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# Directions in current and future phytolith research

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ABSTRACT

The analysis of phytoliths has progressed immensely in recent years. Increases in the number of phytolith works within several disciplines has substantially extended our knowledge about these microfossils, while at the same time diversifying the approaches by which they can be used as archaeological and palaeoenvironmental proxies. The insufficient standardisation of these works, however, greatly increases the difficulty of utilising this body of research within a broader framework of powerfully integrated methodologies and models in archaeobotany and palaeoenvironmental studies. Further standardisation will facilitate the broadening of phytolith research beyond technique-oriented work, permitting greater opportunity for its application to inform on past cultures and their strategies of plant resources exploitation as well as the dynamics related to climate change and anthropic-driven environmental modifications. The aim of this paper is to drive our discipline towards a set of “best practices” that arise from current phytolith research but that are often applied in an unsystematic manner.



## 1. Introduction

The analysis of phytoliths has progressed immensely in recent years. Increases in the number of phytolith researchers (and published works) working within several disciplines has substantially extended our knowledge about these microfossils, while at the same time diversifying the approaches by which they can be used as archaeological and palaeoenvironmental proxies (see as an example the collection of articles in the current special issue). Viewing the published work as a whole we observe many different approaches to data analysis, presentation, and interpretation, reflecting a lack of consensus beyond some irrefutable common ground (see also Shillito, 2013). This greatly increases the difficulty of utilising the available body of research within a broader context of powerfully integrated methodologies and models in archaeobotany and palaeoenvironmental studies. Further standardisation will facilitate the broadening of phytolith research beyond technique-oriented work, permitting greater opportunity for its application to inform on past cultures and their strategies of plant resources exploitation as well as the dynamics related to climate change and anthropic-driven environmental modifications. Phytolith work, like most archaeobotanical and palaeoenvironmental work, is labour intensive and expensive. This often constrains the practical analytical scope for phytolith analysis within a given project, therefore making comparisons with or making the use of previous similar work from other researchers in the field is paramount.

The aim of this paper is to encourage a common set of “best practices” to address these issues. We propose a collection of what we consider “minimum requirements” that should be addressed in any phytolith study and publication, chosen to both facilitate the wider use of such research while also retaining flexibility and practicality in their application.

## 2. Research questions

The decision to collect and analyse certain archaeological or non-anthropic samples (we refer here to phytoliths but this could apply to all artefacts/ecofacts) depends on their potential to answer given research questions. These questions guide the field and laboratory work, from the choice of sampling strategy, extraction and analytical procedures, and ultimately the form and presentation of

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the resulting data. The research questions are an integral part of any study and must be made explicit when presenting the research work.

## 3. Phytoliths patterns of deposition and preservation

A set of different mechanisms governs the composition of phytolith assemblages observed under the microscope. These can be divided into two major groups:

- Original plant input, which can be anthropic, natural or a mixture of the two;
- Pre and post-depositional taphonomy.

Depending on our deposit or context, either the anthropic or the natural input is predominant. Plant deposition in archaeological sites, for example, is affected by planned and accidental activities, as well as by natural events. However, we can be reasonably confident that phytolith deposition in archaeological sites is mostly derived from the actions of the former inhabitants and that different contexts should reflect (at least partially) the variability of human activities (see Briz Godino and Madella, 2013). On the other hand, a pedological sequence or a paleosol without human disturbance can be expected to reflect natural changes in vegetation cover. This understanding will guide our ensuing interpretations and it is therefore fundamental to clearly state the origin of the studied sample(s). For example, with archaeological material we need to state if the samples are from open or closed contexts, or if they are primary, secondary or tertiary depositional contexts (see Fuller et al., 2014 and references therein). Phytoliths recovered from a midden deposit, for instance, can only rarely be assigned to a specific activity, as opposed to phytoliths recovered from in situ baskets (Ryan, 2011), bedding layers (Cabanes et al., 2010), or fireplaces (Allué et al., 2012; Cabanes et al., 2007; Lancelotti, 2010). The same applies when dealing with materials sourced from museums or warehouses (see for instance Barton, 2007 for starch analysis). Unfortunately, many phytolith publications only report the origin of the samples by means of a code or a name for the corresponding strata - often without any description of or reference to sedimentological, archaeological and/or chronological information (a problem also with some of our group's past publications). Making explicit the origin of samples is a simple step that greatly enhances the ability to interpret results and to make future comparison against other studies. A further matter that we consider important in relation to the collected samples is the explicit documentation of any depositional dynamics that may have resulted in the phytolith assemblage originating from multiple, non-synchronous anthropic and/or natural inputs (see for example Shillito, 2011 or Madella and Lancelotti, 2012 for soils and bioturbation).

Taphonomy can influence phytolith assemblages in a variety of ways, producing changes in the original plant input (assemblage composition) either by adding or removing part of the phytolith spectra (see a review by Madella and Lancelotti, 2012). Phytolith preservation (pre and post-depositional) can be affected by mechanical and/or chemical processes that result in the differential breakage and dissolution of morphologies (Cabanes et al., 2011; Cabanes and Shahack-Gross, 2015; Osterrieth et al., 2009; Wu et al., 2012, 2014), impairing their identification during the microscopy scan. Once phytoliths are deposited in the sediments, they can also suffer from vertical movement, with the smallest phytoliths removed (eluviation) and accumulated (illuviation) in deeper strata. This process is also known in the literature as translocation or percolation (Alexandre et al., 1997; Fishkis et al., 2010a, 2010b; Piperno and Becker, 1996) and it can damage the single phytolith particles.

To understand the level of confidence of our assemblages, the data presentation should always state the proportion of "taphonomised" particles - those who have suffered any clear pre- or post-depositional damage. This information should be in the data table, and when possible the damage should be identified as mechanical or chemical in origin. In cases where there is no evidence of taphonomic damage, this absence of evidence should be explicitly indicated in the data table or in the text. Adding information about taphonomical issues in the published data can define the level of uncertainty of the data and effectively contribute to the general understanding of the results. It will also improve further sampling strategy in similar contexts because the sampling will be designed according to previous experiences. We can gather additional information on taphonomic processes from simple sedimentological analyses such as pH (which should be always presented in the raw data table) as well as from more complementary techniques, such as FTIR that can be used to assess the effect of diagenesis.

## 4. Collecting and processing phytolith samples

The methods we use for collecting phytolith samples during fieldwork and the subsequent laboratory processing can bias our assemblages. The research questions are the first step in devising a sampling strategy (see above) but the site or deposit's characteristics are also important. No single sampling scheme is appropriate in every archaeological or sedimentological context, and this is why sampling strategy should be made explicit in all published work. This will increase reproducibility, augment site/context/deposit comparability between studies, and will also improve the design of sampling strategies in similar contexts.

In many archaeological excavations, the extent and significance of the cultural contexts is not clear until after excavation and therefore we recommend adopting a broader sampling strategy than might be implemented based on the evidence available while on-site. Excess samples can be stored for future studies (when possible) or disposed once the study has been successfully completed.

The laboratory procedures currently in use for the extraction of phytoliths are several and rather diverse. This raises questions of validity when comparing results from different studies and different authors. There have been many studies assessing the different extraction techniques used in archaeology and palaeoenvironmental work (Jenkins, 2009; Lentfer and Boyd, 1998; Parr, 2002; Parr et al., 2001), mostly showing similar recovery rates but with some exceptions in certain sediments such as oxisols rich in iron oxides and hydroxides (Calegari et al., 2013). Ideally we should standardise according to very few extraction techniques to facilitate comparison, something that might not be easy due to well-established laboratory procedures. At the very minimum we should clearly refer to or disclose the protocol that was used. A partial alternative to a complete standardisation would be to introduce some standard requirements in all our extractions procedures. For example, the addition of the calculation of the AIF (Acids Insoluble Fraction) in all extractions would provide a standard reference unit quantifying the phytolith content of a sample that could be compared against difference studies.

## 5. Phytolith taxonomy

The expression 'phytolith systematics' has historically been used to refer to classification (Ball et al., 1999; Piperno, 1989; Piperno and Pearsall, 1998; Rapp and Mulholland, 1992). However, we find this term misleading, as phytolith research – with very few exceptions (see Hodson et al., 2005) – does not consider phylogenetic or