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# Use of space in a Neolithic village in Greece (Makri): phytolith analysis and comparison of phytolith assemblages from an ethnographic setting in the same area

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ABSTRACT

Phytolith analyses were conducted in a Pottery Neolithic village (Makri) of Northern Greece in order to reconstruct aspects of past human activities as a function of both space and time. The analyses of phytolith assemblages were based on a reference collection of modern plant phytoliths (Tsartsidou et al., 2007), as well as an ethnographic study in an agropastoral community (Sarakini) in the same area that showed that many phytolith assemblages are characteristic of the activities carried out in different locations within and around the village (Tsartsidou et al., 2008). The same approach was used for studying the phytolith assemblages in the Neolithic village of Makri, namely measuring phytolith concentrations, diversities of phytolith assemblages relative to control samples collected from samples outside the village and detailed analysis of various phytolith morphotypes. At Makri samples from floors and various constructions (i.e. pit, platforms) were analysed, as well as sediments from an open area inside the village. The results show that Neolithic Makri was a society with a mixed agricultural and pastoral economy. Wheat and barley were cultivated for food and fodder and free-range animals were raised in a village inhabited year round. Indoor areas were not clearly differentiated from outdoor areas inside the village. The phytolith assemblages in only one series of floors produced at a specific location over an extended period of time reflected the use of that space for cereal storage or food processing. The phytolith assemblages from all the other floors examined did not reflect the local activities, but rather the constructional materials used for producing the floors.



## 1. Introduction

Phytolith studies in archaeological sites are widely used to identify activity areas and reconstruct past human activities (Rosen, 2005). Examples of such studies include prehistoric sites in Anatolia (Çatalhöyük and Kilise Tepe) and the Near East (Tor Faraj), where phytolith analyses have been used to identify spatial organizations, as well as the use of unknown structures (Madella, 2001; Rosen, 2001, 2005; Shahack-Gross et al., 2003, 2004). Phytoliths have also been used for identifying stabling areas in an urban site (Tel Dor) from the Iron Age in Israel (Shahack-Gross et al., 2005). Studies of buildings, such as a mill from colonial times in Australia (Lentfer et al., 1997) and a 17th century house in Virginia of the USA (Sullivan and Kealhofer, 2004), have elucidated the use of space through the analysis of phytoliths in different activity areas. Here we analysed phytoliths assemblages from sediments from the Neolithic site of Makri (6th millennium B.C.) located on the coast in northern Greece (Fig. 1) in order to reconstruct different human activities within the ancient village.

We first prepared an extensive quantitative phytolith reference collection that documents the concentrations and morphologies of 62 plant species from the area around Makri and the nearby Rhodope Mountains (Tsartsidou et al., 2007). We then calibrated the phytoliths assemblages to known spatial activities using the reference collection in a “traditional” inhabited village called Sarakini, located at 600 m elevation in the Rhodope Mountains (Tsartsidou et al., 2008). Despite the elevation there is no major difference in vegetation between the environments around Makri

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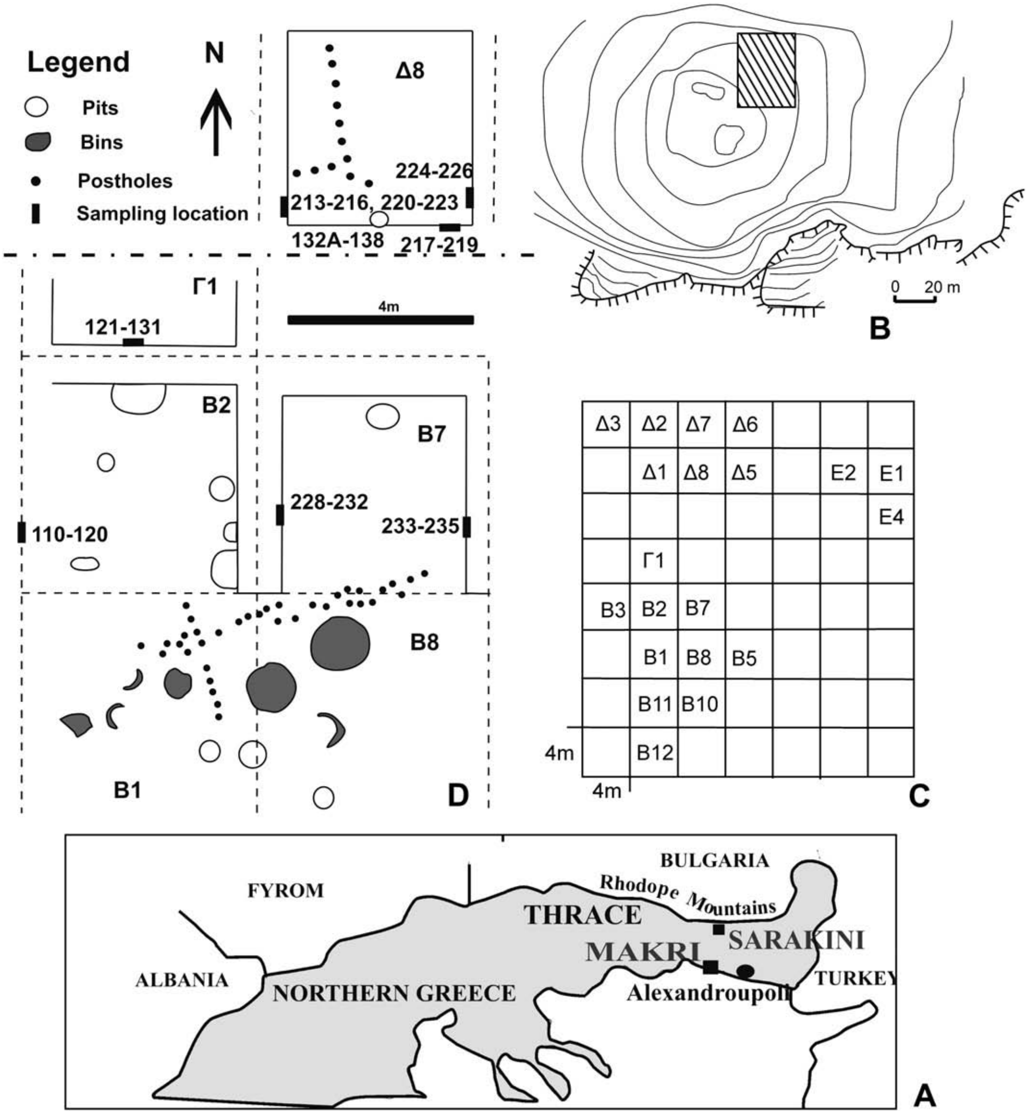


**Fig. 1.** Shows the locations of Makri and Sarakini in Northern Greece (A), as well as the plan view of Makri (B) with the excavated area around the central "complex" area (rectangle). The excavated trenches are shown in the rectangle (C) and the locations of samples analysed are shown on the grid (D).

and Sarakini, because the vegetation of Makri during the Neolithic was similar to that of the deciduous forest around Sarakini today (Ntinou, 2002; Ntinou and Badal, 2000). Tsartsidou et al. (2008) analysed 116 sediment samples from the village of Sarakini and its environment. Each sample contained between approximately 10 and up to 50 or so different phytolith types. The initial analysis of this enormous body of data was facilitated by normalizing the phytoliths diversity of each sample to the average diversity of 4 samples taken from different environments around the village of Sarakini that were relatively uninfluenced by human activities. This so-called Phytolith Difference Index (PDI) ranged from 1 to over 550 and the higher the index the larger was the difference between the sample phytoliths assemblage and the regional sediments. A plot of the PDI values against the concentrations of phytoliths in the samples clearly differentiated various activity areas in and around the village (Tsartsidou et al., 2008). It also provided a framework for defining more focused questions to be addressed by detailed analysis of the different phytolith types in each sample. The PDI is a novel approach developed in the ethnographic environment of Sarakini and has proven to be a useful tool in identifying activity areas in an agropastoral community. In this study of the Neolithic site of Makri it is applied for the first time in an archaeological context. We also use the reference collection, the phytoliths concentrations in the samples and their PDI values to gain an overall perspective of the phytoliths diversity, and then address specific questions using the different phytoliths morphologies. We also take advantage of the ethnoarchaeological observations made in Sarakini (Efstratiou, 1982, 1984, 1985, 2000) to better understand the site of Makri.

Makri is a coastal village site from the 6th millennium B.C. located 500 m south of the modern village with the same name and ten kilometers west of the modern town of Alexandroupolis in Thrace (Fig. 1). It is a tell built on top of an abrupt travertine cliff-edge, 50 m high, overlooking the Thracian sea. In the north, the Rhodope mountain range forms a natural border between Greece and Bulgaria. From sea level to 500 m the bioclimatic conditions in the region are of mesomediterranean type, dry, with mean annual precipitations around 500 mm (Polunin, 1980). The natural vegetation has been largely affected by human intervention. The plain in front of the Rhodope Mountains is currently cultivated with cereals, cotton, tobacco and occasionally olive trees in the warmest niches with limestone bedrock. Almond trees and other fruit trees are also grown. Close to the coastal elevations the vegetation forms a maquis dominated by evergreen holm oaks (*Quercus ilex*), strawberry trees (*Arbutus unedo*) and basswood (*Phillyrea latifolia*). Deciduous vegetation is well represented by terebinths (*Pistacia terebinthus*), manna trees (*Fraxinus ornus*) and pears (*Pyrus amygdaliformis*). From 500 m upwards the bioclimatic sequence follows the supra-mediterranean vegetation of sub-humid to humid type, characterized by deciduous oak woodlands with hornbeams (*Carpinus* sp.) and ashes (*Fraxinus* sp.). (Ntinou, 2002). The vegetation in Neolithic times was different in that a deciduous forest was present in the place of the evergreen vegetation that flourishes today around the site. This forest contained deciduous oaks (*Quercus* sp.), manna trees (*Fraxinus* sp.), terebinths (*P. terebinthus*), wild service trees (*Sorbus* sp.) and elms (Ntinou, 2002; Ntinou and Badal, 2000).

The tell of Makri is a mound 4 m high and extends over at least 0.2 ha (Efstratiou et al., 1998). The excavation of Makri revealed an impressive Neolithic settlement with deep undisturbed deposits, well-preserved architectural features and rich remains. The architectural tradition at the settlement of Makri is impressive and combined with the variety and the state of preservation of its finds it is considered unique for the Neolithic of northern Greece (Efstratiou et al., 1998). It presents a fine example of a post-framed, wattle-and-daub and mudbrick architecture. The ancient buildings often show rows of post-holes and fine plaster floors with several clay reconstructions. Wood impressions on pieces of clay remains or carbonized wooden posts from fallen roofs have also been found. Finally, layers consisting of mud bricks in situ or disaggregated, have also been detected. The use of stones seems to have been rare.

There are three main sectors in the site (Fig. 1): the residential areas (Δ8), the central complex area (B2–B7) and the open area of Makri (Γ1) (Efstratiou et al., 1998). The three different areas can be roughly differentiated by the following observations.

The sedimentological study of the open area suggests the presence of natural sedimentation (rain wash and slow settling deposition) and anthropogenic fillings, but an absence of floor make-up (Efstratiou et al., 1998). It seems that the area was an open-air location inside the village and was at times used as a dump.

The complex area is located in the center of the settlement at the top of the mound (Excavation squares B1–B8 see Fig. 1). It contains the most impressive architectural feature at Makri: a large post-framed structure that revealed interesting features such as many large half-sunk unfired vessels that were used for storage. The unique characteristics of the complex area are its large size, the complicated arrangement of structures and objects, and the abundance of a variety of finds (including some unique objects). This indicated that the area could have been used as a common storage area (Efstratiou et al., 1998). The plant macro-remains of the complex area are consistent with this proposal (Valamoti, 2004).

The residential area (excavation square Δ8 see Fig. 1) consists of many post-framed houses that preserve a number of oval or round clay constructions and features like fireplaces, ovens, platforms, as well as storage and rubbish pits (Efstratiou et al., 1998). A large number of finds such as vessels, grinding stones and stone tools have been recovered from these houses. Generally the residential units present a much more ordered layout and arrangement of constructional details (space, post-holes, scale) and a limited range of finds both in terms of quality and quantity. Such units are more indicative of spatially well-defined household activities such as cooking facilities (fireplaces), sleeping (platforms), disposal of rubbish or storage. The arrangement of these features in the interior of the house gives the impression of an ordinary/common living area. The difference between the complex area and the residential area is reflected on the strong communal storage character of the former as opposed to the latter, which retains a more private function. Both the complex area and the residential area preserve well-defined series of floors. Visual inspection, as well as a micromorphological study (Karkanas, 2007; Karkanas and Efstratiou, in press) conclude that the Makri floors are of two types: the more elaborate, well-prepared lime floors and the poorly prepared floors. The former are 2–3 cm thick and they are white horizontally laid features easily identifiable in the field. Micromorphological analysis showed that they were mainly produced by mixing quicklime fragments (burnt soft porous limestone, i.e. tufa) and unburnt tufa (Karkanas, 2007; Karkanas and Efstratiou, in press). Occasionally additions of clastic sediment (e.g. stream flood silts) and fine domestic refuse (i.e. ash, dung and food remains) were also used. The poorly prepared floors are located between the well-prepared lime floors. Micromorphological analysis shows that they are composed of both loose and compacted material (unburnt tufa, clastic sediment and domestic refuse) (Karkanas and Efstratiou, in press). They are not easily identified in the field and one might tend to interpret them as fillings between the well-prepared floors. But the crude parallel planar bedding identified microscopically (Karkanas and Efstratiou, in press) is a decisive criterion for defining them as in situ floors (see Macphail et al., 2006). Micromorphological analysis provides evidence that these sequences are mostly poorly prepared floors (Karkanas and Efstratiou, in press).

The archaeological record related to these floors has been the subject of several studies that aimed at the identification of activity areas within the site. The first study involved the analysis of the material remains and their distribution patterns (Efstratiou and Kallintzi, 1994). The homogeneous pottery tradition in terms of shapes, decoration and technology, as well as the obscure architectural features, haven't facilitated a clear-cut differentiation of stratigraphical entities (Efstratiou et al., 1998). Various studies (Efstratiou et al., 1998) such as bone tool analysis, lithic tool analysis, studies of animal and plant remains, sedimentological analysis and micromorphology (Karkanas and Efstratiou, in press) have also been used to provide answers to the critical questions of differential use of space at Makri.

## 2. Materials and methods

The samples studied were collected during the 2003–2005 excavation seasons and originate from trenches B2, B7 (complex area), Δ8 (residential area) and Γ1 (open area). Sampling followed detailed microstratigraphic description of the preserved profiles (Karkanas and Efstratiou, in press). The samples collected from the complex area and the houses are from well-prepared lime floors, as well as from the poorly prepared floors. The samples were collected in most cases from the upper 1 cm of the floor. In cases where the floor was thick (e.g. floor 3), we collected more than one sample (see Table 1). Different locations of each vertical floor series were sampled, when possible, in order to investigate the spatial differentiation (horizontally) of the floors. The same stratigraphic unit was also sampled vertically in order to understand the use of space through time. Specific constructions were also sampled: the surfaces of clay platforms and the different layers that accumulated inside a lined pit. Two samples from each layer were also collected from the open area trench profile (square Γ1). Finally, samples were also collected from different locations outside and at some distance from the excavation (regional samples): one from an orchard outside the excavation area and another one from a travertine layer found in a natural trench next to the main road, 1 km away from the site. In total 53 samples were collected (Table 1).

Mineralogical identifications were performed on these bulk samples using Fourier Transform Infrared (FTIR) spectroscopy (MIDAC Corp., Costa Mesa, CA, USA) following methods described in Weiner et al. (1993).

**Table 1**
List with the PDI values and the phytolith concentrations for each of the Makri samples analyzed.

| Samples | Description | PDI | Phytoliths/gram sediment (millions) |
|---|---|---|---|
| MAK 110 | B2: Well-prepared lime floor | 147 | 1.67 |
| MAK 111 | B2: Gray lime floor (with dirt?) | 109 | 0.96 |
| MAK 112 | B2: Well-prepared lime floor | 68 | 0.86 |
| MAK 113 | B2: Reddish brown layer, clay construction | 160 | 0.93 |
| MAK 114 | B2 Sediment on floor | 136 | 3.05 |
| MAK 115 | B2 Gray occupational debris | 143 | 2.40 |
| MAK 116 | B2 Gray sediment on floor | 119 | 1.39 |
| MAK 117 | B2 Sediment on floor | 215 | 0.97 |
| MAK 118 | B2 Well-prepared lime floor | 146 | 0.63 |
| MAK 119 | B2: Dark gray sediment on floor | 246 | 0.70 |
| MAK 120 | B2: Well-prepared lime floor | 165 | 0.90 |
| MAK 121 | Γ1: Fine grained laminated sediment | 136 | 0.18 |
| MAK 122 | Γ1: Fine grained laminated sediment | 95 | 3.30 |
| MAK 123 | Γ1: Destruction stratum | 140 | 0.92 |
| MAK 124 | Γ1: Destruction stratum | 93 | 1.62 |
| MAK 125 | Γ1: Dark lens/dung? | 139 | 1.27 |
| MAK 126 | Γ1: Occupational debris | 84 | 1.69 |
| MAK 127 | Γ1: Occupational debris | 128 | 0.64 |
| MAK 128 | Γ1: Dump base charcoals & shells | 272 | 0.54 |
| MAK 129 | Γ1: Dump base charcoals & shells | 111 | 2.30 |
| MAK 130 | Γ1: Occupational debris | 314 | 0.80 |
| MAK 131 | Γ1: Occupational debris | 104 | 1.20 |
| MAK 132A | Δ8: Pit, Top | 209 | 0.33 |
| MAK 133 | Δ8/Pit, gray sediment | 84 | 1.83 |
| MAK 134 | Δ8/Pit, ashy layer | 206 | 1.46 |
| MAK 135 | Δ8/Pit, ashy layer | 179 | 3.53 |
| MAK 136 | Δ8/Pit, ashy layer above floor | 212 | 1.78 |
| MAK 137 | Δ8/Pit, sediment and ash (mixed) | 300 | 2.99 |
| MAK 138 | Δ8: Pit, clay bottom | 194 | 0.70 |
| MAK 141 | Regional sample (orchard) | 92 | 0.18 |
| MAK 142 | Regional sample (travertine) | 1 | 0.01 |
| MAK 213 | Δ8 Poorly prepared floor above floor 4 (west) | 114 | 3.45 |
| MAK 214 | Δ8 Well-prepared floor 4, west: upper burnt surface | 115 | 3.75 |
| MAK 215 | Δ8 Well-prepared floor 4, west | 136 | 2.67 |
| MAK 216 | Δ8 Poorly prepared floor below floor 4 (west) | 112 | 4.87 |
| MAK 217 | Δ8 Poorly prepared floor above floor 4 (south) | 141 | 4.91 |
| MAK 218 | Δ8 Well-prepared floor 4, south | 94 | 0.44 |
| MAK 219 | Δ8 Poorly prepared floor below floor 4, (south) | 116 | 2.59 |
| MAK 220 | Δ8, Gray sediment above clay construction on floor 6 | 128 | 2.51 |
| MAK 221 | Δ8, Clay construction on floor 6 | 74 | 0.85 |
| MAK 222 | Δ8, Well-prepared floor 6, west | 60 | 0.78 |
| MAK 223 | Δ8, Poorly prepared floor below floor 6, (west) | 68 | 2.03 |
| MAK 224 | Δ8, Poorly prepared floor above floor 6, (east) | 87 | 2.48 |
| MAK 225 | Δ8, Well-prepared floor 6, east | 72 | 0.33 |
| MAK 226 | Δ8, Poorly prepared floor below floor 6, (east) | 71 | 2.37 |
| MAK 228 | B7 Clay construction on floor 3 (west) | 74 | 0.96 |
| MAK 229 | B7, Dark gray sediment above floor 3, west (burrow?) | 93 | 1.39 |
| MAK 230 | B7, Well-prepared floor 3, west (Upper 4 cm) | 94 | 0.07 |
| MAK 231 | B7, Well-prepared floor 3, west | 1 | 0.004 |
| MAK 232 | B7, Poorly prepared floor below floor 3, (west) | 74 | 1.70 |
| MAK 233 | B7, Poorly prepared floor above floor 3, (east) | 71 | 1.16 |
| MAK 234 | B7, Well-prepared floor 3, east | 73 | 0.04 |
| MAK 235 | B7, Poorly prepared floor below floor 3, (east) | 61 | 0.91 |
| SAR 30 | Sarakini regional sample (forest) | 23 | 0.006 |
| SAR 301 | Sarakini regional sample (grassland) | 24 | 0.004 |
| SAR 302 | Sarakini regional sample (grassland) | 10 | 0.002 |
| SAR 316 | Sarakini regional sample (forest) | 30 | 0.10 |
| SAR 80 | Goat dung | 534 | 0.80 |
| SAR 81 | Cattle dung | 220 | 0.25 |

### 2.1. *Phytolith analysis*

The chemical treatment of the samples followed Albert et al. (2000). The phytolith counting and morphotype identification for the samples from Makri was conducted as described for the samples from Sarakini (see Tsartsidou et al., 2008 for details). Ideally 200 phytoliths with consistent morphology (see Albert et al., 1999 for the definition) were counted in each slide. Albert and Weiner (2001) demonstrated that the counting of 194 phytoliths with consistent morphology gives an error of ±23%. Our reproducibility tests show an error of ±22%. The total number of phytoliths on the slide (consistent and variable morphology) was then determined and normalized to 1 g of sediment.

The phytolith morphologies (114 morphotypes of consistent morphology) were classified following the terminology used by Albert (2000), Brown (1984), Metcalfe (1960), Piperno (2006), Twiss et al. (1969) and the International Code for Phytolith Nomenclature (Madella et al., 2005). For the calculation of the Phytolith Difference Index (PDI) each morphotype (expressed as per thousand) was normalized relative to the average of 4 regional samples (SAR 30, 301, 302, 316), which in our estimate have been least affected by human. These regional samples come from the mountainous area of Rhodope, where the ethnoarchaeological survey took place. The average of these regional samples was used for the normalization of Sarakini samples as well as the modern plant phytolith samples. The total of the 114 normalized morphotypes constitutes the Phytolith Difference Index (PDI) (for more details on the PDI see Tsartsidou et al., 2008). We also estimated the error of the PDI by calculating the variability of the PDI for 20 arbitrary samples introduced by using each regional sample separately. The standard deviation of the average of this value is ±7% (see for details Tsartsidou et al., 2008). The total error is thus ±29%. The PDI facilitates comparisons to be made easily between phytolith assemblages.

## 3. Results

Table 1 shows all the samples analysed, their locations, phytolith concentrations and PDI values. The phytolith concentrations versus PDI values from all the sediment samples from Makri are shown in Fig. 2. Also shown are two samples (MAK 142, 231) that have too few phytoliths with consistent morphologies for reliably calculating a PDI value. These were arbitrarily assigned a PDI value of 1. Samples 80 and 81 are modern goat and cattle dung samples respectively, collected at Sarakini. These are shown for reference. The per gram phytolith concentrations of Makri sediments range from less than 10,000 to almost 5 million. The PDI values range from 1 to around 315. Fig. 2 clearly shows that almost all samples analysed from Neolithic Makri have higher concentrations of phytoliths and higher PDI values than the modern regional samples. This implies that the phytoliths from the sediments in the site have somehow been concentrated, and are also much more diverse in terms of phytolith morphologies as compared to the non-archaeological regional sediments. Most samples cluster in a region (circle) that has phytolith concentrations between a million and 5 million per gram of sediment and their PDI values between 60 and around 160. This range of PDI values is much lower than the PDI value of goat dung from the village of Sarakini (sample 80), which has a value of 534. This high PDI value reflects the diverse diet of goats that also includes a large proportion of dicot leaves. This is consistent with the morphological analysis of goat dung phytoliths (Tsartsidou et al., 2007). The morphological analysis of the phytoliths from Makri shows that indeed dicot leaf phytoliths are only a minor component of the total assemblages of almost all the Makri samples. Since the dicot plants of the area are high producers of leaf phytoliths (Tsartsidou et al., 2007), it is unlikely that many goats were present in the Neolithic village of Makri. Nevertheless, it is possible that goats were kept elsewhere in the site or goat dung may have been used for other purposes. The animal bones analysis provides no clear evidence for the presence of goats: ovicaprines constitute 86.4% of the domestic animals recovered by the animal bone analysis and for only a limited number of these was it possible to distinguish between the genera of *Ovis* and *Capra* (Curci and Tagliacozzo, 2003).

The samples in the cluster (Fig. 2) are from floors and associated sediments from squares B2, B7 and Δ8 and from an open area (square Γ1) (Fig. 1). Platform samples (clay constructions with flat surfaces or just compact clay features on the stratigraphy that indicate some kind of a construction) are also clustered in this location. Most of the phytoliths from the samples in the cluster derive from grasses. It is however difficult to determine the relative proportions of wild and domesticated grasses. The Chloridoid grass phytoliths constitute up to 30% and these mainly derive from wild grasses (Tsartsidou et al., 2007). The remaining Festucoid grass phytoliths could have derived from both wild and domesticated grasses. Phytoliths which have definitely been deduced from domesticated cereals (wheat and barley) are present in concentrations of up to 4% in some of the assemblages. We also note that the cluster in Fig. 2 contains samples from both the floor series and the open area sediments, raising the possibility of the floors being constructed in part, using materials taken from the open area within the site, together with lime plaster.

The samples that have PDI values higher than 117 include all 6 samples from a lined pit (Fig. 3), two samples (MAK 117 and MAK 119) from sediments just above floors in square B2 and two samples (MAK 128 and MAK 130) from the sediments of square Γ1. All the above observations are analysed in more detail below.

### 3.1. Open area (Γ1) phytolith assemblages

All the open area samples, with two exceptions, fall within the cluster (Fig. 2). Fig. 4 shows a detailed analysis of the phytolith assemblages from the open area. Chloridoid phytoliths consist a large component of all the samples (Fig. 4a). Tsartsidou et al. (2008) observed that the Chloridoid grass phytoliths constitute up to 40% of the grass phytoliths in cattle dung in this geographical area. Valamoti (2004) also noted that the Chloridoid grasses and more specifically *Cynodon dactylon* are related to animal dung. Phytoliths deriving from grass stems are more common than husk phytoliths (Fig. 4b). This is consistent with a major portion of the

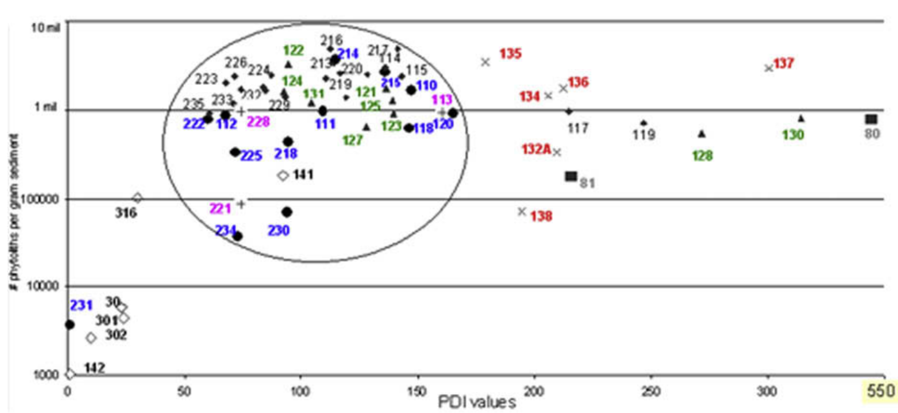


**Fig. 2.** Plot of the phytolith concentrations versus PDI values of all the sediment samples from Makri. Circles (blue characters) are from the well-prepared floors, black rhombs (black characters) are from the poorly-prepared floors, triangles (green characters) are from the sediment samples of the open area. Samples from platforms are shown with crosses (purple characters) and samples from the lined pit are shown with x (red characters). White rhombs are the regional samples from Makri and Sarakini. The black squares are the goat and cow dung samples from Sarakini. (For interpretation of color in this figure please refer to the web version of this article).

**Fig. 3.** Photograph of the lined pit in square Δ8.

phytoliths being derived from animal fodder. One sample (MAK 130) contains more husk phytoliths than stem phytoliths (Fig. 4b). This sample also contains predominantly wheat phytoliths (Fig. 4c). Micromorphological analysis shows that the layer, from which MAK 130 was obtained, is composed mainly of occupational debris deriving from the houses (Karkanas, personal communication).

### 3.2. Floor associated samples

Following the study of Karkanas (2007) and Karkanas and Efstratiou (in press) we differentiate between well-prepared and poorly prepared floors (Figs. 2 and 5). Most of the well-prepared floors have phytolith concentrations of less than a million phytoliths per gram sediment. One such floor (MAK 231) has less than 10,000 phytoliths per gram sediment. The poorly prepared floors tend to have higher phytolith concentrations. These two floor types however cannot be differentiated by their PDI values. Furthermore all floors contain material that have phytolith assemblages similar to sediments from the open area within the site, but are quite different from the regional sediments.

In this study we have analysed several series of well-prepared and poorly prepared floors from four different locations, such as the one shown in Fig. 5. These are called floor series B2, floor series 3, floor series 4 and floor series 6. Fig. 6 shows details of the phytolith assemblages in these floor series. Fig. 6a shows that floor series B2 includes the only 5 samples that have a higher proportion of phytoliths from grass husks as compared to stems, whereas all the samples from the other floor series are dominated by stem phytoliths. Floor series 6 has the highest amounts of stem phytoliths. Fig. 6b shows that most of the phytoliths from cereals are present in floor series B2 and that these are dominated by wheat as compared to barley. Fig. 6c shows that Chloridoid phytoliths (wild grasses only in this study) are present in all samples. Floor series 4 contains the highest concentrations of Chloridoid phytoliths. We also note that the well-prepared floors (MAK 215, 218 and 214) and the poorly prepared floors (MAK 213, 216, 217 and 219) contain dung spherulites. This implies that dung itself somehow penetrated into these floors.

### 3.3. Lined pit phytolith assemblages

A unique assemblage of phytoliths (Fig. 7a) was found within the lined pit (Fig. 3). Variable morphology phytoliths comprise up to 8% of the assemblages. This indicates the presence of wood ash. All of these samples contain a large amount of calcite. We also note from the infrared spectra that the clays associated with these

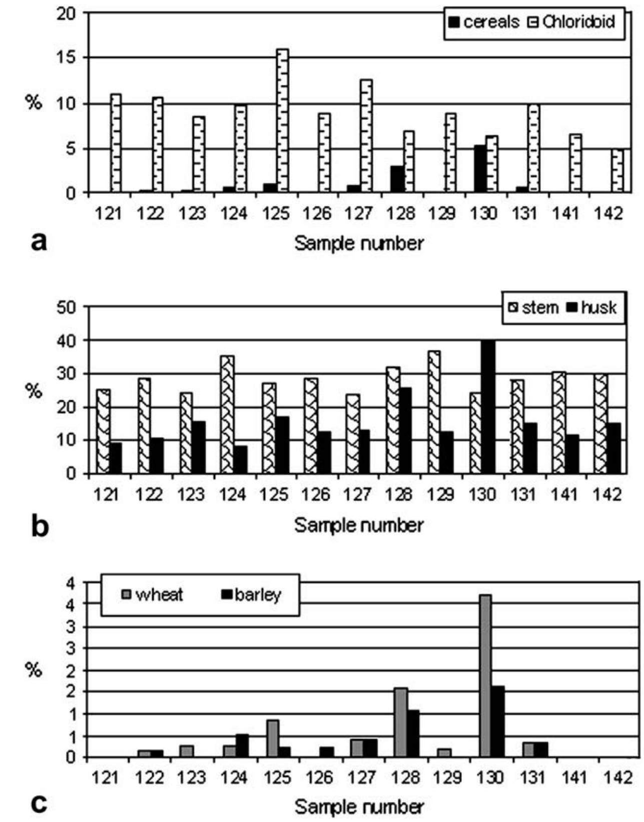


**Fig. 4.** Morphological and taxonomical analyses of the phytolith assemblages from the open area.

samples were exposed to elevated temperatures based on the absence of peaks at 3705 and 3620 $cm^{-1}$ (Berna et al., 2007). The clay used for the construction of the pit was not burnt based on infrared spectra following Berna et al. (2007). The ash-rich samples also contain Chloridoid phytoliths (Fig. 7c) and spherulites, indicating that dung was also present in the pit. Another unique aspect of the pit phytolith assemblages is the large component of leaf derived phytoliths (Fig. 7b) present mainly in the two samples close to the base of the pit.

## 4. Discussion

The analysis of phytoliths from the sediments of Neolithic Makri shows that the overall diversity is low compared to the phytoliths assemblages from the "traditional" village of Sarakini. This is attributed mainly to the scarcity of phytoliths from leaf dicots. The analysis also shows that there is no clear distinction between the overall phytolith assemblages from within the residential areas as compared to an outside area within the village. Finally, one series of floors contains phytoliths that appear to reflect the activities that took place at that locality.

### 4.1. Agricultural and pastoral activities in Neolithic Makri

The phytolith assemblages of Neolithic Makri point to a society with a mixed agricultural and pastoral economy. The presence of phytoliths derived from wheat and barley clearly shows that the villagers were engaged in agricultural activities. The fact that a major component of the phytoliths assemblages is from wild grasses, this including the Chloridoid grasses, which in this area are known to be major components of the dung of free-ranging cattle

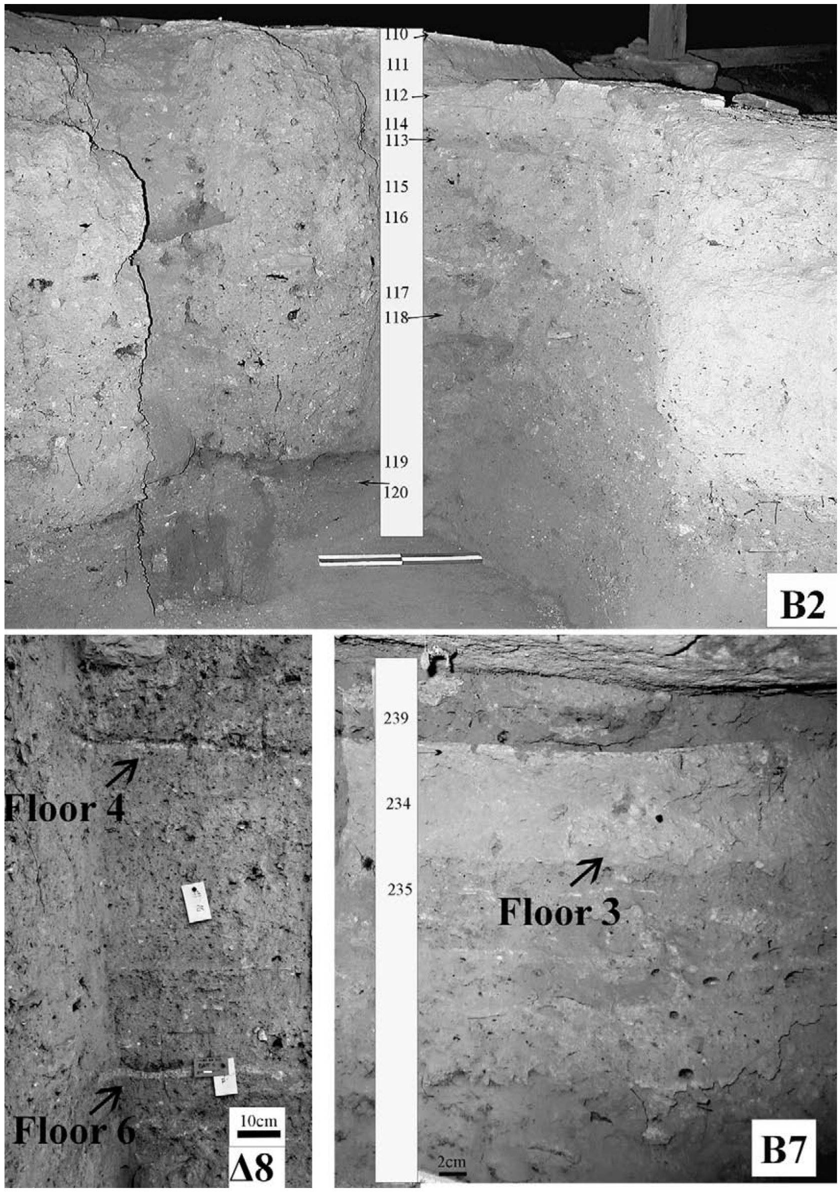


**Fig. 5.** Stratigraphic sections of squares B2, B7 and Δ8. Sample numbers are shown and arrows show the locations of the well-prepared floors.

and goats (Tsartsidou et al., 2008), points to the presence of pastoral activities. Phytoliths from dicot leaves are however present in only minor quantities. This is inconsistent with the presence of significant amounts of dung from goats, unless for some reason goat dung was used specifically for some other purpose. This, however, seems unlikely.

The macro-remains analysis (Valamoti, 2004) showed that wild grasses are a major component of the Makri archaeological layers. Most of the plants identified by Valamoti (2004) were not studied in our phytolith reference collection, except for *Bromus* sp. and *Aegilops* sp. These species have relatively low PDI values (210, 243 respectively). These values are compatible with the PDI values of the floors and open area sediments. *C. dactylon*, a Chloridoid grass identified in the macro-remains analysis, has a high PDI value (459). This is one of the main components of the diet of the cattle of Sarakini as it covers large areas in the mountains. Nevertheless the cattle dung sample from Sarakini has a relatively low PDI value (220) (Fig. 2). Clearly the diet of these free-ranging domestic animals included grasses with low PDI values.

### 4.2. Seasonal versus permanent habitation

The phytolith assemblages are rich in the husks of wild grasses that flourish during the summer, as well as the presence of cereal by-products, which necessitate agricultural activities such as harvesting, threshing and winnowing in the summer. In addition the seeding of cereals takes place during the fall for emmer wheat (Hillman, 1981) and spring for barley (Hillman, 1981). Thus the presence of the farmer is necessary in both winter and spring, when the plants grow (Halstead, 1999). These agricultural practices imply that the Neolithic village of Makri was occupied year round.

### 4.3. Continuous versus punctuated habitation

The high phytolith concentrations in all the samples from Makri, including those from the open area, point to a continuous habitation. The phytolith assemblages imply that there is no indication of abandonment for either long or for short periods. We cannot exclude the possibility of seasonal mobility, i.e. a seasonal

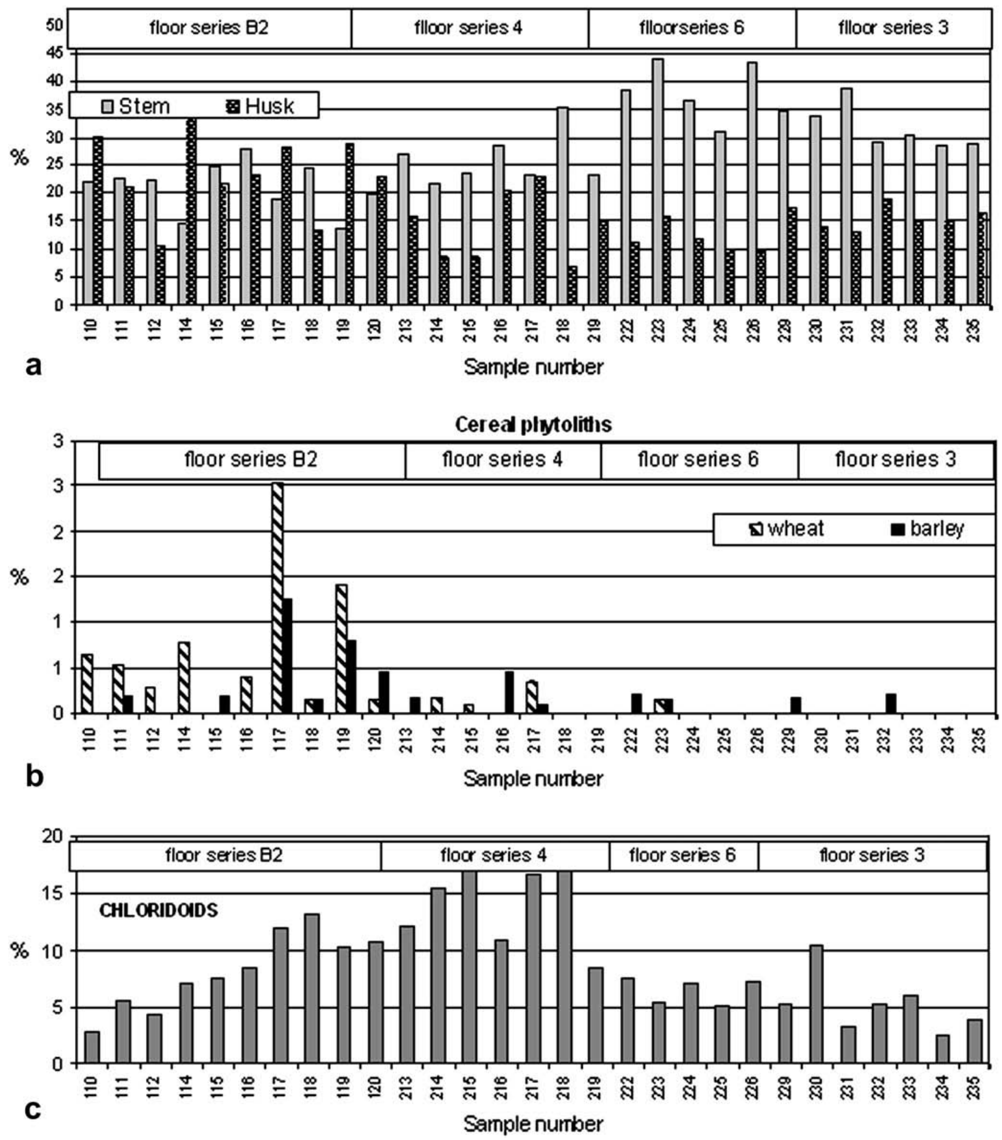


**Fig. 6.** Morphological and taxonomical analyses of the phytolith assemblages in the floor series B2, 3, 4 and 6.

movement of some groups from the village. We note that in Sarakini the village is normally inhabited in the summer, even though some members, mostly men, move out of the village in the summer and take the animals up the mountain in search of pastures. The phytolith analysis of the Makri samples provides hard evidence for the current theoretical debate relating to the degree of permanence in tell and flat sites (Demoule and Perlès, 1993; Halstead, 2005; Kotsakis, 1999). Flat settlements are considered sites of non-permanent habitation (Bailey, 2000; Perlès, 2001; Whittle, 1996), whereas tells, such as Makri, are considered places of permanent habitation (Halstead, 1999; Perlès, 2001).

### 4.4. Floors

The analysis of phytoliths from floors of houses in ethnographic Sarakini shows that they contain very small concentrations of phytoliths (Tsartsidou et al., 2008). The floors of Neolithic Makri, with one exception, contain relatively high concentrations of phytoliths. Furthermore, the floors are not differentiated in terms of PDI values from the sediments of the open area (Fig. 2). The floors and the open areas are characterized by a large amount of wild grass phytoliths.

The clustering of the floors and the open area sediments in Fig. 2 implies that the sediments from the open area were most probably used for the construction of the floors. The micromorphological studies of the floors and the open area seem to verify this interpretation (Karkanas and Efstratiou, in press). There is however a distinction between the well-prepared floors, the poorly prepared ones and the open area sediments with respect to phytolith concentrations. Most of the well-prepared floors have low concentrations of phytoliths. This probably reflects the fact that these well-plastered lime floors are relatively consolidated, and as a result trampling in of food remains was minimal. They may have also been routinely swept. Micromorphological data are consistent with this interpretation, highlighting that the upper surfaces of well-prepared floors are in most cases clean of dirt (Karkanas and Efstratiou, in press). Similar floors with low concentrations of phytoliths have been excavated in Neolithic Çatalhöyük (Hodder and Cessford, 2004; Mathews et al., 1996) and in Tel Dor, an urban site from the Iron Age in Israel (Shahack-Gross et al., 2005). They have also been reported in ethnoarchaeological research of Greece

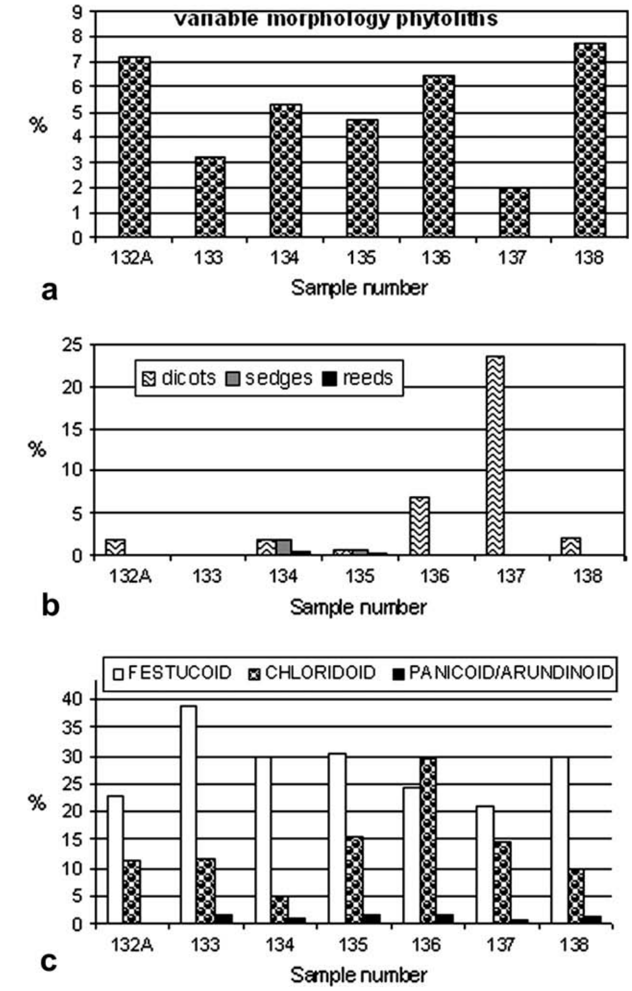


**Fig. 7.** Morphological and taxonomical analyses of the phytolith assemblages from the lined pit.

(Tsartsidou et al., 2008) and India (Boivin, 2000). The possibility of phytolith dissolution in the Makri floors due to the high pH of the lime is ruled out by the fact that all the lime floors contain thousands of phytoliths that show no strong evidence of dissolution. Ethnoarchaeological studies show that the change in the quality of the floors indicates different access to construction materials or even a change of the socioeconomic status of the owners (Kramer, 1979). The ethnoarchaeological study in Sarakini showed that the sediment from the open area next to the house was used to construct the walls of the houses, but special clay-rich sediments were used to construct and periodically remake the floors.

### *4.5. Spatial and temporal variability of use of space*

The phytolith assemblages from Makri floors do not generally reflect the use of space, with few exceptions. The floor series in Square B2 contains the only 5 samples analysed in which husk phytoliths are more abundant than stem phytoliths. This implies that these phytoliths do reflect the activity in this area. This area may have been used as a place for the production of food or the storage of cereals. We also note that evidence of hearth and cereal seed processing was found in several floors from the same vertical series. This implies that the inhabitants used this area for the same purpose, i.e. food production or cereal processing, for an extended period of time. We thus identify a repetitive practice involving the location of the food processing and/or cereal storage activities. Similar repetitive practices involving different locations (i.e. art, burials) and repetitive sweeping activities have been recognized in Çatalhöyük (Hodder and Cessford, 2004).

We also note the presence of large amounts of variable morphology phytoliths in the sediments of this square indicating the presence of wood ash. The ash may imply the presence of a hearth in this area. Ethnographic studies show that hearths are common in rooms where cereal processing takes place as they are used for drying seeds for better preservation (Hillman, 1981). In addition, a clay construction-platform found in the same area also contains high concentrations of husk phytoliths. This could conceivably have been used for processing the seeds, e.g. flour production.

A puzzling observation is that even some well-plastered floors with well-defined smooth upper surfaces, have relatively high phytolith concentrations within the floor construction. It is difficult to conceive that this could be due to trampling.

One possibility is that trash lying on the floor is incorporated into the floor during the periodic reconstruction of the floor. The storeroom of a Sarakini house had higher amounts of phytoliths than the adjacent living room (Tsartsidou et al., 2008). The living room floors were swept more carefully than the storeroom floors, and were reconstructed more often.

The residential area in excavation square Δ8 (Fig. 1) presents a different picture regarding the use of space through time. Floors 4 and 6 belong to the same stratigraphic unit: floor 6 is older than floor 4 (Fig. 5). Well constructed floor 4, as well as the poorly constructed floors just above and below floor 4, show evidence for the presence of dung as the phytolith assemblages include Chloridoid phytoliths and dung spherulites. As there is no evidence of microlaminated layers in the micromorphological sections (Karkanas and Efstratiou, in press), which would indicate trampling, this area was probably not used as a stable. It could be that dung was used to coat the floors or was stored on the floors, or that the phytoliths and spherulites derived from burnt dung ash. As the same phenomenon occurs in a series of floors, this location was used repetitively for the same residential activity. Floor 6 in the same sequence does not have any indications of dung constituents. It shows a low amount of husk phytoliths and the highest concentration of stem phytoliths. This may imply the continuous presence of straw in these floor series. The different phytolith characteristics recognized in floor series 4 and 6 point to a possible change in the use of space in that location (Δ8) through time.

### *4.6. The use of space on platforms*

Most of the platforms in Makri do not preserve phytolith assemblages indicative of their use. The only exception is the clay platform (MAK 113) excavated in square B2. It contains a large amount of husk phytoliths and cereal phytoliths that could indicate cereal seed processing on its surface. This is consistent with its presence in a room that also has the highest amounts of cereal and husk phytoliths.

The use of platforms is common in the Neolithic settlements of Greece and the Near East. They are often associated with everyday activities such as sleeping, benches for sitting or for ritual activities (Mathews et al., 1997). Similar structures with well-plastered floors that were excavated in Çatalhöyük were associated with gender or age variations or ritual purposes (Boivin, 2000). This is the case also in other studies where platforms have been related to gender variations (Waterson, 1990). Platforms located on the right side of the house have been used only by the male members of the family, others have been used only by adults and there were platforms that used to serve as the place for women to give birth (Waterson, 1990).

The clay platforms found in Makri do not define any specifically recognizable context of use in terms of their finds (Efstratiou et al., 1998).

### 4.7. The use of a pit

The phytolith assemblages from the ash layers excavated in the pit in square Δ8 (Fig. 3) show that the pit was not a storage pit but a hearth feature, where dung was used as fuel. A thick layer at the base contained abundant leaf phytoliths. The leaves were spread on the bottom of the pit for unknown purposes and then layers of dung were placed above it. Dung was the fuel used in the houses of Greek Thessalian villages until recently (1950) (Gourgiotis, 1994).

## 5. Conclusions

The phytolith assemblages from the Neolithic village of Makri indicate a continuous habitation of the village and both agricultural and pastoral activities. The analysis shows that the phytolith assemblages from Makri are different in phytolith diversity as compared to the assemblages in an ethnographic environment (Sarakini village). One difference is the minor presence of dicot leaves in the sediments of Makri implying the near absence of goat dung. The analysis also shows that there is no clear distinction between the overall phytolith assemblages from within the indoor areas as compared to an outdoor area within the village. The most probable reason is the use of the sediments from outside as a construction material for the floors inside. Only one series of floors contains phytoliths that appear to reflect the activities that took place at that locality and they point to cereal storage or food processing area. The cereals cultivated at the village were wheat and barley and they were used for both food and fodder.

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