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

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Claire Delhon, Didier Binder, Pascal Verdin, Arnaud Mazuy. Phytoliths as a seasonality indicator? The example of the Neolithic site of Pendimoun, south-eastern France. *Vegetation History and Archaeobotany*, 2020, 29, pp.229-240. 10.1007/s00334-019-00739-0 . hal-02391424

**HAL Id: hal-02391424**

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Submitted on 16 Nov 2021

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Article Sub-Title		
Article CopyRight	Springer-Verlag GmbH Germany, part of Springer Nature (This will be the copyright line in the final PDF)	
Journal Name	Vegetation History and Archaeobotany	
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Schedule	Received	26 October 2017
	Revised	
	Accepted	11 July 2019

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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>
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Keywords (separated by '-')	Phytolith - Neolithic - South-eastern France - Seasonality - Panicoideae - Pastoralism
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Footnote Information	Communicated by K. Neumann.
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## 2 Phytoliths as a seasonality indicator? The example of the Neolithic site 3 of Pendimoun, south-eastern France

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5 Received: 26 October 2017 / Accepted: 11 July 2019  
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### 7 Abstract

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

### 23 Introduction

24 Pendimoun is a very important site for understanding of  
25 the Neolithic transition in the northwestern Mediterranean.  
26 Farming economies, which spread throughout the Near-  
27 East and the Aegean, reached southern Italy shortly after  
28 6000 BCE (Binder et al. 2017). The Neolithic innovations  
29 were brought to the Western Mediterranean by groups of  
30 pioneers belonging to the Impresso-cardial cultural complex  
31 who arrived by sea from Italy. These groups settled close to  
32 the littoral, while parts of the hinterlands were still occupied  
33 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;

A1 Communicated by K. Neumann.

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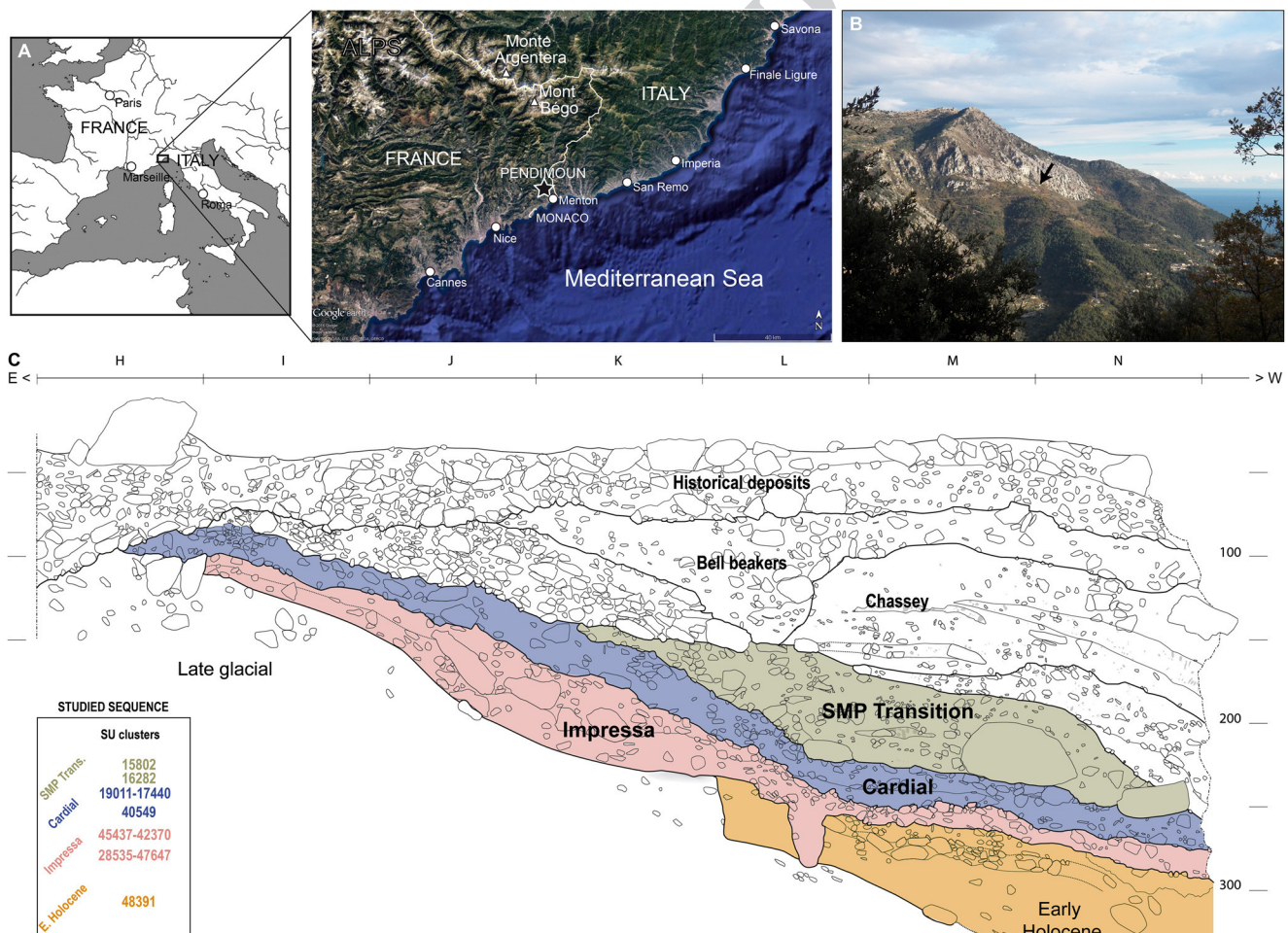
54 Lancelotti et al. 2014). In our study, phytolith analysis of  
 55 Early Neolithic levels at Pendimoun shelter has been used  
 56 as a means, among others (there are several ongoing studies  
 57 concerning the same site which rely on a wide range of ana-  
 58 lytic approaches: see Binder et al.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

## 60 Archaeological background

61 Pendimoun is a rock-shelter located in south-eastern France,  
 62 near the Italian border, just above the City of Menton  
 63 (Fig. 1). Due to the steep topography, this can be considered  
 64 to be both a coastal site (at less than 4 km from the sea as the  
 65 crow flies) as well as a low mountain site (at an elevation of  
 66 nearly 700 m). The site is currently on the ecotone between  
 67 Meso- and Supramediterranean Vegetation Belts and the  
 68 surrounding landscape is strongly characterized by pasto-  
 69 ral 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 occupa-  
 tion 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 unfortu-  
 nately hinders any strict correlation between the two stratig-  
 raphies (Binder et al. 1993).

The oldest archaeological level is attributed to the Sau-  
 veterrian 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 sec-  
 tor 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)

89 identification of sheep bones and the composition of the  
 90 sediment, partly made up of mineralized dung and rich in  
 91 spherulites and ashes, indicate that the shelter was used  
 92 for pastoral purposes since the earliest Neolithic occupa-  
 93 tion, but more intensively during the Chassey Neolithic  
 94 (Late fifth–Early fourth millennium) (Binder et al. 1993, in  
 95 press). Charcoal analysis has shown that the impact of pas-  
 96 toral practices on the vegetation remained low until the end  
 97 of the fifth millennium but increased markedly during the  
 98 3rd millennium BCE. It also shows the exploitation of diverse  
 99 patches of a mosaic vegetation, probably linked to a staged  
 100 agro–sylvo-pastoral system based on the exploitation of the  
 101 resources from various altitudes (Battentier et al. 2015).  
 102 Several domestic activities also took place at the site, in  
 103 particular an abundant and distinctive production of ceramic  
 104 wares (Basso et al. 2006; Gomart et al. 2017). Numerous  
 105 hearths and waste from everyday life suggest that the shelter  
 106 was used as a dwelling by shepherd-potter groups. A set of  
 107 burials has also been discovered in the Cardial levels (Mid-  
 108 6th millennium BCE) (Zemour et al. 2016). Agriculture is  
 109 attested since the earliest Neolithic by the presence of cereal  
 110 grains in the Impressa levels, which are amongst the oldest  
 111 in France (Binder et al. 1993; Guilaine et al. 2007), and  
 112 various tools linked with agricultural activities or with grain  
 113 processing, such as sickle blades or grindstones. Seashell  
 114 gathering is also attested during the 6th millennium BCE.

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

142 Afterwards, during the Cardial Neolithic, the shelter seems  
 143 to be used during briefer but repeated periods, although the  
 144 spectrum of activities remains globally the same (livestock  
 145 keeping, pottery production), with the noticeable exception  
 146 of the use of the shelter to bury the dead. The importance  
 147 of hunting in the economy is not clear, partly because of  
 148 difficulties in the identification of *Suidae* (wild boar vs.  
 149 domestic pig). During the transition phase to the Square  
 150 Mouthed Pottery (SMP) culture, the shelter was used for  
 151 the penning of herds, but also for various other domestic and  
 152 craft activities, which suggest long-lasting occupations. A  
 153 hiatus of several centuries isolates the first SMP settlement  
 154 from the rest of the Neolithic sequence, which exhibits an  
 155 increasing specialization of the site towards pastoral activi-  
 156 ties: during the Middle Neolithic, the occupation is typical  
 157 of the *grottes-bergeries* (sheepfold caves) known elsewhere  
 158 in the Alps and the northwestern Mediterranean area dur-  
 159 ing that period (Delhon et al. 2008; Angelucci et al. 2009;  
 160 Martin et al. 2011 and references therein); afterwards, dur-  
 161 ing the Bell Beaker period, the pastoral economy switches  
 162 to rearing cattle rather than small ruminants (Binder et al.  
 163 1993). Because Pendimoun is a reference site for the first  
 164 stage of the Neolithic in the area and because the following  
 165 levels (from mid-fifth to the end of 3rd millennia BCE) pro-  
 166 vided less artefacts and ecofacts, this paper focuses on the  
 167 earliest Neolithic sequence, i.e. the Impressa first Neolithic,  
 168 the Cardial Neolithic and the transition towards the SMP.

## 169 Materials and method

170 Phytoliths are microscopic opal silica particles produced in  
 171 and between plant cells during the life of the plant. Due to  
 172 their chemical composition, they are usually well preserved  
 173 in various contexts, even when the organic plant remains are  
 174 decomposed (Kibblewhite et al. 2015). Because of the high  
 175 phytolith content of grasses (including cereals) and the spec-  
 176 ificity of the forms produced by the Poaceae, these biore-  
 177 mains are appropriate for reconstructing agricultural prac-  
 178 tices, cereal processing and the diet of herbivores (including  
 179 domesticated species). Seventeen stratigraphic units were  
 180 sampled for phytolith analysis, in order to give clues to the  
 181 relationships between the human groups that frequented the  
 182 shelter during Prehistory and the surrounding vegetation.  
 183 In particular, we aimed to gain a better understanding of the  
 184 share of agriculture in the economy of the Early Neolithic  
 185 societies by tracking cereal remains, and of the management  
 186 of herds through the phytolith record of their diet. Focusing  
 187 on the most promising archaeological levels, phytolith analy-  
 188 sis was carried out on 1 sample from a Mesolithic burial  
 189 and 16 samples covering most of the 6th millennium BCE  
 190 (Impressa, Cardial, Early SMP). Our analysis targets chrono-  
 191 cultural 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.

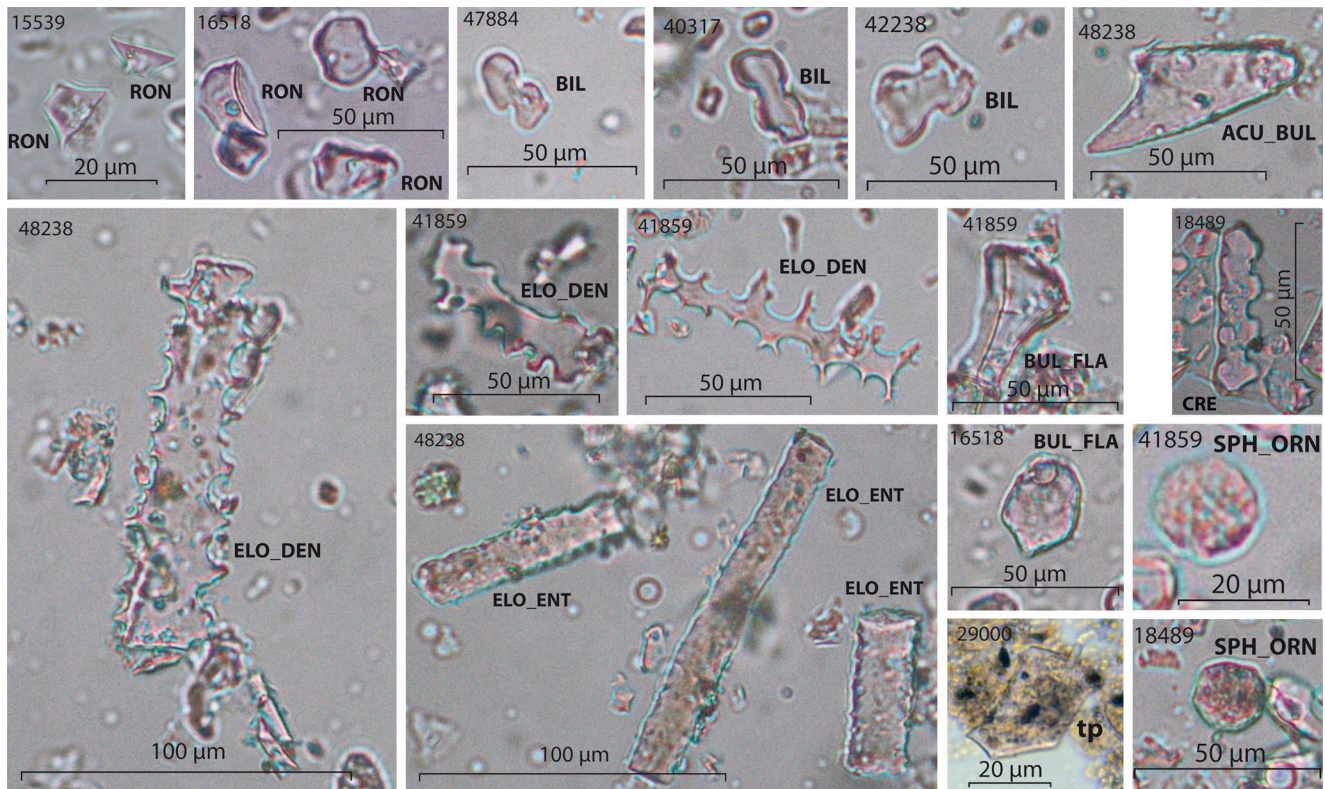


**Table 1** Results of the phytolith analysis of the Mesolithic and Early Neolithic levels of Pendimoun shelter (analyses C. Delhon)

Chronocultural attribution	Sauveterrien		Impressa (base)		Cardial (base)		Cardial (mid.)		Cardial (top)		Cardial (top2)		SMP trans. (base)		SMP trans. (mid.)	
	48,391	28,535	28,936 <sup>a</sup>	29,000 <sup>a</sup>	45,437	42,370	40,549	19,011	41,859	40,048	18,489	17,440	16,282	16,863	16,518	15,802
Sample	48,413	28,936 <sup>a</sup>	29,000 <sup>a</sup>	47,884	45,596	43,662	42,110	40,317	41,859	40,048	19,879	18,489	16,863	16,518	15,539	15,539
Zone	North	South	South	North	North	North	North	North	North	North	North	North	North	North	North	North
Square	N22C	O13C	N15C	M22B	L21A	L21B	L21D	L23A	L22A	L20A	K21D	K20D	L22C	M23C	M22	M22
Stratigraphic unit	48,391	28,890	28,889	47,803	47,647	43,661	42,108	19,909	19,000	19,908	19,011	17,440	16,581	16,283	14,999	14,999
Structure	Burial			Combustion		Posthole	Burial (sec. fill)									
Silica skeleton	69	118	42	3	1	81	96	77	115	80	51	89	86	92	70	70
ELONGATE ENTIRE																
ELONGATE SINUATE																
ELONGATE DENDRITIC	2	6	32	43	35	6	4	17	8	7	2	7	6	11		
BULLIFORM	28	2	2	28	12	13	4	22	10	15	5	7	6	17	16	16
Articulated BLOCKY								3								
ACUTE BULBOSUS	9	16	40	14	16	9	17	22	17	14	8	13	30	21	11	11
RONDEL	149	60	162	168	117	145	123	149	132	176	94	129	146	155	158	158
CRENATE	2	12	2	4	10	2	5	6	6	2	1	1	3	8	2	2
BILOBATE	4	18	26	8	5	5	1	8	1	8	5	7	10	15	13	13
SADDLE	2			1	2											
PAPILLATE				1		1			1							
SPHEROID ORNATE	18			6	3		4	5	3	3		1		2		2
Tabular polygonal	1	44	94													
Total no. classified phytoliths	284	276	400	396	287	264	256	305	245	409	167	254	290	329	270	270

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

<sup>a</sup>Analyses: 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\_FL), ACUTE BULBOSUS (ACU\_BUL), SPHEROID ORNATE (SPH\_ORN), tabular polygonal (tp). The number in the left corner refers to the phytolith sample

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

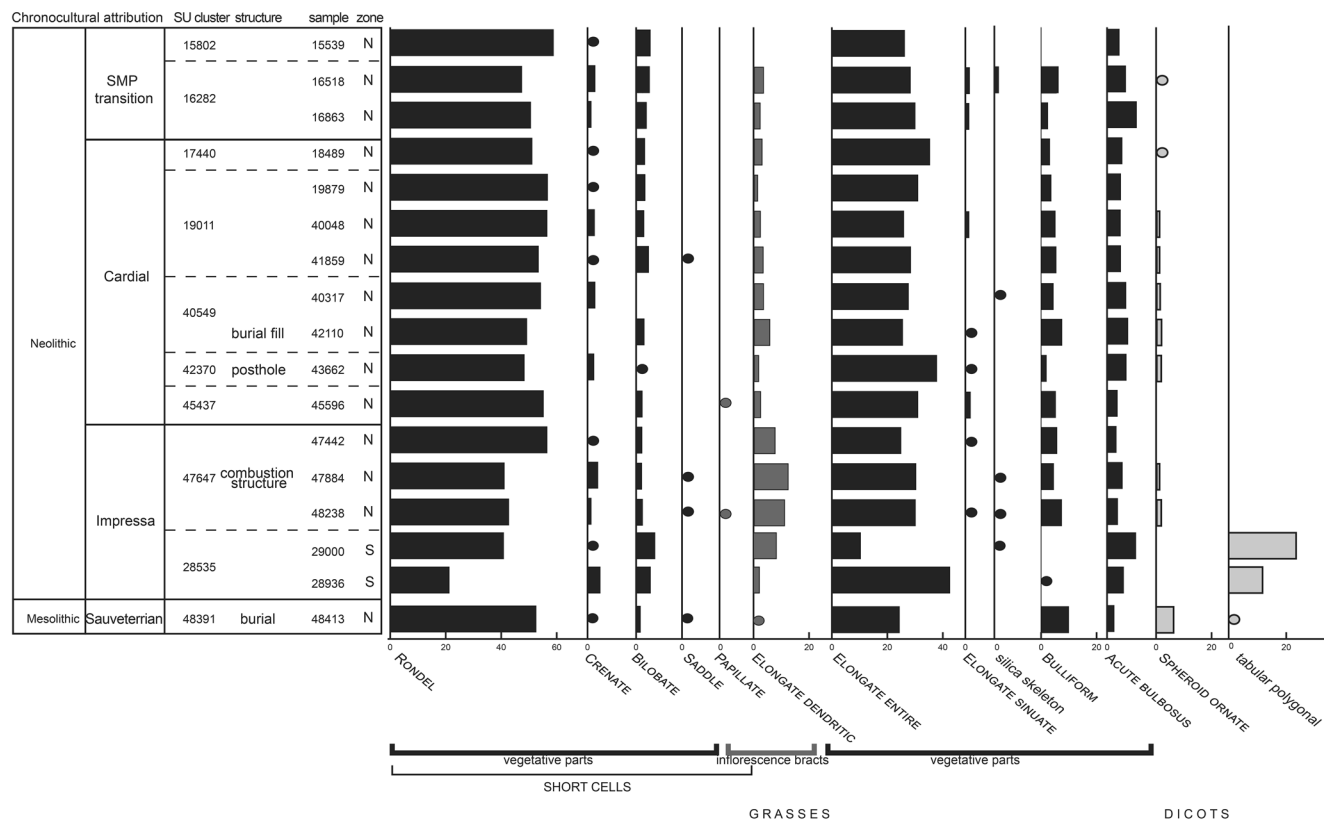
305 Most of the spectra show a strong dominance of grass  
306 phytoliths (Fig. 3). In the Neolithic samples from the  
307 northern sector, dicot morphotypes show a discontinuous  
308 curve and only account for nil to 1.6% of the total. The  
309 pattern is completely different for the samples from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

this sector in terms of dicots, which represent 6.7% of its  
319 phytolith content. 320

## 321 Discussion

### 322 Livestock diet

323 In pastoral sites like Pendimoun, phytolith accumulation  
324 is thought to be mainly due to shepherds bringing vegeta-  
325 tion into the cave as bedding or fodder for the livestock,  
326 and also, depending on the frequency and the duration of  
327 their presence in the shelter, to the transportation of plant  
328 material within the digestive systems of the animals. Nev-  
329 ertheless, it remains difficult to determine whether these  
330 microremains mainly stem from livestock alimentation or  
331 if they could also partly result from the use of plants for  
332 other purposes. Based on ethnoarchaeological observations,  
333 a significant presence of multi-cell phytoliths (also called  
334 silica-skeleton) is sometimes considered as a marker of  
335 dung accumulation (Portillo et al. 2014) or of the presence  
336 of bedding (Cabanes et al. 2009). Yet, these forms are rather  
337 rare in Pendimoun. Nevertheless, in some cases, like in La  
338 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

339 sediment mainly derives from dung, despite the fact that  
 340 the abundance of grass multi-cell phytoliths remains low  
 341 (from 0 to 6%, Delhon 2014). Taphonomical processes may  
 342 enhance the breakage of these forms into single-cell partic-  
 343 les. Moreover, depending on environmental factors and on  
 344 the age of the vegetal tissues, multicelled phytoliths may  
 345 not be present in the browsed grasses. Thus, the absence or  
 346 scarcity of silica skeletons at Pendimoun is not sufficient to  
 347 rule out the possibility that the phytolith assemblages derive  
 348 from dung accumulation. Focusing on the northern zone, it  
 349 thus seems that the livestock mainly fed on grasses, either  
 350 brought into the shelter by the shepherds or grazed from the  
 351 surrounding vegetation. Even though phytolith production is  
 352 far more important in grass than in dicots (Delhon 2010), the  
 353 presence of dicot phytoliths suggests that such plants were  
 354 introduced into the shelter, albeit in smaller quantities com-  
 355 pared to grasses. In dicots from temperate areas, phytolith  
 356 production seems to be mainly concentrated in leaves (epi-  
 357 dermal cells) and wood (globular morphotypes), although it  
 358 remains very low in the latter (Scurfield et al. 1974; Kondo  
 359 et al. 1994; Alexandre et al. 1997; Albert and Weiner 2001;  
 360 Delhon 2010). Wood was used on the site, at least for fuel,  
 361 as documented by the presence of scattered charcoal in all  
 362 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 bear-  
 ing leaves and/or flowers has been demonstrated on various  
 other Neolithic shelters in southern France (*grottes-berger-  
 ies*) (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 pur-  
 pose 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 mor-  
 phology) (Battentier 2018). Perhaps a climatic gradient  
 might explain the need to gather tree fodder only at certain

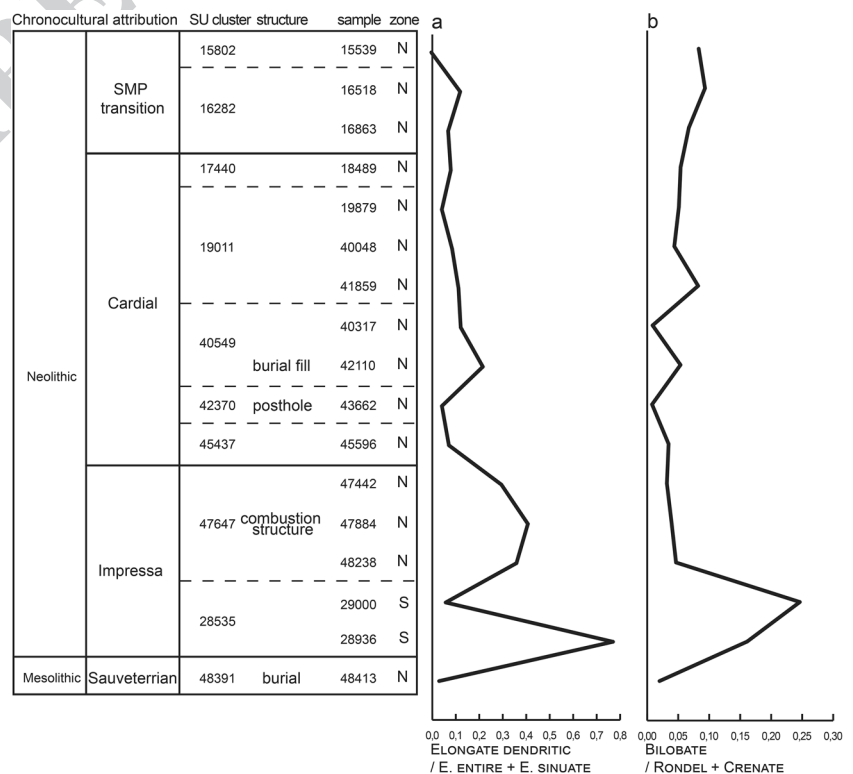
altitudes or latitudes (for example at La Grande Rivoire and not at Pendimoun) where it would have compensated for a lack of vegetation. However husbandry practices could also be involved, such as the duration of the period when the animals were stabled, the season during which the shelter was used as 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.

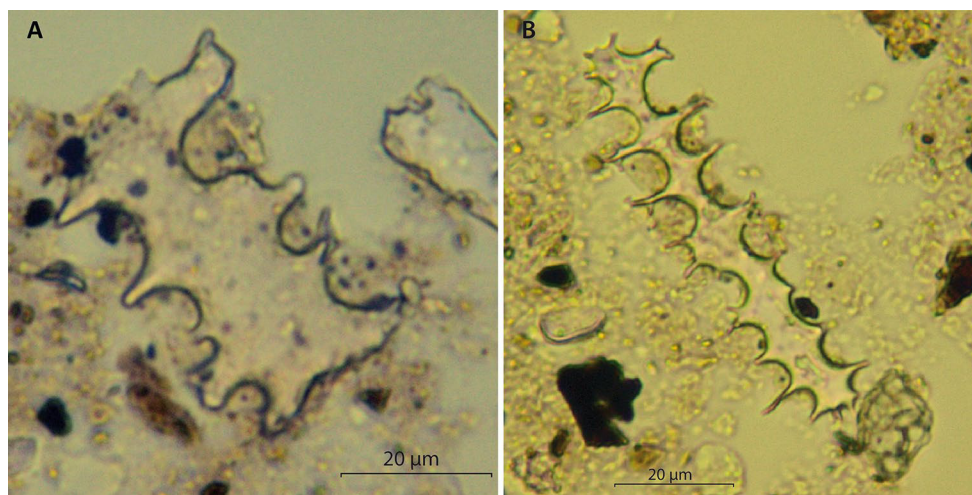
#### Cereal processing on the site

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

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

450 With the exception of the Impressa levels, the very low  
451 presence of inflorescence bract phytoliths seems to indicate  
452 that no crop processing occurred at the site in other periods  
453 of occupation. Cereal macroremains were identified in the  
454 Cardial levels and in very low quantities in the SMP transi-  
455 tion levels (Binder et al. in press). These cereals, presum-  
456 ably consumed by the shelter's inhabitants, seem to have  
457 been introduced onto the site in a dehusked form. At Els  
458 Trocs (Early and Middle Neolithic, Pyrenees, Spain, 1,564 m  
459 a.s.l., end of the sixth/beginning of the third millennia: Rojo  
460 Guerra et al. 2013), very low amounts of inflorescence bract  
461 phytoliths have been interpreted not only as suggesting an  
462 absence of cereal processing but also as a sign of a very low  
463 input of grass inflorescences, either domesticated or wild,  
464 at the site (Lancelotti et al. 2014). The authors suggest that  
465 the site was occupied before the complete formation and  
466 silicification of the inflorescence bracts, which is achieved  
467 at the end of the summer at the altitude which the site is  
468 located. Concerning the Cardial and SMP occupations of  
469 Pendimoun, the low but variable amount of inflorescence  
470 bract phytoliths could also be evidence for the grazing of  
471 young grasses, before they bear mature inflorescences, i.e. at  
472 an early stage of their life-cycle. Nevertheless, it is more dif-  
473 ficult to connect it to a specific season of occupation because  
474 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 C<sub>4</sub>-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

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

611 **Acknowledgements** This paper is based on a lecture presented at the  
612 10th International Meeting of Phytolith Research, held in Aix-en-  
613 Provence in September 2016. We wish to thank the organizers of the  
614 meeting, Doris Barboni, Jean-Dominique Meunier, Anne Alexandre  
615 and Marine Pasturel, as well as the Scientific Committee for giving us  
616 the opportunity to present our work. The authors are grateful to two  
617 anonymous reviewers for their constructive comments on the man-  
618 uscript and to Katharina Neumann for drawing our attention on the  
619 newly completed ICPN 2.0 and for providing significant improvements  
620 concerning phytolith nomenclature.

## 621 References

622 Albert RM, Weiner S (2001) Study of phytoliths in prehistoric ash lay-  
623 ers using a quantitative approach. In: Meunier JD, Colin F (eds)  
624 Phytoliths: applications in earth sciences and human history.  
625 Balkema Publishers, Lisse, pp 251–266  
626 Alexandre A, Meunier JD, Lézine AM, Vincens A, Schwartz D (1997)  
627 Phytoliths: indicators of grassland dynamics during the Late Hol-  
628 ocene in intertropical Africa. *Palaeogeogr Palaeoclimatol Palaeo-*  
629 *ecol* 136:213–229  
630 Angelucci DE, Boschian G, Fontanals M, Pedrotti A, Vergès JM  
631 (2009) Shepherds and karst: the use of caves and rockshelters in  
632 the Mediterranean region during the Neolithic. *World Archaeol*  
633 41:191–214  
634 Arobba D, Caramiello R (2009) Indagini archeobotaniche sul deposi-  
635 to neolitico del Ripario di Pian del Ciliegio. *Quad Mus Archeol*  
636 *Finale* 5:117–130  
637 Ball T, Vrydaghs L, Mercer T, Pearce M, Snyder S, Lisztes-Szabó Z,  
638 Pető Á (2017) A morphometric study of variance in articulated  
639 dendritic phytolith wave lobes within selected species of Triticeae  
640 and Aveneae. *Veget Hist Archaeobot* 26:85–97  
641 Basso E, Binder D, Messiga B, Riccardi MP (2006) The Neolithic pot-  
642 tery of Abri Pendimoun (Castellar, France): a petro-archaeometric  
643 study. In: Maggetti M, Messiga B (eds) *Geomaterials in cultural*  
644 *heritage. Geological Society Special Publications* 257. The Geo-  
645 *logical Society, London*, pp 33–48  
646 Battentier J (2018) *Gestion des espaces forestiers provençaux et figures*  
647 *au Néolithique: approche anthracologique. PhD Thesis, Université*  
648 *Côte d'Azur*  
649 Battentier J, Thiébaud S, Binder D, Théry-Parisot I, Carré A, Delhon  
650 C (2015) L'abri Pendimoun (Castellar, Alpes-Maritimes): nou-  
651 velles données sur l'évolution du couvert forestier et l'exploitation  
652 du milieu au Néolithique (5800–2000 ans cal. BCE). *Quaternaire*  
653 26:277–290  
654 Battentier J, Lepère C, Théry-Parisot I, Carré A, Delhon C (2016) La  
655 grotte de Pertus II (Méailles, Alpes-de-haute-Provence): exploi-  
656 tation du couvert forestier au chasséen récent (3850–3650 cal.

657 BC). In: Cauliez J, Sénépart I, Jallot L, de Labriffe P-A, Gilabert  
658 C, Gutherz X (eds) «De la tombe au territoire» & Actualité de  
659 la Recherche. Actes des 11e Rencontres Méridionales de Préhis-  
660 toire Récente, Montpellier (Hérault) 2014. *Archives d'Écologie*  
661 *Préhistorique, Toulouse*, pp 223–232  
662 Beeching A, Berger J-F, Brochier JL, Ferber F, Helmer D, Sidi  
663 Maamar H (2000) Chasséens: agriculteurs ou éleveurs, séden-  
664 taires ou nomades? Quels types de milieux, d'économies et de  
665 sociétés? In: Leduc M, Valdeyron N, Vaquer J (eds) *Sociétés*  
666 *et Espaces, Rencontres méridionales de Préhistoire récente.*  
667 *Archives d'Écologie Préhistorique, Toulouse*, pp 59–79  
668 Binder D (1991) Une économie de chasse au néolithique ancien: La  
669 grotte Lombard à Saint-Vallier-de-Thiery (Alpes-Maritimes). *Mon-*  
670 *ographies du Centre de Recherches Archéologiques* 5. CNRS, Paris  
671 Binder D, Brochier J-E, Duday H, Helmer D, Marinval P, Thiébaud  
672 S, Watzet J (1993) L'abri Pendimoun (Castellar, Alpes-  
673 Maritimes): nouvelles données sur le complexe culturel de  
674 la céramique imprimée méditerranéenne dans son contexte  
675 stratigraphique. *Gall Préhst* 35:177–251  
676 Binder D, Lanos P, Angeli L et al (2017) Modelling the earliest north-  
677 western dispersal of the Mediterranean Impressed Wares: new  
678 dates and Bayesian chronological model. *Doc Praehist* 44:54–77  
679 Binder D, Battentier J, Bouby L et al (in press) First farming in the  
680 North-Western Mediterranean: evidences from Castellar–Pendi-  
681 moun during the 6th millennium BCE. In: Gron KJ, Sørensen L,  
682 Rowley-Conwy P (eds) *Farmers at the frontier: a Pan-European*  
683 *perspective on Neolithisation. Oxbow Books, Oxford*  
684 Bréhard S, Beeching A, Vigne J-D (2010) Shepherds, cowherds and  
685 site function on Middle Neolithic sites of the Rhône Valley: an  
686 archaeozoological approach to the organization of territories  
687 and societies. *J Anthropol Archaeol* 29:179–188  
688 Brown DA (1984) Prospects and limits of a phytolith key for grasses  
689 in the Central United States. *J Archaeol Sci* 11:345–368  
690 Cabanes D, Burjachs F, Expósito I, Rodríguez A, Allué E, Euba I,  
691 Vergès JM (2009) Formation processes through archaeobotani-  
692 cal remains: the case of the Bronze Age levels in El Mirador  
693 Cave, Sierra de Atapuerca, Spain. *Quat Int* 193:160–173  
694 Delhon C (2010) Phytolithes et taphonomie, apport de  
695 l'expérimentation à la quantification des phytolithes dans les  
696 cendres de bois. In: Théry-Parisot I, Chabal L, Costamagno S  
697 (eds) *Taphonomie des résidus organiques brûlés et des struc-*  
698 *tures de combustion en milieu archéologique. P@lethnologie* 2.  
699 *Université Jean-Jaurès, Toulouse*, pp 97–107  
700 Delhon C (2014) Analyse phytolithique des niveaux de bergerie du  
701 Néolithique (coupes stratigraphiques S30 et S32). In: Nicod  
702 P-Y, Picavet R (eds) *Fouille archéologique de la Grande Riv-*  
703 *oire à Sassenage (Isère), rapport de fouille 2012–2014. Lampea,*  
704 *Aix-en Provence*, pp 387–389  
705 Delhon C, Martin L, Argant J, Thiébaud S (2008) Shepherds and  
706 plants in the Alps: multi-proxy archaeobotanical analysis of  
707 Neolithic dung from “La Grande Rivoire” (Isère, France). *J*  
708 *Archaeol Sci* 35:2,937–2,952  
709 Fredlund GG, Tieszen LL (1997) Calibrating grass phytolith assem-  
710 blages in climatic terms: application to Late Pleistocene assem-  
711 blages from Kansas and Nebraska. *Palaeogeogr Palaeoclimatol*  
712 *Palaeoecol* 136:199–211  
713 Gomart L, Weiner A, Gabriele M et al (2017) Spiralled patchwork in  
714 pottery manufacture and the introduction of farming to Southern  
715 Europe. *Antiquity* 91:1,501–1,514  
716 Guilaine J, Manen C, Vigne JD (2007) Pont de Roque-Haute (Porti-  
717 ragnes, Hérault). Nouveaux regards sur la néolithisation de la  
718 France méditerranéenne. *Archives d'Écologie Préhistorique,*  
719 *Toulouse*  
720 Harvey EL, Fuller DQ (2005) Investigating crop processing using phy-  
721 tolyth analysis: the example of rice and millets. *J Archaeol Sci*  
722 32:739–752

- 724 ICPT: Neumann K, Albert RM, Ball T, Scott Cummings L, Strömberg  
725 C, Vrydaghs L (in press) International Code for Phytolith Nomen-  
726 clature (ICPN) 2.0. Ann Bot  
727 Institut Technique de l'Agriculture Biologique (2012) Connaitre les  
728 adventices pour les maîtriser en grandes cultures sans herbicides  
729 - Annuelles germination d'été. [http://www.itab.asso.fr/downloads/  
730 desherb-meca/dm-brochure-adventices\\_6\\_ete.pdf](http://www.itab.asso.fr/downloads/desherb-meca/dm-brochure-adventices_6_ete.pdf). Accessed 1  
731 Dec 2015
- 731 Kibblewhite M, Tóth G, Hermann T (2015) Predicting the preservation  
732 of cultural artefacts and buried material in soil. Sci Total Environ  
733 529:249–263
- 734 Kondo R, Childs CW, Atkinson I (1994) Opal phytoliths of New Zea-  
735 land. Manaaki Whenua Press, Lincoln
- 736 Lancelotti C, Balbo AL, Madella M et al (2014) The missing crop:  
737 investigating the use of grasses at Els Trocs, a Neolithic cave site  
738 in the Pyrenees (1564 m asl). J Archaeol Sci 42:456–466
- 739 Martin L (2014) Premiers paysans des Alpes. Alimentation végétale et  
740 agriculture au Néolithique. Tables des Hommes. Presses Univer-  
741 sitaires de Rennes, Rennes
- 742 Martin L, Delhon C, Argant J, Thiébault S (2011) Un aperçu de  
743 l'élevage au Néolithique par l'archéobotanique. L'exemple d'une  
744 bergerie dans le Nord du Vercors. In: Lefèvre C, Denis B (eds)  
745 Le mouton, de la domestication à l'élevage. Ethnozootechnie 91.  
746 Société d'Ethnozootechnie, Toul, pp 37–45
- 747 Nisbet R (1997) The phytoliths from the Neolithic levels of Arene  
748 Candide. In: Maggi R (ed) Arene Candide: a functional and envi-  
749 ronmental assessment of the Holocene Sequence (Excavations  
750 Bernabo' Brea-Cardini 1940-50). Memorie dell'Istituto Italiano  
751 di Paleontologia Umana 5. Ministero per i Beni Culturali e Ambi-  
752 entali, Roma, pp 113–118
- 753 Novello A, Barboni D (2015) Grass inflorescence phytoliths of useful  
754 species and wild cereals from Sub-Saharan Africa. J Archaeol  
755 Sci 59:10–22
- 756 Ollendorf AL, Mulholland SC, Rapp G Jr (1988) Phytolith analysis  
757 as a means of plant identification: *Arundo donax* and *Phragmites*  
758 *communis*. Ann Bot 61:209–214
- 759 Parry DW, Smithson F (1966) Opaline silica in the inflorescences of  
760 some British grasses and cereals. Ann Bot 30:25–538
- 761 Portillo M, Kadowaki S, Nishiaki Y, Albert RM (2014) Early Neolithic  
762 household behavior at Tell Seker al-Aheimar (Upper Khabur,  
Syria): a comparison to ethnoarchaeological study of phytoliths  
and dung spherulites. J Archaeol Sci 42:107–118
- 763 Rojo Guerra M, Peña Chocarro L, Royo Guillén JI et al (2013) Pastores  
764 trashumantes del Neolítico antiguo en un entorno de alta montaña:  
765 secuencia crono-cultural de la Cova de Els Trocs (San Feliú de  
766 Veri Huesca). BSAA Arqueol 79:9–55
- 767 Rosen A (1992) Preliminary identification of silica skeletons from near  
768 eastern archaeological sites: an anatomical approach. In: Rapp G  
769 Jr, Mulholland SC (eds) Phytolith systematics: emerging issues.  
770 Plenum Press, New York, pp 129–147
- 771 Rovner I (1971) Potential of opal phytoliths for use in paleoecological  
772 reconstruction. Quat Res 1:343–359
- 773 Rowley-Conwy P (1991) Arene Candide: a small part of a larger pas-  
774 toral system? Riv studi liguri 56:89–112
- 775 Rowley-Conwy P, Gourichon L, Helmer D, Vigne J-D (2013) Early  
776 domestic animals in Italy, Istria, the Tyrrhenian Islands and south-  
777 ern France. In: Colledge S, Conolly J, Dobney K, Manning K,  
778 Shennan S (eds) The origins and spread of domestic animals in  
779 southwest Asia and Europe. Left Coast Press, Walnut Creek, pp  
780 161–194
- 781 Scurfield G, Anderson CA, Segnit ER (1974) Silica in woody stems.  
782 Aust J Bot 22:211–229
- 783 Thiébault S (2005) L'apport du fourrage d'arbre dans l'élevage depuis  
784 le Néolithique. Anthropozoologica 40:95–108
- 785 Twiss PC (1992) Predicted world distribution of C<sub>3</sub> and C<sub>4</sub> grass phy-  
786 tooliths. In: Rapp G Jr, Mulholland SC (eds) Phytolith systematics:  
787 emerging issues. Plenum Press, New York, pp 113–128
- 788 Twiss PC, Suess E, Smith RM (1969) Morphological classification of  
789 grass phytoliths. Soil Sci Soc Am J 33:109–115
- 790 Zemour A, Binder D, Coppa A, Duda H (2016) La sépulture au  
791 début du Néolithique (VI<sup>e</sup> millénaire et première moitié du V<sup>e</sup>  
792 millénaire cal BC) en France méridionale et en Italie: de l'idée  
793 d'une « simple » fosse à une typologie architecturale. Bull Mém  
794 Soc d'Anthropol Paris 29:94–111
- 795  
796
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