Phytolith analysis: Environmental reconstruction derived from a Sarmatian kiln used for firing pottery

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Abstract

The present study focuses on the investigation of silicified plant remains (phytoliths) deriving from the wall of a Sarmatian kiln in order to asses the provenience of the material used for constructing the kiln itself. It also aims to determine the type and origin of the fuel used for firing, which could not have been determined from other plant remains (charcoal, pollen). As shown by our findings, the fuel used for firing was wood probably from the nearby floodplain gallery forests of the river Danube. The vegetation inferred from the phytoliths of the Sarmatian occupation horizon indicates forest-steppe/dry steppe conditions.

Keywords: phytoliths, kiln material, fuel, provenience, environmental conditions

Introduction

The word "Phytolith" comes from the Greek *phyto* (plant) and *lithos* (stone). Phytoliths are silica casts of plant cells or spaces between cells in plants. Silica, dissolved in groundwater as monosilicic acid, is taken up into the plant during its life. The silica is then deposited in the plant as opal silica, chemically identical to the "opal" that is known as a semi-precious stone. These tiny opal particles take on the shape of cells, or "negative" casts of the space between cells (Archer 2004). Phytoliths are found in many plant families though not all, but their production is most abundant in grasses, possibly 20 times that in other plant opal-producing families (Albert & Weiner 2001).

Phytoliths are released from the the plant's tissues when the plant decays or is burned. This can happen among various circumstances. Either at the site where a plant naturally died and decayed or where humans artifically disposed some plant residue, or in the drop of various herbivouros animals. Phytoliths are of particular interest to archaeologists because on the one hand, they are highly resistant to decay and are capable to survive in such places and among such extreme conditions where preservation of other types of archaeological plant remains e.g. pollen is not possible. Because phytoliths are essentially stones, they are preserved indefinitely in all but the most extremely alkaline burial conditions (Archer 2004). On the other hand, while pollen grains generally represent the vegetation of the study site usually at a greater regional scale, due to the general characteristics and ease of transport of the grains, phytoliths present very important information about the local vegetation or other events, since they are preserved where the plant material was actually deposited or carried onto. However, the nature of deposition (by humans like in the case of wood used as fuel in kilns, animals or the original plant) must be clarified for accurate interpretation.

In 2005 the Department of Geology and Paleontology at the University of Szeged was requested to carry out the phytolith analysis of samples taken from an excavated kiln preserved in outstanding conditions. The samples derive from the site of Apostag, located in the center of the Carpathian Basin on the right bank of the river Danube (Fig. 1). The archeological site of Apostag-Hetény is located in the middle of a dirt road, and as such was not subjected to extensive agricultural activities in the past and is consequently free of any structural disturbances. The excavated kiln used for baking pottery comes from the Late Sarmatian Period (2nd–3rd centuries AD). The kiln was built adjacent to the wall of a house.

Fig. 1 The study site in the Carpathian Basin.

The wall of the kiln was prepared by trampling and the stokehold was covered by Sarmatian pottery fragments.

The major aim of our work was to elucidate an environmental history of the area based on the phytolith analysis of the material deriving from and adjacent to the kiln. In addition, we aimed to determine the nature and origin of the fuel used for firing pottery (wood or straw). The identification of the fuel is often problematic using traditional macrobotanical approches, as kilns are subjected to successive cleaning and charcoal remains and other macrobotanical fragments are rarely preserved in larger concentrations to provide sufficient information on the nature of the fuel. Conditions inside a working kiln are not favorable for the preservation of pollen grains either. However, phytoliths, which are highly resistant to heat or any other form of decay, may prove useful to solve such conundrums.

Material and methods

The sample taken from the kiln and handed over for investigation preserved material of not only the wall itself but the adjacent soils into which the kiln and the house had been deepened (Fig. 2). This way information on the original and older soils could also be gained. The entire sample was subsampled, and 10 samples marked as AK-1 to AK-10 representing

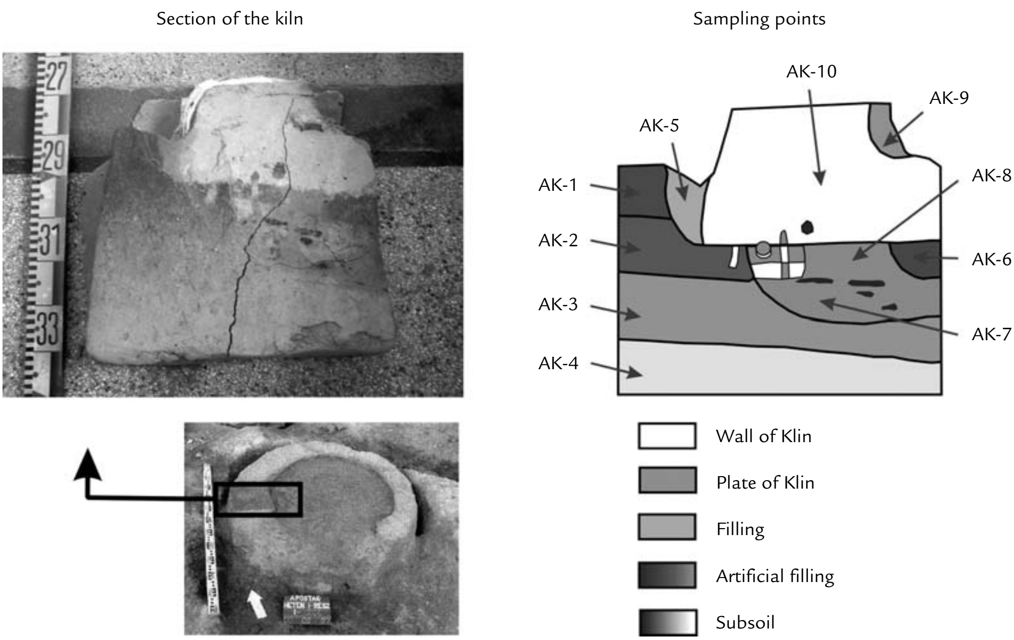

Fig. 2 The location of the sample and the subsamples subjected to detailed investigations.

different parts (the wall and adjacent soils) were subjected to detailed analysis. Approximately 50-100 g subsamples were taken from the individual parts of the section depicted on Fig. 2, out of which only 5 g were used for phytolith extraction.
The first step involved the determination of the major sedimentological parameters of organic and carbonate content of the subsamples via Dean's method (Dean 1974) of loss on ignition. For the extracion of the phytoliths approximately 5 g of the subsamples were used (marked as AK1-AK10). For the extraction the method of Piperno was adopted (Piperno 2006). After standard flotation, the extracted phytolith samples were mounted on slides in glycerine and 250 phytoliths were counted in each sample. Classification of phytolith types was based on the Twiss et al. (1969) classification and Golyeva's (2001) interpretation of phytolith characteristics using our personal phytolith photographic and descriptive references (Fig. 3). Microcharcoal in the samples was also counted to infer possible burnt horizons and fuel usage. Abundance and percentage data was depicted graphically using the PSIMPOLL software of Bennet et al. (2000).
A matrix of samples with types of phytoliths depicting phytolith abundances was subjected to multivariate (ordination) analysis: Principal Component Analyis – PCA. It is widely used in ecological and paleoecological studies; we applied the PAST software (O' Hammer et al. 2000). Using some advanced techniques within the mentioned approaches, the material used for the construction of the kiln, the material of the fuel and that deriving from the original vegetation deposited in the paleosoil horizons, into which the kiln was dug, were identified and separated. The received "eigenvalues" (i.e., measures of magnitude of separation) of the first and second components of the ordination were used as proxies for the factors of environment that could cause the observed patterns.
Information on the environmental conditions derived via the graphical and multivariate analyses (ordinations, classification) of the phytolith data was compared visually to the pollen diagram of Császártöltés (Törőcsik in press).

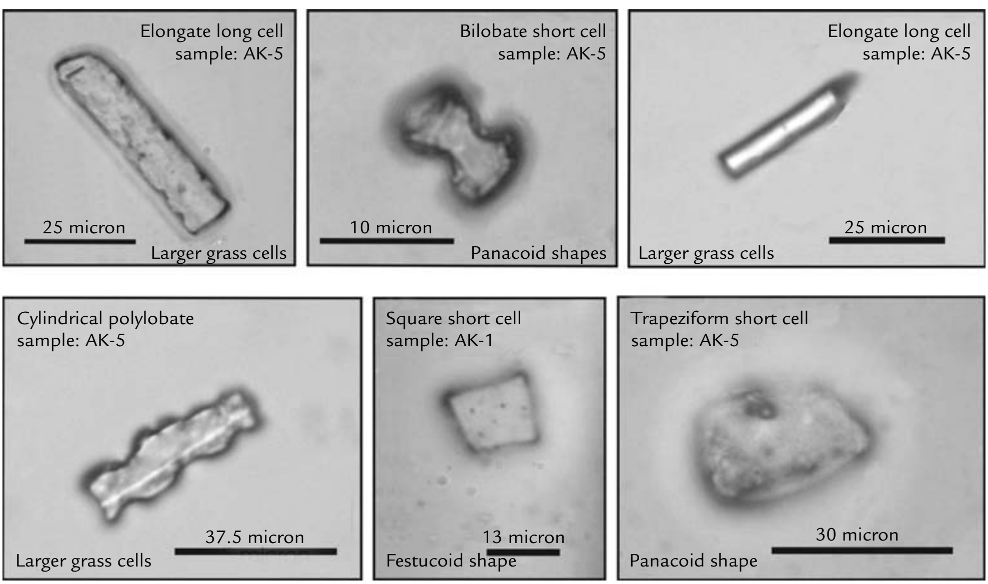

Fig. 3 Different phytolith types found in the samples (Photo by Gergő Persaits).

Results

Based on the location and nature of the subsamples (infill, soil adjacent to the kiln wall, material of the kiln wall itself), as well as on the observed features of the phytoliths (burnt, unburnt, abundance, color) three groups were identified. The first group represents the subsamples of the soil into which the kiln was dug (AK-1 to AK-4 – see Fig. 2). The second group of AK-5 and AK-6 represents an infill adjacent to the wall and under the kiln corresponding to the former Sarmatian habitation horizon (soil level). Samples deriving from here are most informative on the nature of the fuel material. The remaining third group of samples (AK-7 to AK-10) represents the building material of the walls and foundation of the kiln itself. The results of phytolith analyses are depicted on the phytolith diagram (Fig. 4) with three major phytolith groups suitable for deriving environmental information inscripted under the diagram.

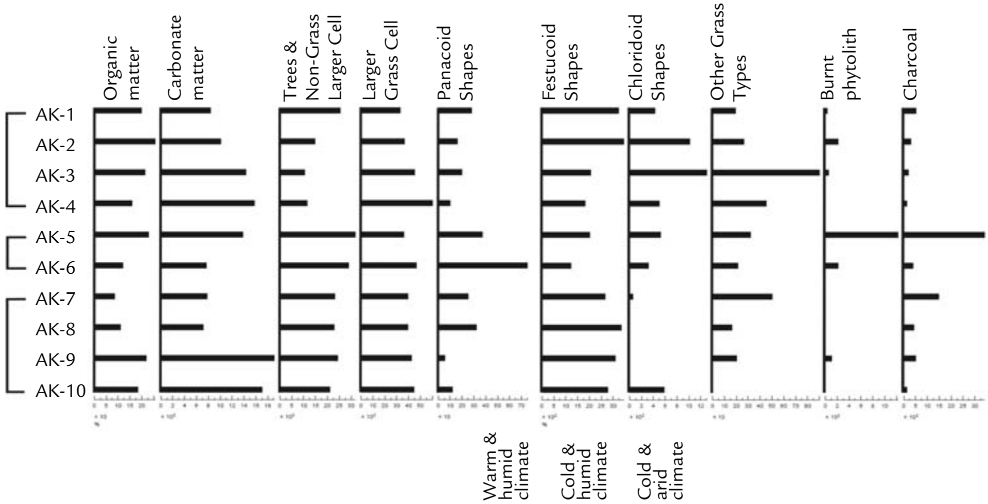

Fig. 4 The phytolith diagram of the studied subsamples.

The results were interpreted in the light of the three mentioned subsample groups. In the first group (AK-1 to AK-4), there is a general downward decrease in the organic content accompanied by an increase in the carbonate content highlighting the individual horizons (A-B) of the Sarmatian soil into which the kiln was dug. The amount of charcoal and burnt phytoliths is negligible in these samples. There is an upward increase in the amount of arboreal and non-grass phytoliths, almost double of the original value in this group. The Festucoid type phytoliths display a similar trend to the values of the arboreal phytoliths. Festucoid shapes generally indicate cold and humid climatic conditions (Twiss et al. 1969). The observed pattern on the diagram thus may indicate progressively colder and more humid climatic conditions as we move upwards in the soil section (from AK-4 to AK-1).

A clear separation of subsamples AK-1-AK-4 along the first axis (=component) of the PCA scatterplot also shows their subsequent positioning within the soil horizons. The observed phytolith characteristics (colour, typical size, etc.) refer to an origin from lower soil horizons after Goyeva (2001). Changes in the environmental conditions of soils are clearly reflected along the first axis of the PCA scatterplot (Fig. 5), as inferred from the component loadings of the individual axes, expressing the importance of the environmental indicator phytolith groups in the separation of the samples after Fig. 2 (Fig. 5). Subsample AK-3 displays special characteristics. Phytoliths counted tend to have a maximum in this horizon, probably as a result of secondary accumulation via leaching. The phytoliths refer to a landscape of supressed vegetation in a forest-steppe zone.

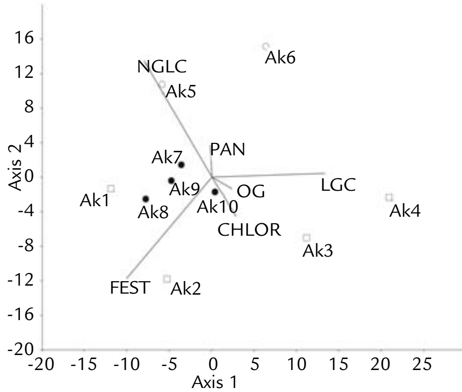

Fig. 5 Results of multivariate ordination (PCA) (AK-1– AK-10= subsamples; NGLC=Non-grass large components, FEST=Festucoid shapes, CHLOR= Chloridoid shapes, PAN= Panacoid shapes, LGC=Large grass components, OG= Other grass components; direction of lines show the importance of the original variables in the explanation of sample ordinations along the first two axes)

Subsamples AK-5 and AK-6 form the second group. Subsample AK-5 is highly valuable as we can gain information about the fuel material in this zone. Arboreal and burnt phytoliths as well as microcharcoal all have a maxima in this subsample (Fig. 4). Charcoals and arboreal phytoliths most likely derive from the fuel used for firing the kiln and must have been buried during the successive cleaning of the kiln located at the Sarmatian habitation horizon. Conditions recorded in AK-5 may accurately capture the environmental conditions of the Sarmatian Period as the studied material most likely derives from the actual occupation layer. On the other hand, subsample AK-6 must have been created artificially during the construction of the kiln via trampling, that is why it is clearly separated from AK-5 on Axis 1 of the scatterplot on Fig. 5. Refering to moderatly abundant phytoliths and their assemblage (Fig. 4), the second group of subsamples represents upper soil horizon conditions in a forest-steppe/dry steppe setting.

The interpretation based on groups 1 and 2 is the following. The earlier cold and humid climate (AK-4) was replaced by warmer and humid (until AK-1) and later on by warm and drier (AK-5, AK-6) conditions. This is indicated by an increase in Panacoid and Festucoid phytoliths for AK-5 (Fig. 4). The large number of stick-shaped phytoliths (>70%) refer to intensive human impact (manure) (Golyeva 2001). The second group presents collective evidence of rapid changes in the vegetation.

The third group of subsamples AK-7 to AK-10 represents the material of the kiln and its foundation. Illustrative of the third group was the lower concentration of total phytoliths compared to the other horizons in the studied slides, not visible in Fig. 2 as proportions there are given for a counted amount of 250 phytoliths. Total phytolith numbers were not counted. Yet due to the high discrepancy between the total phytolith numbers we decided to leave this third group of samples out of the environmental reconstruction for the Sarmatian Period. Nevertheless these horizons are well clustered with the soil horizons of subsamples AK-1 and AK2 on Axis 1, which might refer to an origin of similar environmental conditions.

The transition from the steppe to forest steppe (AK-4–AK1) and back (AK5–AK6) captured using the eigenvalues of the first and second principal axis of the PCA most likely representing changes in aridity as inferred from component loadings (1^{st} component correlated positively by abundance values of large grass components, other grass and chloricoid phytoliths probably indicating arid conditions, and negatively by non-grass and festucoid phytolith abundances probably indicating humid conditions) is clearly visible on

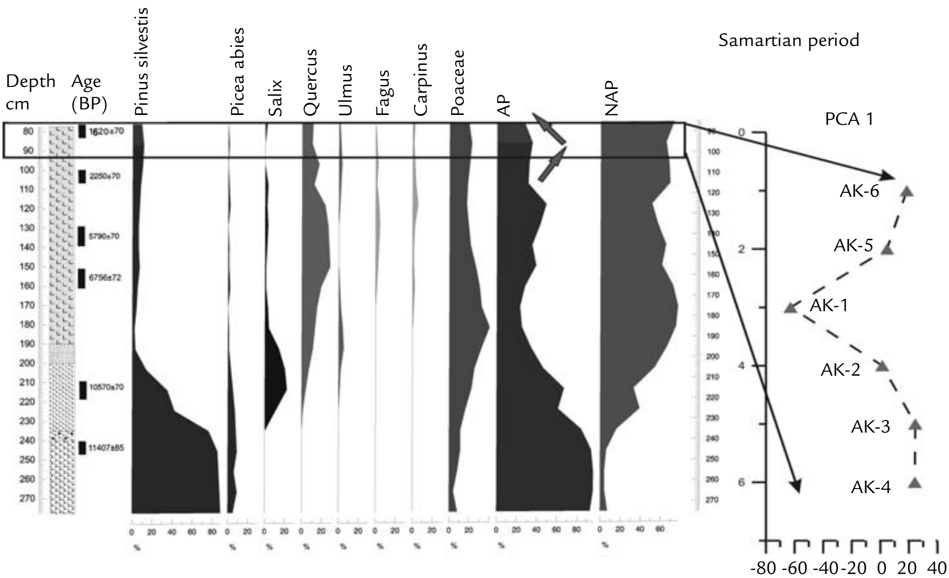

Fig. 6 A comparison of the findings of phytolith studies with those on the pollen diagram of the wider surroundings of the kiln (Császártöltés).

the bend of AP/NAP values on the pollen diagram of Császártöltés, too. This pollen diagram comes from around Apostag and represents the vegetation changes on a larger scale. However, the climatic signals inferred from the the kiln sample can also be found in the pollen diagram (Fig. 6).

Conclusions

Three groups were created a-priori, according to the physical origin of subsamples (AK-1 to AK4, AK-5 and AK6, AK-7 to AK10). Analyses have shown their mutual relations and helped to reveal the environmental conditions at the time the subsamples originated. The first and the second phytolith groups were suitable to reconstruct the vegetation in the Sarmatian Period. The maximum of arboreal, burnt phytolith and charcoal particles in sample AK-5 indicate that wood was the main fuel in the studied kiln.

The samples from the former soil (from AK-1 to AK-4) show a gentle climatic change – a fall in temperature and an increase in humidity from AK-4 to AK-1 followed by an increase in aridity for samples AK-5 and AK-6 representing the Sarmatian habitation layer. The environmental pattern inferred from the local phytolith diagram and that via using the components of multivariate analysis as proxies of environmental gradients are congruent with the pollen diagram prepared for the larger area of the site. In other words an increase in the number of arboreal pollens (corresponding to changes between AK-4 and AK-1) was followed by an inverse trend in the upper part of the section (representing changes recorded by AK-5 and AK-6).

Phytolith analysis proved to be a highly useful tool in environmental reconstruction in geoarchaeology. The results are highly informative on their own as well as in comparison to findings of other types of plant material investigations. Hopefully the findings shown in this paper will bring the attention of archaeologists and other specialists in climate or vegetation history to the importance of phytolith investigations in their work.

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