly belong to the RONDEL and CRENATE types, which is not surprising given the importance of Pooideae in the area. Nevertheless, BILOBATE is regularly encountered and in certain instances is quite abundant (around 5% of the total) (Fig. 4b). As a comparison, the forms mainly attributed to Panicoideae are not reported at Pian del Ciliegio (Arobba and Caramiello 2009), are nearly absent at La Grande Rivoire (Delhon et al. 2008) and seem to show very variable amounts at Arene Candide (Nisbet 1997). In the area of Pendimoun, during the Neolithic, only three different grasses may have contributed to the production of BILOBATE: *Setaria* sp. (mainly *Setaria viridis*), *Digitaria sanguinalis* and *Echinochloa crus-galli*. Such plants were thus present near the shelter and/or used by the dwellers during the Neolithic. All of these grasses exhibit a C₄-metabolism and display a ruderal behaviour. *Echinochloa* seems to be the least likely of the three as it

	J	F	M	A	M	J	J	A	S	O	N	D
<i>Setaria</i> sp.												
<i>Digitaria sanguinalis</i>												
<i>Echinochloa crus-galli</i>												

Fig. 6 Life calendar (dark grey) of the panicoid grasses which could have grown near Pendimoun shelter during the Neolithic, from sprouting (light grey) to seed maturity (black) (data from Institut Technique de l'Agriculture Biologique 2012)

needs humid contexts, but its presence cannot be excluded. All of these plants are annual, with short so-called “summer” lifecycles (for example no more than 8 weeks for *S. viridis*) (Fig. 6). According to modern data for weeds from organic crops (Institut Technique de l’Agriculture Biologique 2012), germination occurs from the end of spring to the middle of autumn (June/September for *S. viridis*, May/October for *E. crus-galli*, June/October for *D. sanguinalis*) and seed maturity, followed by plant decay, is reached at the end of summer or during autumn (August/October for *S. viridis* and *E. crus-galli*, September/October for *D. sanguinalis*). Because they contain significant amount of BILOBATE short cells, most of the studied levels should therefore record plant collection or grazing during summer (broadly speaking: from the end of spring to the beginning of autumn). Combining this evidence with the absence or scarcity of inflorescence bracts phytolith (in most of the SMP and Cardial levels) allow us to narrow down the season of pastoral use of the shelter to the end of spring and early summer, before the complete silicification of inflorescence bracts cells. The levels where BILOBATE are lacking (43662, 40317) might record winter/early spring frequentation of the site, unless a heterogeneous use of plants through time and space led to their absence in the posthole (43,662) and when the site was used for burial (40,317). Nevertheless, a survey of the actual life-cycles of these plants in the area around the Pendimoun shelter would clarify the picture of suggested seasonality of the Neolithic frequentation of the shelter for pastoral purposes. Indeed, we cannot exclude the possibility that these short-lived grasses may be able to take advantage of temporarily favourable climatic conditions so as to colonize limited areas outside of their “normal” growing season.

Conclusions

The phytolith spectra from the Pendimoun shelter indicate an important use of grasses, mainly wild Poaceae. Because mineralized dung is a major component of the sediment, we assume that these plants microremains mainly originate from digested animal food. However, the phytolith spectra also partly originate from a mixture of plant used for various purposes. It can be easily argued that cereals, which were probably processed inside the shelter during the earliest Neolithic, were intended to feed the human inhabitants rather than their flocks.

In the most probable case, i.e. that phytoliths mainly result from the plant parts eaten by the animals, the low level of morphotypes attributed to dicots indicates that livestock management during the Early/Middle Neolithic did not require any additional food supply in the form of leaf fodder. Thus, the available vegetation in the pasturelands was probably sufficient to address the needs of the farmers. The

reasons why livestock fodder was supplemented with leafy or flowering branches in some pastoral Neolithic sites (for instance at La Grande Rivoire) and not in others (for instance at Pendimoun) requires further investigation. The recourse to additional food supply may have been necessary in certain areas due to the duration of the bad season, or because of pastoral practices resulting in the presence of livestock in some areas (mountains) before or after the period when pasturelands were accessible or productive (before the melting of snow or the greening of the vegetation, after the first snowfalls or the senescence of grasses, in cases of severe drought...); the species of animal being raised (goat, sheep, cow...) may also have an influence. Woody leafy branches are easy to dry and stock over few months, and are thus convenient for filling a seasonal shortage of fresh vegetation. Tree fodder may also have been used simply to facilitate the housing of flocks (Battentier et al. 2016) and would have allowed the spacing of the browsing periods. It is broadly acknowledged that mobility was a component of the Neolithic farming systems in the south of France, as shown by the existence of various types of sites, some of them exhibiting an organization typical of long-term settlements associated with crop production, others being more occupied for shorter periods of time and dedicated to hunting activities, and others, like Pendimoun, which provide evidence for probable seasonal pastoral occupation. These different patterns illustrate the increasing complexity of the territory exploitation system, in the form of a network of more or less specialized sites used during certain periods of the year and by different elements of the social groups (Binder 1991; Rowley-Conwy 1991; Beeching et al. 2000; Bréhard et al. 2010; Martin 2014). Nevertheless, the season(s) when the pastoral shelters (*grottes-bergeries*) were occupied, the duration of the occupation and its frequency (once a year, several times a year, repeatedly in a given period of the year) are difficult to specify, and could differ from one site to another.

In the area concerned, where the winters are mild, the observation that leaf fodder was not used gives no information on the season, but the data from Pendimoun offer other clues concerning that issue: the grasses were consumed before the development of the inflorescences, which seems to exclude a period from mid-summer to the beginning of autumn, and the presence of panicoid grasses restricts the window to a period focused on summer (broadly speaking). Finally, phytolith data make it probable that pastoral activities in Pendimoun during the Early/Middle Neolithic principally took place from the end of spring to the beginning of the summer.

Of course, this initial hypothesis concerning seasonality now has to be verified by means of other kinds of data. Other phenomena could explain part of the observed spectra, for example the use of grass fodder (harvested during spring and stocked to be used later), which is still not evidenced

for the Early Neolithic period, or intense browsing which would prevent the plants from flowering. Moreover, it must be kept in mind that, thanks to their very short lifecycle, the panicoids may have been able to sprout and grow locally outside of the usual season, thanks to temporarily favourable climatic conditions. Besides, the seasonality of pastoral activities may have changed over time. During the Impressa period, pastoralism is combined with agriculture and the shelter seems to be almost continuously occupied, while during the Cardial/SMP periods shepherds may have used the shelter at certain period of the year only, in a system where pastoralism alternated with other activities.

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