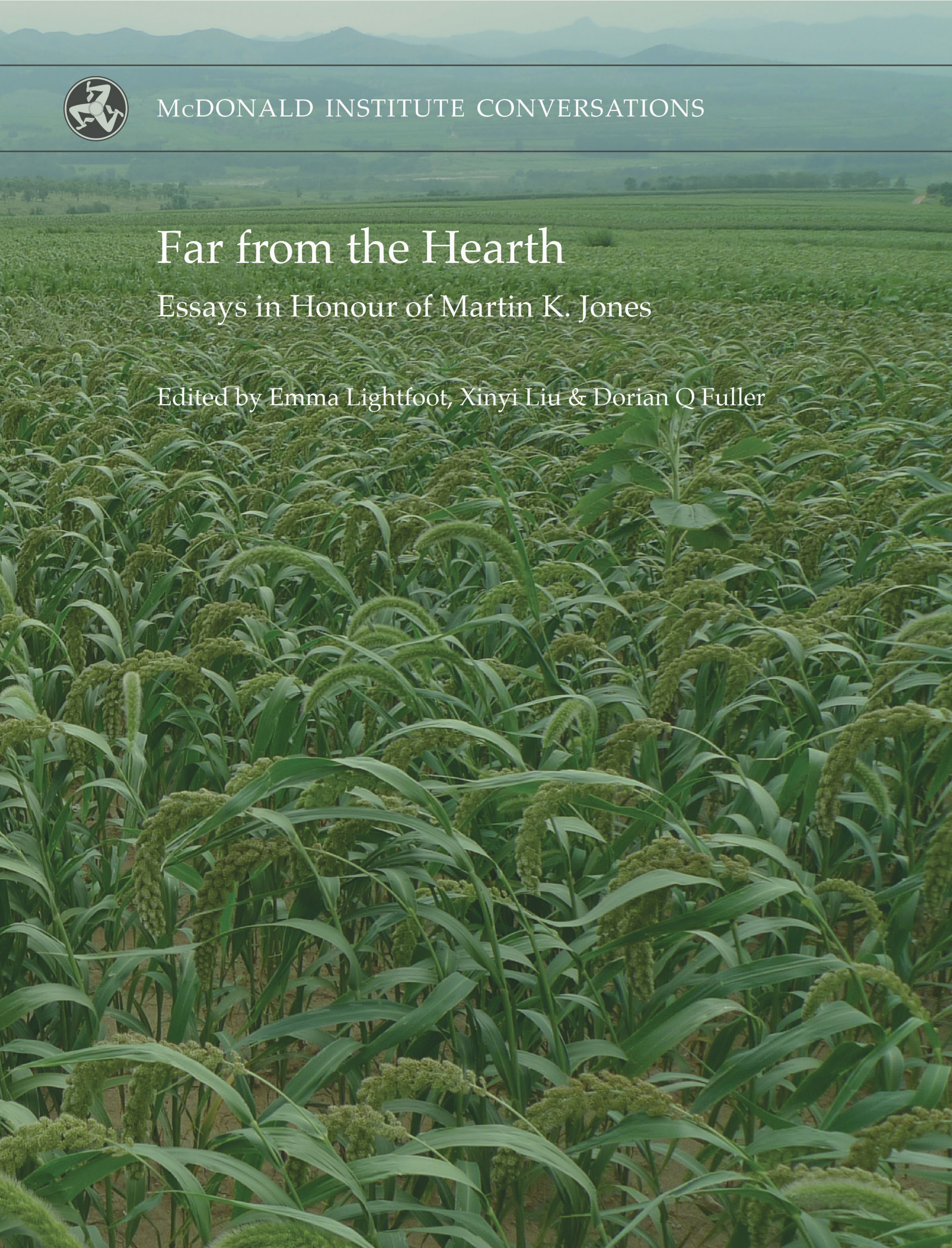

McDONALD INSTITUTE CONVERSATIONS

Far from the Hearth

Essays in Honour of Martin K. Jones

Edited by Emma Lightfoot, Xinyi Liu & Dorian Q Fuller

Far from the Hearth

(Above) Martin Jones at West Stow, 1972 (with thanks to Ian Alister, Lucy Walker, Leonie Walker, and West Stow Environmental Archaeology Group); (Below) Martin Jones in a millet field, Inner Mongolia, 2010. (Photograph: X. Liu.)

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Cover image: *Foxtail millet field near Xinglonggou, Chifeng, China, photographed by Xinyi Liu, September 2014.*

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Figures

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Acknowledgements

The initial idea of editing this volume grew out of a conversation between Xinyi Liu and Graeme Barker at St John's College, Cambridge in June 2016. The editors subsequently discussed the provisional layout of the volume. By April of the following year, our list of agreed contributors was complete. Abstracts followed, and the chapters themselves soon after. First of all, the editors would like to pay tribute to our 36 authors, whose excellent work and timely contributions made it all possible.

For the last two-and-a-half years, the volume has been known as 'Fantastic Beasts' in order to keep it a secret from Martin. As we enter the final stage, we wish to extend our thanks to all who have ensured Martin remains blissfully unaware, including Lucy Walker, and we offer her our sincere thanks. We are extremely grateful to Harriet Hunt, Diane Lister, Cynthia Larbey and Tamsin O'Connell, who are kindly organizing the gatherings to mark Martin's retirement and the publication of this volume.

With respect to the volume's production, we would like to thank the McDonald Institute for Archaeology Research for financial support. The McDonald Monograph Series Editor James Barrett oversaw and encouraged all aspects of this project, and we offer him sincere thanks. We would also like to acknowledge the support of Cyprian Broodbank, not least for allowing us to host the workshop at the institute, but also for his encouragement throughout all phases of the volume's implementation. Particular thanks must go to several key individuals: Anne Chippindale, Ben Plumridge, Emma Jarman, Simon Stoddart and Samantha Leggett. Finally, we are also grateful to the anonymous reviewers who recommended changes that have greatly enhanced the final version of this volume.

Xinyi Liu, Emma Lightfoot and Dorian Fuller
August 2018

Foreword

The 28-year term of Martin Jones as the first George Pitt-Rivers Professor of Archaeological Science witnessed, and in part created, a transformation in the fields of environmental and biomolecular archaeology. In this volume, Martin's colleagues and students explore the intellectual rewards of this transformation, in terms of methodological developments in archaeobotany, the efflorescence of biomolecular archaeology, the integration of biological and social perspectives, and the exploration of archaeobotanical themes on a global scale. These advances are worldwide, and Martin's contributions can be traced through citation trails, the scholarly diaspora of the Pitt-Rivers Laboratory and (not least) the foundations laid by the Ancient Biomolecules Initiative of the Natural Environment Research Council (1989–1993), which he chaired and helped create. As outlined in Chapter 6, Martin's subsequent role in the bioarchaeology programme of the Wellcome Trust (1996–2006) further consolidated what is now a central and increasingly rewarding component of archaeological inquiry. Subsequently, he has engaged with the European Research Council, as Principal Investigator of the Food Globalisation in Prehistory project and a Panel Chair for the Advanced Grant programme. As both practitioner and indefatigable campaigner, he has promoted the field in immeasurable ways, at critical junctures in the past and in on-going capacities as a research leader.

The accolades for Martin's achievements are many, most recently Fellowship of the British Academy. Yet it is as a congenial, supportive—and demanding—force within the Pitt-Rivers Laboratory that the foundations of his intellectual influence were laid. Here, each Friday morning, the archaeological science community would draw sticks to decide who would deliver an impromptu research report or explore a topical theme. Martin is among the most laid-back colleagues I have worked with, yet simultaneously the most incisive in his constructive criticism. As a provider of internal peer-review he was fearless without being unkind. The themed Pitt-Rivers Christmas parties were equally impactful—on one occasion Alice Cooper appeared, looking ever so slightly like our professor of archaeological science.

Martin's roles as a research leader extended to several stints as head of the Department of Archaeology, chairing the Faculty of Archaeology and Anthropology and serving as a long-term member of the Managing Committee of the McDonald Institute for Archaeological Research. Having started his professional career as an excavation-unit archaeobotanist in Oxford, he was a long-standing proponent of the highly successful Cambridge Archaeological Unit. In the wider collegiate community, he is a Fellow (and was Vice-Master) of Darwin College and was the staff treasurer of the Student Labour Club. In all roles he fought valiantly and often successfully for the interests of his constituency. His capacity to fight for deeply held priorities while recognizing the value of diverse perspectives was of utmost importance. His nostalgic enthusiasm for the debate with archaeological science that was engendered by the post-processual critique is one signal of an underlying appreciation of plurality. His active support for the recent merger of the Divisions of Archaeology and Biological Anthropology, within our new Department of Archaeology, is another. As a scientist (Martin's first degree, at Cambridge, was in Natural Sciences) he values the peer-reviewed journal article above all scholarly outputs, yet has authored as many highly regarded books as a scholar in the humanities. His *Feast: Why humans share food* has been translated into several languages and won Food Book of the Year from the Guild of Food Writers. He views academia and society as a continuum, campaigning for archaeobotanical contributions to global food security (e.g. by promoting millet as a drought-resistant crop) and working with world players such as Unilever to encourage archaeologically informed decisions regarding food products.

That Martin's achievements and influence merit celebration is clear. That his colleagues and students wish to honour him is equally so. Yet does the McDonald Conversations series publish *Festschriften*? This is a semantic question. As series editor I am delighted to introduce a collection of important papers regarding the past, present and future of archaeobotany, representing its methodological diversity and maturity. That this collection concurrently pays respect to a treasured colleague is a very pleasant serendipity.

Dr James H. Barrett

Chapter 4

Phytoliths and the Human Past: Archaeology, Ethnoarchaeology and Palaeoenvironmental Studies

Carla Lancelotti & Marco Madella

In this chapter we will explore the evolution of phytolith studies since its inception in Europe. We will bring together the historical development of the methodological approach and the current contribution of this proxy to our understanding of plant use, the origin of agriculture and agricultural techniques in the past.

A brief history of phytolith studies

Microscopic hydrated silica particles formed in plants have over the years been referred to as 'opal phytoliths', 'biogenic silica', 'silica phytoliths', 'plant opal', 'biogenic opal' and simply 'phytoliths'. The first observation of mineral particles from plants was reported by Leeuwenhoek in 1675, though he used the term phytoliths to describe calcium oxalates (Mulholland & Rapp 1992). The term phytolith for defining microscopic opaline bodies deposited in plants initially appeared in a paper by Ruprecht (cited in Baker 1959a,b), but their discovery and description dates back to the first half of the nineteenth century. According to Powers (1992 and references therein), the history of phytolith studies can be divided into four periods.

*Discovery and exploration period: (*c. *1835–1900)*
Struve, a German scholar at the University of Berlin, in 1835 produced a dissertation on silica in plants (cited in Powers 1992), thus placing the 'scientific discovery' of phytoliths one year before that of pollen. A decade later Ehrenberg, another German scholar, observed, described and classified silica particles he found in sediment samples, calling them 'Phytolitaria' (from the greek φυτόν/*phutón* 'plant' and λίθος/*líthos* 'stones'). It was Ehrenberg himself who identified phytoliths in the samples of dust collected by Darwin on the deck of HMS *Beagle* (Darwin 1846).

*Botanical research period (*c. *1895–1936)*
Towards the end of the nineteenth century and during the first half of the twentieth, phytoliths were recognized as particles produced within plants and studies related to production, taxonomy and morphology flourished (Grob 1896; Haberlandt 1914; Mobius 1908). It is in this period that the first applications of phytolith analysis to archaeological studies appear (Netolitzky 1900; 1914; Schellenberg 1908). As for the previous period of discovery and exploration, the German school dominates phytolith studies and the body of literature is therefore published in German.

*Ecological and paleoecological research (*c. *1955–1975)*
During the 1950s and 1960s, scholars from the United States, the United Kingdom and Australia started investigating phytoliths, thus producing the earliest body of literature in English. In this period morphology is examined in more detail and in many more plant families, resulting in studies that are considered the bases of phytolith classification and they are still in use (e.g. Metcalfe 1960; Twiss *et al*. 1969). Studies in archaeology also proliferate, with researchers starting to work on different types of deposits and materials (e.g. Helbaek 1961; 1969: working on ashes and ceramics from the Near East) and in different areas of the world (e.g. Watanabe 1955; 1968; 1970: identifying rice phytoliths in prehistoric deposits from Japan). A seminal publication, which contributed to increase phytoliths visibility in Quaternary studies, was the review of the potential of phytoliths in palaeoecological reconstruction published by Rovner (1971) in the journal *Quaternary Research*.

*Modern period (*c. *1978–2000)*
The last two decades of the twentieth century are characterized by an exponential increase in phytolith studies (Fig. 4.1), both geographically and in scope. Specific studies on families or species become routine: Cucurbitaceae (Bozarth 1987; Piperno *et al*. 2000), Fabaceae (Bozarth 1990) and Cyperaceae (Ollendorf 1992; Ollendorf *et al*. 1987) become a focus of interest, as well as some dicotyledonous species for their inter-

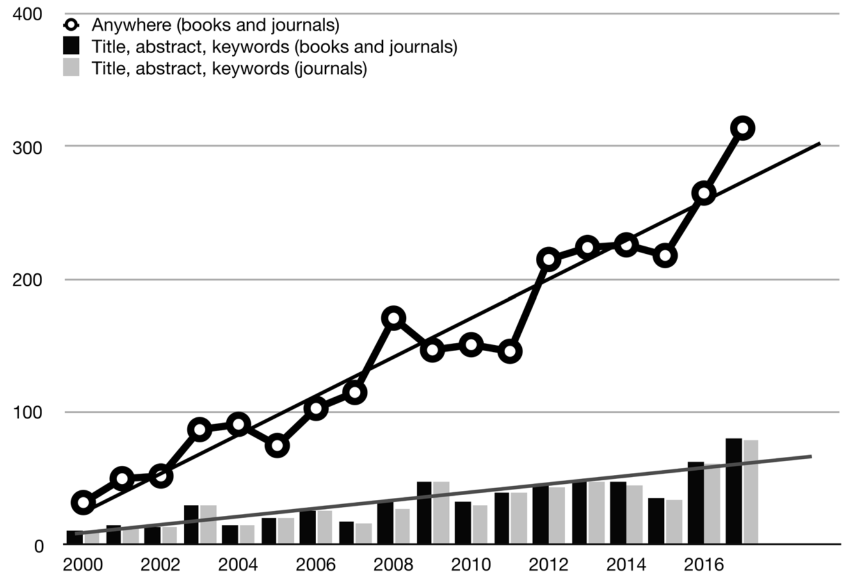

Figure 4.1. *Increase in phytolith studies in the last 15 years from a search on ScienceDirect, using as keyword the term 'phytolith' in any field (trend line); only in 'title', 'abstract' and 'keywords' in both books and journals (black columns); and only journals (grey columns).*

est in past vegetation and human use (Bozarth 1992). Maize (Mulholland *et al*. 1988; Piperno 1984; Piperno & Pearsall 1993), rice (Houyan *et al*. 1997) and wheat/barley (Ball *et al*. 1993; 1999) occupy, for their economic interest, a prominent spot in this area of studies. The geographical zones investigated in phytolith studies also expand, with research in Africa (Alexandre *et al*. 1997; Barboni *et al*. 1999; Jansen & van Iperen 1991; Mercader *et al*. 2000; Runge & Runge 1997), Central Asia (Madella 1997) and South East Asia (Bowdery 1999; Kealhofer & Penny 1998) appearing together with New Zealand (Kondo *et al*. 1994), Israel (Albert *et al*. 1999; 2000), China (Yongji 1991) and Brazil (Alexandre *et al*. 1999). The scope of research also widens and phytoliths are used as activity markers to study irrigation (Rosen & Weiner 1994), identify dietary practices from dental calculus (Ciochon *et al*. 1990; Danielson & Reinhard 1998; Fox *et al*. 1994) and infer function of stone tools (Anderson 1980; Jahren *et al*. 1997; Kealhofer *et al*. 1999; Sobolik 1996) and the formation of pastoral sites (Brochier *et al*. 1992). New techniques such as the isotopic study of phytoliths are also introduced (Fredlund & Tieszen 1997; Kelly *et al*. 1998; McClaran & Umlauf 2000; Shahack-Gross *et al*. 1996; Webb & Longstaffe 2000). Phytolith studies also assume the character of a mature discipline with the proliferation of meta-studies, in particular on extraction methods (Lentfer & Boyd 1998; Madella *et al*. 1998; Middleton & Rovner 1994; Powers & Gilbertson 1987).

In the next paragraphs, we will outline some of the major breakthroughs and developments in phytolith research in archaeology and palaeoenvironmental studies and, especially, in ethnoarchaeology.

Methodological advances

The stage of maturity reached by the discipline in the last 15 years is testified by the number of works published since 2000 that critically reflect on the methodology itself. At the same time, technological improvements and the introduction of more sophisticated analytical tools contributed to an increase in research involving isotopic and genetic analysis of phytoliths.

Phytolith extraction, identification and interpretation

On the one hand, phytoliths from archaeological sites have been used to document crop plants, plant food, plant-made objects like mats and baskets, fuel types and construction materials. On the other hand, phytoliths from natural sequences have been used to understand vegetation changes between major ecological types (e.g. savannah, forest, grassland, etc.) or the dynamics of soil-formation processes. Several authors, however, have concentrated on extraction methods, either proposing new and improved techniques (Lombardo *et al*. 2016), concentrating on specific and problematic types of sediments (Calegari *et al*. 2013), combining extraction of several micro-remains (Horrocks 2005), improving the efficiency both in time and cost (Katz *et al*. 2010), comparing the results of different extraction methods (Parr 2002), or assessing the best extraction method for specific analyses for example isotopic studies (Asscher *et al*. 2017; Corbineau *et al*. 2013) or genetic analyses (Kistler 2012). Other methodological aspects on which researchers have concentrated are counting and nomenclature. Strömberg (2009) and Zurro (2017) question whether changing the count size influences the interpretations of results and propose minimum count size as well as statistical techniques to ensure the robustness of results. The creation in 2000 of the International Committee on Phytolith Morphology responded to the need of the phytolith communities to standardize the terms that were used to describe phytoliths. The main result of this committee was the publication of the first International Code for Phytolith Nomenclature in 2005 (Madella *et al*. 2005). In 2014 the International Society for Phytolith Research appointed a new International Committee for Phytolith Taxonomy to continue this effort. Their first output was the publication of standardized guides for morphometric analysis of phytoliths (Ball *et al*. 2016b). Another important issue that has been deeply addressed in recent years concerns the role of taphonomic processes on the composition of phytolith assemblages. Madella and Lancelotti (2012) have offered a comprehensive review of the possible impacts of various taphonomic processes and proposed some ways of counterbalancing them in the analysis. At the same time, Cabanes and Shahack-Gross (2015) have performed experiments to assess phytolith preservation fully in sediments and understand the role of dissolution on the robustness of interpretations.

Isotopes and DNA

Isotopes from archaeological sites have been used for understanding, among other things, climatic and environmental change, past human diet, nutrition and mobility, past animal and crop management practices, and to build reliable chronologies. The isotopic analysis of occluded carbon in phytoliths, both for dating as well as for palaeoenvironmental reconstruction purposes, is an issue that has been abundantly debated in recent years (Piperno 2016). Studies have been performed to understand soil carbon sequestration in phytoliths (Parr & Sullivan 2005; Song *et al*. 2016), as well as the incidence of atmospheric carbon occluded in phytoliths (Carter 2009). Some of these publications have generated a debate centred on the validity of carbon isotopic analyses in phytoliths and what exactly is the signature measured through this technique (Santos & Alexandre 2017; Santos *et al*. 2016). Hodson and colleagues (2008) explored the potential of oxygen and silicon isotopes alongside carbon on the same plants of *Triticum* sp. and concluded that silicon and carbon are the most promising isotopic systems to be used in palaeoenvironmental studies, while more work on oxygen isotopes was needed to explain its patterns of variation. Following this, several groups have been working on oxygen isotope methodology (Chapligin *et al*. 2011; Crespin *et al*. 2008) up to the point where this technique has been fully validated for palaeoenvironmental studies (Alexandre *et al*. 2012). Work on silicon isotopes, on the contrary, is much rarer, although the potential of this technique is gaining recognition (Leng & Sloane 2008; Leng *et al*. 2009), to the point that Hodson (2016) recognizes it as a commonly used technique.

Ancient DNA in archaeology has been used to understand human evolution and, when extracted from plants and animals, as a way to understand the processes involved in domestication. The extraction of DNA directly from phytoliths is related to the possible presence of organic material occluded within the silica. However, this seems to be a problematic avenue of study, as observed by Elbaum *et al*. (2009). An interesting side of DNA studies and phytoliths is the exploration of the genetic mechanisms involved in phytolith production. Despite the evidence that silicon is fundamental for plant growth, as it provides strength, detoxification and protection from animals (Piperno 2006), the exact mechanism for phytolith formation is still not fully understood. Piperno *et al*. (2002) indicate that phytolith formation in Cucurbitaceae is regulated by a dominant genetic locus previously associated with the production of lignin. The same research establishes that this locus also has an important role in phytolith morphology, constituting a major breakthrough in the understanding of phytolith formation and taxonomy.

Phytoliths in archaeology

The process of domestication of plants and the setting and spread of agriculture was a transformational moment in the socio-ecological history of our species. Currently, the archaeological record shows that, starting around 12,000 years ago, plant cultivation and domestication developed independently in several regions of the world and then spread via cultural or demic diffusion into most geographical areas (Larson *et al*. 2014). Archaeobotany has focused on developing methods for identifying the domestication process, the cultivation of plants and fully fledged agriculture from wild plants and crops remains. During the last 20 years, phytoliths in all regions of the world have become an important proxy in this research, alongside macro remains, pollen and starch grains (e.g. Pearsall 2015b; Piperno 2006; 2009). After many years of work focused on the standardization of identification characteristics based on reference collections and morphometric analysis of phytoliths from wild species and crops, the discipline has finally reached sound and replicable procedures. Piperno (2006) performed the first review of crop phytoliths, followed by more recent endeavours from Piperno (2012) and Ball *et al*. (2016a).

Table 4.1. *Phytolith production and taxonomic specificity for the world's major crops.*

	Plant	Phytolith production	Taxonomic specificity	Plant Part
Southwest Asia	*Triticum* spp. (einkorn, emmer, other species)	Very high	Genus	Inflorescence bracts (glume, lemma and palea)
	Hordeum spp. (barley, other wheats)	Very high	Genus	Inflorescence bracts (glume, lemma and palea)
East Asia	*Oryza sativa* (rice)	Very high	Species	Glume, Leaf (bulliform cells)
	Setaria spp. (foxtail millets)	Very high	Genus	Glume
	Panicum spp. (broomcorn millets)	Very high	Genus	Glume
South and Southeast Asia	*Musa* spp. (bananas)	High	Genus, Section, Species	Leaf, Seed
	Benincasa hispida (wax gourd)	Very high	Genus (?)	Fruit rind
	Cocos nucifera (coconut)	Very high	Family or Subfamily	All plant parts
Africa	*Lagenaria siceraria* (bottle gourd)	Moderate	Genus	Fruit rind
	Ensete ventricosum (Abyssinian or Ethiopian bananas)	High	Genus	Leaf and seed
	Sorghum bicolor (sorghum)	High	Genus	Glume
Americas	*Zea mays* (maize)	Very high to low	Species	Cob (glume/cupule), Leaf, Husk
	Cucurbita spp. (squashes and gourds)	Very high/high	Family, Genus, Species	Fruit rind, Leaf
	Lagenaria siceraria (bottle gourd)	Moderate	Species	Fruit rind
	Sicana odorifera (cassabanana)	High	Genus	Fruit rind
	Manihot esculenta (manioc or yuca)	Very low	Genus	Most plant parts
	Maranta arundinacea (arrowroot)	Very high	Species	Seed
	Calathea allouia (llerén)	Very high to Moderate	Species	Seed, Rhizome
	Ananas comosus (pineapple)	Very high	Family	Leaf, Seed
	Canna edulis (achira)	Very high	Genus (?)	Leaf
	Phaseolus vulgaris and *lunatus* (common/lima bean)	Moderate	Genus	Pod
	Helianthus annuus (sunflower)	High	Family (Genus?)	Achene
	Arecaceae (palms)	Very high	Family, Subfamily, Genus (?)	All parts

Phytoliths have been used in a number of different ways to understand agricultural origin and dispersal:

1) as direct proxies for cultivation and domestication of certain species
2) as part of a multi-proxy research to identify past crops or wild species
3) as low-level taxonomic identifiers (e.g. species level) or identifiers of plant structures (e.g. inflorescences, leaves) less visible with other fossils
4) as proxies for the expansion of ancient crops.

Phytoliths significantly increase the traceability of several Old and New World crops, including taxa that are normally invisible in the charred record, such as some fruits or root crops, as well as enabling the identification of different plant structures pertaining to the same crop (e.g. Corteletti *et al*. 2015; García-Granero *et al*. 2015a,b; Iriarte *et al*. 2012; Madella *et al*. 2014). The level of taxonomic significance of phytoliths will differ from species to species in the same manner as other fossil indicators of plant exploitation, such as charred remains of seeds.

In Table 4.1 we summarize the present understanding of crop identification based on phytoliths and in the following text we discuss the utility of phytoliths for identifying major crops and therefore agricultural origins and crop dispersal.

Triticum *and* Hordeum *spp. (wheat and barley)*

Wheat and barley are major silica accumulators, producing a variety of morphotypes such as the ones from epidermal cells: short cells; long cells; cork cells; papillae; trichomes; and trichome bases. These bodies are very characteristic and can be diagnostic at genus level when a morphotypic and morphometric approach is used (e.g. Ball *et al*. 1999; 2009). There has also been some success in identification to species level, primarily based on the morphometric differences observed in the short cell (rondel), dendritic and/or papillae phytoliths (e.g. Ball *et al*. 1999; Rosen 1992; Tubb *et al*. 1993). Moreover, features of the anatomy displayed in the silicified epidermal tissues of cereals can be used to distinguish plant parts.

Setaria *and* Panicum *millets (foxtail and broomcorn millets) and other small millets*

Phytoliths from the inflorescence of *Setaria* and *Panicum* are extremely useful for identifying *Setaria italica* (foxtail millet), *Setaria viridis* (green foxtail) and *Panicum miliaceum* (common or broomcorn millet) and thus documenting the earliest history of domesticated millets in Eurasia (García-Granero *et al*. 2015a,b; Zhang *et al*. 2011; 2013). Important features to distinguish these taxa are the silica body shape, papillae characteristics (including presence/absence), epidermal long cell patterns and glume surface sculpture (Lu *et al*. 2009). A cautionary note is due when differentiating crop phytoliths from their Panicoid weedy wild relatives in archaeological contexts, as this can be a challenge due to similarities of identifiable Panicoid husk morphotypes. Strict identification criteria must therefore be followed for correct identifications. The discrimination between *S. italica* and its wild ancestor, *S. viridis*, is based on the morphometry of phytoliths in the upper lemma and palea (Zhang *et al*. 2011), although some uncertainty remains and more studies are needed to detect the presence of other potentially diagnostic features. Morphological and basic morphometric studies of glumes of other minor millets also show the potential of phytoliths for differentiating these important crops in the prehistory of Eurasia and Africa (Madella *et al*. 2014).

Oryza sativa *(rice)*

Phytoliths play a very important part in the archaeological study of rice domestication and cultivation. Currently, three distinct phytolith morphotypes are used to identify rice: double-peaked glume cells from the rice husk; bulliform cell phytoliths from the leaves; and articulated bilobate phytoliths from stems and leaves (Gu *et al*. 2013; Piperno 2006). Double-peaked glume cell phytoliths are unique to the genus *Oryza* and can discriminate domesticated rice from wild rice species of South and Southeast Asia on the basis of linear discriminant function analysis of glume cell measurements (Zhao & Piperno 2000) or three-dimensional measurements (Gu *et al*. 2013). The morphological characters of bulliform cell phytoliths seems to be under genetic control, therefore reflecting taxonomical significance (Gu *et al*. 2013), and some features such as surface ornamentations have been employed to distinguish domesticated from wild rice (Huan *et al*. 2014; Wang & Lu 2012). Phytoliths can also be used as a tool for understanding the development and spread of rice (*Oryza* sp.) arable systems using arable weed ecologies as pioneered by Fuller and Weisskopf (2011).

Musa *spp. (true bananas) and* Ensete ventricosum *(Ethiopian/Abyssinian banana)*

The domestication and spread of true bananas (*Musa* spp.) is difficult to untangle. Current domestic bananas derive from the Eumusa (*Musa acuminata* [AA] and *Musa balbisiana* [BB]) and Australimusa (*M. maclayi*) sections of Musaceae through intra- and interspecific hybridization, polyploidization and somaclonal mutations, which resulted in seed sterility and parthenocarpy (De Langhe *et al*. 2009). Prehistoric and historical human populations spread domesticated Eumusa throughout the tropics and any evidence for *Musa* phytoliths outside Asia is indicative of cultivation (Vrydaghs & De Langhe 2003). Phytoliths can be produced in various plant tissues and organs of bananas (e.g. Chen & Smith 2013), with seed and leaf phytoliths being the most studied to date. In *Musa* and *Ensete* leaves, the silicification of cells from around the vascular tissue produces volcaniform (volcano-shaped) phytoliths (Ball *et al*. 2006). Both morphotypic (e.g. Vrydaghs *et al*. 2009) and morphometric studies (e.g. Lentfer 2009; Vrydaghs *et al*. 2009) have been carried out to be able to identify different *Musa* and *Ensete* species. The results show that volcaniform phytoliths can be discriminated at the genus level (distinguishing bananas from *Ensete* in archaeological records: e.g. Lentfer 2009; Mbida *et al*. 2001), but reliable identification at the species level is still wanting.

Sorghum bicolor *(sorghum),* Pennisetum glaucum *(pearl millet)*

A certain number of recent studies have showcased phytolith production in African domesticated grains and their wild progenitors (Logan 2012; Madella *et al*. 2014; Novello & Barboni 2015; Out & Madella 2017; Radomski & Neumann 2011). However, there are currently too few studies on phytolith production in the wild grasses inflorescences (Novello & Barboni 2015) to be able to identify specific morphotypes diagnostic to the genus or species level.

Zea mays *(maize)*

Maize is native to the central Balsas River region of tropical southwest Mexico (see van Heerwaarden *et* *al*. 2011) and represents the main cereal crop of the Americas. More than three decades of focused research have demonstrated that phytoliths produced in the leaf and cob of maize are diagnostic, and distinguishable from those of teosinte (its wild ancestor) and other wild non-*Zea* grasses native to North, Central and South America (Ball *et al*. 2016a). The criteria used for the identification of maize phytoliths employ both size and morphology and, as with phytoliths from other crop plants, vegetative and inflorescence structures can be distinguished (leaf, stalk and seed chaff).

Cucurbita *squashes and gourds and other Cucurbitaceae*
Squashes and gourds pertaining to the genus *Cucurbita*, as well as other types of Cucurbitaceae, were important early plants of the Americas, and they produce phytoliths of high taxonomic information to document their archaeological history. Many parts of the squash/gourd plants are high phytolith producers and the phytoliths obtained from fruit rinds are the most diagnostic. Morphotypic and morphometric studies have been used to discriminate between wild and domesticated *Cucurbita* species, with domesticated fruits often producing much larger and thicker phytoliths (Piperno 2006). Bottle gourd (*Lagenaria siceraria*) is indigenous to Africa, but spread to other continents by the early Holocene, and its large, scalloped phytoliths from fruit rinds have been recovered from early Holocene and later deposits in Central and South America (e.g. Piperno 2011).

Maranta *and* Calathea *(arrowroot and llerén, Marantaceae); Canna (*Achira*, Cannaceae); Manioc (*Manihot esculenta*, Euphorbiaceae)*
These tropical root crops (roots, rhizomes, tubers and corms) are today of minor importance, with the exception of manioc. The plants from the Zingiberales (Marantaceae and Cannaceae) generally produce (abundant) phytoliths that can be taxonomically diagnostic at order, family, genus and species level (e.g. Pearsall 2015a). Manioc, today one of the major root crops of the Americas, is a low silica accumulator (Piperno 2006), but by processing considerable quantities of tissues it was possible to identify silicified secretory bodies in the root rind, leaf, stem and fruit (Chandler-Ezell *et al*. 2006).

Modern comparative approaches

Phytolith studies with an ethnoarchaeological or modern comparative approach started to become widespread from the late 2000s. This type of research concentrates on the analysis of phytoliths—often combined with other proxies—extracted from modern or historical ethnographic contexts. The aim of these studies is to build strong reference collections of phytolith assemblages produced by specific activities or materials. The rationale, grounded in middle-range theory, is that phytolith assemblages observed in ethnographic contexts can be linked directly to the anthropic or natural activity that produced them, thus offering interpretative values for archaeological and natural assemblages. The main themes in which ethnoarchaeological research on phytolith have been concentrated are:

1) The creation of plant and soil reference collections
2) Subsistence practices and other plant-related activities, such as crop processing
3) Use of space and spatial activities
4) The use of non-food plant resources, with a special focus on the identification of dung.

Plant and soil reference collections
Although not normally considered part of ethnoarchaeological research, the creation of reference collections responds to the general aim of creating a middle-range theory approach that help interpreting the archaeological (or environmental) record. Several studies have been devoted to the morphological and morphometric analyses of phytoliths produced by some of the major crops: Triticaceae and Avenae (Ball *et al*. 2009; 2017; Portillo *et al*. 2006); millets and sorghum (Lu *et al*. 2009; Madella *et al*. 2016; Out & Madella 2016; 2017; Tripathi *et al*. 2013; Zhang *et al*. 2011); and banana (Ball *et al*. 2006; Vrydaghs *et al*. 2009). Fewer studies have concentrated on non-domesticated species, focusing on phytolith production in wild grasses (Babot *et al*. 2017; Neumann *et al*. 2017), in dicotyledonous species (Collura & Neumann 2017; Mercader *et al*. 2009) or in a combination of plants (Tsartsidou *et al*. 2007). Reference collections of phytolith assemblages from sediments and soils are also investigated in order to be able to identify past vegetation cover (e.g. Blinnikov *et al*. 2013; Esteban *et al*. 2017; Gomes Coe *et al*. 2017; Iriarte & Paz 2009; Mercader *et al*. 2009). Either directed to the phytolith production of specific species or groups of species, conducted directly on the plants, or of phytolith assemblages representative of a specific vegetation type, these studies form the basis of the correct reconstruction of past plant use and plant cover.

Subsistence practices and plant-related activities
The major advances regarding subsistence practices and plant-related activities, in general, include the identification of the exploitation of wild and garden species (Weisskopf 2016) thereby addressing one of the major problems in archaeobotany, that is the vis-

ibility of so-called 'alternative resources'. Phytoliths, being both exceedingly resistant to taphonomic alterations and plant-part specific, can be extremely useful in identifying different crop-processing steps. Harvey and Fuller (2005) showed how the *chaîne opératoire* of processing of millets and rice produces phytolith assemblages exclusive for each step. Specific stages of the crop-processing chain can also be investigated: Liu *et al*. (2017) analyse the use-wear effect of phytoliths on lithic tools, an approach that can offer fundamental insights to our understanding of pre-domestication processes. Ruiz-Perez *et al*. (2016) analysed phytolith assemblages from two ethnographic threshing floors, showing that the general pattern of phytolith deposition on the floor mirrored the circular movement of the activity performed.

Spatial analyses of anthropic activities

One of the most novel aspects of phytolith research in ethnoarchaeology is the application of multi-proxy and statistical methods for the identification of spatial distribution of activities. Briz Godino *et al*. (2011) and Zurro *et al*. (2017) use phytoliths in combination with other proxies to detail the formation processes and distinguish between specialized and generic activities in a shell-midden context in Tierra del Fuego. Hunter-gatherer contexts are especially difficult to study as they leave much more scanty evidence on the ground in respect to settled villages. Thus the work by Friesem *et al*. (2016) is particularly important in that it outlines a methodology that allows the identification of activity areas and their maintenance even in hostile preservation environments, such as tropical rainforests. On the other hand, settled farming villages produce assemblages that are much richer and often better preserved so that activities are recognizable at both domestic and village level (Jenkins *et al*. 2017; Portillo *et al*. 2014; Tsartsidou *et al*. 2008; 2009).

Use of non-food resources: dung and mud bricks

Amongst the plant non-food resources, much research has been invested in using phytoliths as one of the proxies for the identification of animal dung. Dung is widespread in archaeological contexts, although it is not always easy to identify as sometimes it leaves ephemeral traces and the most common proxy for dung—spherulites—is not always reliable (Lancelotti & Madella 2012). The correct identification of animal dung is fundamental for the implication that the use of this material has on the interpretation of human behaviour, on the one hand, for the correct identification of husbandry practices and pastoral sites (Elliott *et al*. 2015; Shahack-Gross *et al*. 2003; 2004) and on the other hand, for its importance as a fuel resource in arid and semi-arid environments, where its presence and constant use can indicate signs of environmental degradation and wood-resource overexploitation. Ethnographic fireplaces have thus been intensively investigated in recent years in order specifically to identify signatures of dung (Portillo *et al*. 2017) or with the aim of discriminating various fuel sources (Friesem *et al*. 2017; Gur-Arieh *et al*. 2013; Lancelotti *et al*. 2017). All of these studies have highlighted the potential of phytoliths, as part of a wider set of proxies and with the right statistical treatment of data, for the identification of fireplaces and fuels, including fuels alternative to wood. Lastly, a few studies have concentrated on the analysis of construction materials, such as mud bricks (Friesem *et al*. 2014; Jenkins *et al*. 2017), to be able to distinguish between the signature left by their degradation and that of other intentional human activities.

Environmental reconstructions and past land use

Phytoliths have been successfully used as a proxy for reconstructing Quaternary vegetations, especially in depositional environments where other organic proxies are poorly preserved, such as alluvial deposits and soils (e.g. Bremond *et al.* 2017; Calegari *et al.* 2017; McMichael *et al.* 2013; Wallis 2001) and rocks (e.g. Strömberg *et al.* 2007). Phytolith assemblages from ancient superficial sediments reflect deposition from local vegetation and therefore local climatic characteristics, making it possible to use them to infer palaeoclimate and palaeoenvironments. However, precise assessment of past environments might be hampered by pre- and post-depositional processes that tend to alter the original plant community production. A diverse set of approaches supported by multivariate statistical methods, such as phytolith indexes (Bremond *et al*. 2005; 2008) and modern analogues analysis (Watling *et al*. 2016), were recently developed partly to solve this problem. The application of these quali/quantitative techniques has made it possible to determine which vegetation and environmental factors are dominant in influencing phytolith type distributions and to identify these parameters in the fossil phytolith assemblages on the basis of modern assemblages.

Earth system models help in understanding the earth system as a whole and the drivers of change and assist in envisaging our future. A major research question that cross-cuts the social, biological and physical sciences is to understand the scope of early human land use, the resultant changes in land cover and the consequent feedbacks to climate and human cultural systems during the Holocene and Anthropocene. There remains disagreement over the forms, scope and intensity of prehistoric land use and the degree to which early anthropogenic land-cover change affected the global climate system. Researchers agree that the intensity and extent of human land use increased during the Holocene, when hunter-gatherer societies gave way to early pastoral and agricultural societies, which in turn increased in complexity. These effects of human land use on terrestrial ecosystems were profound at local to regional scales, but there is uncertainty about how important they were at global scale, and this uncertainty is fostered by the lack of high-quality data-based syntheses of global land use and anthropogenic land-cover change for the last 12,000 years. Phytoliths have been useful in extending on- and off-site high-quality datasets to supply more refined synthesis of land use in areas such as understanding the irrigation of crops (Madella *et al*. 2009), arable land (Golyeva & Svirida 2017), past agricultural systems (Meister *et al*. 2017) and forest management (Levin & Ayres 2017; Levis *et al*. 2017; Nogué *et al*. 2017).

Final remarks

Phytoliths were observed, as part of mineral particles produced by plant tissues, more than 340 years ago, but it was Struve who pioneered the first scientific study in 1835. Research on phytoliths has seen various moments of interest, such as the early works on plant studies and (palaeo)ecology, but it was within archaeology that phytoliths gained momentum and widespread acknowledgement. This 'popularity' originates in the new avenues opened by phytoliths to investigate central archaeological questions, with the possibility of identifying previously unrecognizable (or difficult to discern) plants in the archaeological record, as well as human activities (e.g. crop processing). The development and refinement of phytolith systematics and crop identification via a double morphotypic and morphometric approach were major endeavours that stemmed from archaeology. Future advances should look at augmenting the comparative collections available together with their accessibility to researchers and refining the field-sampling approach and laboratory processing to further standardization, and push on the ethnoarchaeology and experimental archaeology work to provide a framework for a better understanding of the relationship between human activities and phytolith signatures.

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References

Albert, R.M., O. Lavi, L. Estroff, S. Weiner, A. Tsatskin, A. Ronen & S. Lev-Yadun, 1999. Mode of occupation of Tabun Cave, Mt Carmel, Israel during the Mousterian period: A study of the sediments and phytoliths. *Journal of Archaeological Science* 26(10), 1249–60.

Albert, R.M., S. Weiner, O. Bar-Yosef & L. Meignen, 2000. Phytoliths in the Middle Palaeolithic deposits of Kebara Cave, Mt Carmel, Israel: study of the plant materials used for fuel and other purposes. *Journal of Archaeological Science* 27(10), 931–47.

Alexandre, A., J.D. Meunier, A.M. Lézine, A. Vincens & D. Schwartz, 1997. Phytoliths: indicators of grassland dynamics during the late Holocene in intertropical Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology* 136(1–4), 213–29.

Alexandre, A., J.D. Meunier, A. Mariotti & F. Soubies, 1999. Late Holocene phytolith and carbon-isotope record from a latosol at Salitre, South-Central Brazil. *Quaternary Research* 51(2), 187–94.

Alexandre, A., J. Crespin, F. Sylvestre, C. Sonzogni & D.W. Hilbert, 2012. The oxygen isotopic composition of phytolith assemblages from tropical rainforest soil tops (Queensland, Australia): validation of a new paleoenvironmental tool. *Climate of the Past* 8(1), 307–24.

Anderson, P.C., 1980. A testimony of prehistoric tasks: diagnostic residues on stone tool working edges. *World Archaeology* 12(2), 181–94.

Asscher, Y., S. Weiner & E. Boaretto, 2017. A new method for extracting the insoluble occluded carbon in archaeological and modern phytoliths: detection of 14C depleted carbon fraction and implications for radiocarbon dating. *Journal of Archaeological Science* 78, 57–65.

Babot, M. del Pilar, M.G. Musaubach & A. Plos, 2017. An archaeobotanical perspective in the study of inflorescence phytoliths of wild grasses from arid and semi-arid environments of Argentina. *Quaternary International* 434, 129–41.

Baker, G., 1959a. Opal phytoliths in some Victorian soils and 'Red Rain' residues. *Australian Journal of Botany* 7, 64–87.

Baker, G., 1959b. Fossil opal phytoliths and phytolith nomenclature. *Australian Journal of Science* 21, 305–6.

Ball, T.B., J.D. Brotherson & J.S. Gardner, 1993. A typologic and morphometric study of variation in phytoliths form einkorn wheat (*Triticum monococcum*). *Canadian Journal of Botany* 71(9), 1182–92

Ball, T., K. Chandler-Ezell, R. Dickau, *et al.*, 2016a. Phytoliths as a tool for investigations of agricultural origins and dispersals around the world. *Journal of Archaeological Science* 68, 32–45.

Ball, T.B., A. Davis, R.R. Evett, J.l. Ladwig, M. Tromp, W.A. Out & M. Portillo, 2016b. Morphometric analysis of phytoliths: recommendations towards standardization from the International Committee for Phytolith Morphometrics. *Journal of Archaeological Science* 68, 106–11.

Ball, T.B., R. Ehlers & M.D. Standing, 2009. Review of typologic and morphometric analysis of phytoliths produced by wheat and barley. *Breeding Science* 59(5), 505–12.

Ball, T.B., J.S. Gardner & N. Anderson, 1999. Identifying inflorescence phytoliths from selected species of wheat (*Triticum monococcum*, *T. dicoccon*, *T. dicoccoides*, and *T. aestivum*) and barley (*Hordeum vulgare* and *H. spontaneum*) (Gramineae). *American Journal of Botany* 86(11), 1615–23.

Ball, T., L. Vrydaghs, T. Mercer, M. Pearce, S. Snyder, Z. Lisztes-Szabó, & Á. Pető, 2017. A morphometric study of variance in articulated dendritic phytolith wave lobes within selected species of Triticeae and Aveneae. *Vegetation History and Archaeobotany* 26(1), 85–97.

Ball, T., L. Vrydaghs, I. Van Den Hauwe, J. Manwaring & E. De Langhe, 2006. Differentiating banana phytoliths: wild and edible *Musa acuminata* and *Musa balbisiana*. *Journal of Archaeological Science* 33(9), 1228–36.

Barboni, D., R. Bonnefille, A. Alexandre & J.D. Meunier, 1999. Phytoliths as paleoenvironmental indicators, west side Middle Awash Valley, Ethiopia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 152(1), 87–100.

Blinnikov, M.S., C.M. Bagent & P.E. Reyerson, 2013. Phytolith assemblages and opal concentrations from modern soils differentiate temperate grasslands of controlled composition on experimental plots at Cedar Creek, Minnesota. *Quaternary International* 287, 101–13.

Bowdery, D., 1999. Phytoliths from tropical sediments: reports from Southeast Asia and Papua New Guinea. *Bulletin of the Indo-Pacific Prehistory Association* 18, 159–68.

Bozarth, S.R., 1987. Diagnostic opal phytoliths from rinds of selected Cucurbita species. *American Antiquity* 52(3), 607–15.

Bozarth, S.R., 1990. Diagnostic opal phytoliths from pods of selected varieties of common beans (*Phaseolus vulgaris*). *American Antiquity* 55(1), 98–104.

Bozarth, S.R., 1992. Classification of opal phytoliths formed in selected dicotyledons native to the Great Plains, in *Phytolith Systematics: Emerging issues*, eds. G. Rapp Jr & S.C. Mulholland. (Advances in Archaeological and Museum Science 1.) Boston (MA): Springer, 193–214.

Bremond, L., A. Alexandre, C. Hély & J. Guiot, 2005. A phytolith index as a proxy of tree cover density in tropical areas: calibration with Leaf Area Index along a forest–savanna transect in southeastern Cameroon. *Global and Planetary Change* 45(4), 277–93.

Bremond, L., A. Alexandre, M.J. Wooller, *et al.*, 2008. Phytolith indices as proxies of grass subfamilies on East African tropical mountains. *Global and Planetary Change* 61, 209–24.

Bremond, L., S.C. Bodin, I. Bentaleb, C. Favier & S. Canal, 2017. Past tree cover of the Congo Basin recovered by phytoliths and $\delta^{13}C$ along soil profiles. *Quaternary International* 434, 91–101.

Briz Godino, I., M. Álvarez, A. Balbo, D. Zurro, M. Madella, X. Villagrán & C. French, 2011. Towards high-resolution shell midden archaeology: experimental and ethnoarchaeology in Tierra del Fuego (Argentina). *Quaternary International* 239(1), 125–34.

Brochier, J.E., P. Villa, M. Giacomarra & A. Tagliacozzo, 1992. Shepherds and sediments: geo-ethnoarchaeology of pastoral sites. *Journal of Anthropological Archaeology* 11(1), 47–102.

Cabanes, D. & R. Shahack-Gross, 2015. Understanding fossil phytolith preservation: the role of partial dissolution in paleoecology and archaeology. *PloS One* 10(5), p.e0125532.

Calegari, M.R., S.D. Lopes Paisani, F.A. Cecchet, P.L. de Lima Ewald, M.L. Osterrieth, J.C. Paisani & M.E. Pontelli, 2017. Phytolith signature on the Araucarias Plateau – Vegetation change evidence in Late Quaternary (South Brasil). *Quaternary International* 434, 117–28.

Calegari, M.R., M. Madella, P. Vidal-Torrado, X.L. Otero, F. Macias & M. Osterrieth, 2013. Opal phytolith extraction in oxisols. *Quaternary International* 287, 56–62.

Carter, J.A., 2009. Atmospheric carbon isotope signatures in phytolith-occluded carbon. *Quaternary International* 193(1), 20–29.

Chandler-Ezell, K., D.M. Pearsall & J.A. Zeidler, 2006. Root and tuber phytoliths and starch grains document manioc (*Manihot esculenta*), arrowroot (*Maranta arundinacea*), and llerén (*Calathea* sp.) at the Real Alto site, Ecuador. *Economic Botany* 60, 213–20.

Chapligin, B., M.J. Leng, E. Webb, *et al.*, 2011. Inter-laboratory comparison of oxygen isotope compositions from biogenic silica. *Geochimica et Cosmochimica Acta* 75(22), 7242–56.

Chen, S.T. & S.Y. Smith, 2013. Phytolith variability in Zingiberales: a tool for the reconstruction of past tropical vegetation. *Palaeogeography, Palaeoclimatolology, Palaeoecology* 370, 1–12.

Ciochon, R.L., D.R. Piperno & R.G. Thompson, 1990. Opal phytoliths found on the teeth of the extinct ape *Gigantopithecus blacki*: implications for paleodietary studies. *Proceedings of the National Academy of Sciences* 87(20), 8120–24.

Collura, L.V, K. Neumann, 2017. Wood and bark phytoliths of West African woody plants. *Quaternary International* 434, 142–59.

Corbineau, R., P.E. Reyerson, A. Alexandre & G.M. Santos, 2013. Towards producing pure phytolith concentrates from plants that are suitable for carbon isotopic analysis. *Review of Palaeobotany and Palynology* 197, 179–85.

Corteletti, R., R. Dickau, P. DeBlasis & J. Iriarte, 2015. Revisiting the economy and mobility of southern proto-Jê (Taquara-Itararé) groups in the southern Brazilian highlands: starch grain and phytolith analyses from the Bonin site, Urubici, Brazil. *Journal of Archaeological Science* 58, 46–61.

Crespin, J., A. Alexandre, F. Sylvestre, C. Sonzogni, C. Paillès & V. Garreta, 2008. IR laser extraction technique applied to oxygen isotope analysis of small biogenic silica samples. *Analytical Chemistry* 80(7), 2372–8.

Danielson, D. & K. Reinhard, 1998. Human dental microwear caused by calcium oxalate phytoliths in prehistoric diet of the lower Pecos region, Texas. *American Journal of Physical Anthropology* 107, 297–304.

Darwin, C., 1846. An account of the fine dust which often falls on vessels in the Atlantic Ocean. *Quarterly Journal of the Geological Society of London* 2, 26–30.

De Langhe, E., L. Vrydaghs, P. de Maret, X. Perrier & T. Denham, 2009. Why bananas matter: an introduction to the history of banana domestication. *Ethnobotany Research and Applications* 7, 165–77.

Elbaum, R., C. Melamed-Bessudo, N. Tuross, A.A. Levy & S. Weiner, 2009. New methods to isolate organic materials from silicified phytoliths reveal fragmented glycoproteins but no DNA. *Quaternary International* 193(1), 11–19.

Elliott, S., R. Bendrey, J. Whitlam, K.R. Aziz & J. Evans, 2015. Preliminary ethnoarchaeological research on modern animal husbandry in Bestansur, Iraqi Kurdistan: integrating animal, plant and environmental data. *Environmental Archaeology* 20(3), 283–303.

Esteban, I., J.C. De Vynck, E. Singels, *et al.*, 2017. Modern soil phytolith assemblages used as proxies for Paleoscape reconstruction on the south coast of South Africa. *Quaternary International* 434, 160–79.

Fox, C.L., A. Perez-Perez & J. Juan, 1994. Dietary information through the examination of plant phytoliths on the enamel surface of human dentition. *Journal of Archaeological Science* 21(1), 29–34.

Fredlund, G.G. & L.L. Tieszen, 1997. Phytolith and carbon isotope evidence for late Quaternary vegetation and climate change in the southern Black Hills, South Dakota. *Quaternary Research* 47(2), 206–17.

Friesem, D.E., G. Tsartsidou, P. Karkanas & R. Shahack-Gross, 2014. Where are the roofs? A geo-ethnoarchaeological study of mud brick structures and their collapse processes, focusing on the identification of roofs. *Archaeological and Anthropological Sciences* 6(1), 73–92.

Friesem, D.E., N. Lavi, M. Madella, P. Ajithprasad & C. French, 2016. Site formation processes and hunter-gatherers use of space in a tropical environment: a geo-ethnoarchaeological approach from South India. *PloS One* 11(10), p.e0164185.

Friesem, D.E., N. Lavi, M. Madella, E. Boaretto, P. Ajithparsad & C. French, 2017. The formation of fire residues associated with hunter-gatherers in humid tropical environments: a geo-ethnoarchaeological perspective. *Quaternary Science Reviews* 171, 85–99.

Fuller, D.Q & A.R. Weisskopf, 2011. The early rice project: from domestication to global warming. *Archaeology International* 13/14, 44–51.

García-Granero, J.J., C. Lancelotti, M. Madella & P. Ajithprasad, 2015a. Plant processing activities at Loteshwar (North Gujarat, India): a micro-botanical approach, in *South Asian Archaeology and Art 2012*, Vol. 1. *Man and Environment in Prehistoric and Protohistoric South Asia: New perspectives*, eds. V. Lefèvre, A. Didier & B. Mutin. Turnhout: Brepols, 99–116.

García-Granero, J.J., C. Lancelotti & M. Madella, 2015b. A tale of multi-proxies: integrating macro- and microbotanical remains to understand subsistence strategies. *Vegetation History and Archaeobotany* 24, 121–33.

Golyeva, A. & N. Svirida, 2017. Quantitative distribution of phytoliths as reliable diagnostical criteria of ancient arable lands. *Quaternary International* 434, 51–7.

Gomes Coe, H.H., Y.B. Medina Ramos, C. Pereira dos Santos, A.L. Carvalho da Silva, C. Pereira Silvestre, N. Borrelli & L. de Oliveira Furtado de Sousa, 2017. Dynamics of production and accumulation of phytolith assemblages in the Restinga of Maricá, Rio De Janeiro, Brazil. *Quaternary International* 434, 58–69.

Grob, A. 1896. Beiträge zur Anatomie der Epidermis der Gramineenblätter. *Bibliotheca Botanica* 36, 1–63.

Gu, Y., Z. Zhao & D.M. Pearsall, 2013. Phytolith morphology research on wild and domesticated rice species in East Asia. *Quaternary International* 287, 141–8.

Gur-Arieh, S., E. Mintz, E. Boaretto & R. Shahack-Gross, 2013. An ethnoarchaeological study of cooking installations in rural Uzbekistan: development of a new method for identification of fuel sources. *Journal of Archaeological Science* 40(12), 4331–47.

Haberlandt, G., 1914. *Physiological Plant Anatomy* (trans. M. Drummond). London: Macmillan.

Harvey, E.L. & D.Q Fuller, 2005. Investigating crop processing using phytolith analysis: the example of rice and millets. *Journal of Archaeological Science* 32(5), 739–52.

Helbaek, H., 1961. Studying the diet of ancient man. *Archaeology* 14, 95–101.

Helbaek, H., 1969. Plant-collecting, dry-farming and irrigation agriculture in prehistoric Deh Luran, in *Prehistory and Human Ecology of the Deh Luran plain. An early village sequence from Khuzistan, Iran*, eds. F. Hole, K.V. Flannery & J.A. Neely. (Memoirs of the Museum of Anthropology.) Chicago (IL): University of Michigan, 383–426.

Hodson, M.J., 2016. The development of phytoliths in plants and its influence on their chemistry and isotopic composition. Implications for palaeoecology and archaeology. *Journal of Archaeological Science* 68, 62–9.

Hodson, M.J., A.G. Parker, M.J. Leng & H.J. Sloane, 2008. Silicon, oxygen and carbon isotope composition of wheat (*Triticum aestivum* L.) phytoliths: implications for palaeoecology and archaeology. *Journal of Quaternary Science* 23(4), 331–9.

Horrocks, M., 2005. A combined procedure for recovering phytoliths and starch residues from soils, sedimentary deposits and similar materials. *Journal of Archaeological Science* 32(8), 1169–75.

Houyuan, L., W. Naiqin & L. Baozhu, 1997. Recognition of rice phytoliths, in *The State of the Art of Phytoliths in Soils and Plants,* eds. A. Pinalla, J. Juan-Tresserras & M.J. Machado. (Monografias del Centro de Ciencias Medioambientales.) Madrid: Consejo Superior de Investigaciones Cientificas, 59–174.

Huan, X., Q. Li, Z. Ma, L. Jiang & X. Yang, 2014. Fan-shaped phytoliths reveal the process of rice domestication at Shangshan site, Zhejiang Province. *Quaternary Sciences* 34, 106–13. (In Chinese)

Iriarte, J. & E.A. Paz, 2009. Phytolith analysis of selected native plants and modern soils from southeastern Uruguay and its implications for paleoenvironmental and archeological reconstruction. *Quaternary International* 193(1), 99–123.

Iriarte, J., M.J. Power, S. Rostain, *et al.*, 2012. Fire-free land use in pre-1492 Amazonian savannas. *Proceedings of the National Academy of Sciences* 109, 6473–8.

Jahren, A.H., N. Toth, K. Schick, J.D. Clark & R.G. Amundson, 1997. Determining stone tool use: chemical and morphological analyses of residues on experimentally manufactured stone tools. *Journal of Archaeological Science* 24(3), 245–50.

Jansen, J.H.F. & J.M. van Iperen, 1991. A 220,000-year climatic record for the east equatorial Atlantic Ocean and equatorial Africa: evidence from diatoms and opal phytoliths in the Zaire (Congo) deep-sea fan. *Paleoceanography* 6(5), 573–91.

Jenkins, E.L., S.L. Allcock, S. Elliott, C. Palmer & J. Grattan, 2017. Ethno-geochemical and phytolith studies of activity related patterns: a case study from Al Ma'tan, Jordan. *Environmental Archaeology* 22(4), 412–33.

Katz, O., D. Cabanes, S. Weiner, A.M. Maeir, E. Boaretto & R. Shahack-Gross, 2010. Rapid phytolith extraction for analysis of phytolith concentrations and assemblages during an excavation: an application at Tell es-Safi/Gath, Israel. *Journal of Archaeological Science* 37(7), 1557–63.

Kealhofer, L. & D. Penny, 1998. A combined pollen and phytolith record for fourteen thousand years of vegetation change in northeastern Thailand. *Review of Palaeobotany and Palynology* 103(1), 83–93.

Kealhofer, L., R. Torrence & R. Fullagar, 1999. Integrating phytoliths within use-wear/residue studies of stone tools. *Journal of Archaeological Science* 26(5), 527–46.

Kelly, E.F., S.W. Blecker, C.M. Yonker, C.G. Olson, E.E. Wohl & L.C. Todd, 1998. Stable isotope composition of soil organic matter and phytoliths as paleoenvironmental indicators. *Geoderma* 82(1), 59–81.

Kistler, L., 2012. Ancient DNA extraction from plants, in *Ancient DNA: Methods and protocols*, eds. B. Shapiro & M. Hofreiter. (Methods in Molecular Biology 840.) New York (NY): Humana Press, 71–9.

Kondo, R., C. Childs & I. Atkinson, 1994. *Opal Phytoliths of New Zealand* (Vol. 85). Lincoln (NZ): Manaaki Whenua Press.

Lancelotti, C. & M. Madella, 2012. The 'invisible' product: developing markers for identifying dung in archaeological contexts. *Journal of Archaeological Science* 39(4), 953–63.

Lancelotti, C., J. Ruiz-Pérez & J.J. García-Granero, 2017. Investigating fuel and fireplaces with a combination of phytoliths and multi-element analysis; an ethnographic experiment. *Vegetation History and Archaeobotany* 26(1), 75–83.

Larson G., D. Piperno, R.G. Allaby, *et al.,* 2014. Current perspectives and the future of domestication studies. *Proceedings of the National Academy of Sciences* 111, 6139–46.

Leng, M.J. & H.J. Sloane, 2008. Combined oxygen and silicon isotope analysis of biogenic silica. *Journal of Quaternary Science* 23(4), 313–19.

Leng, M.J., G.E. Swann, M.J. Hodson, J.J. Tyler, S.V. Patwardhan & H.J. Sloane, 2009. The potential use of silicon isotope composition of biogenic silica as a proxy for environmental change. *Silicon* 1(2), 65–77.

Lentfer, C.J., 2009. Tracing domestication and cultivation of bananas from phytoliths: an update from Papua New Guinea. *Ethnobotany Research and Applications* 7, 247–70.

Lentfer, C.J. & W.E. Boyd, 1998. A comparison of three methods for the extraction of phytoliths from sediments. *Journal of Archaeological Science* 25(12), 1159–83.

Levin, M.J. & W.S. Ayres, 2017. Managed agroforests, swiddening, and the introduction of pigs in Pohnpei, Micronesia: phytolith evidence from an anthropogenic landscape. *Quaternary International* 434, 70–7.

Levis, C., F.R.C. Costa, F. Bongers, *et al.*, 2017. Persistent effects of pre-Columbian plant domestication on Amazonian forest composition. *Science* 355, 925–31.

Liu, L., J. Wang & M.J. Levin, 2017. Usewear and residue analyses of experimental harvesting stone tools for archaeological research. *Journal of Archaeological Science: Reports* 14, 439–53.

Logan, A.L., C.A. Hastorf & D.M. Pearsall, 2012. 'Let's drink together': early ceremonial use of maize in the Titicaca Basin. *Latin American Antiquity* 23, 235–58.

Lombardo, U., J. Ruiz-Pérez & M. Madella, 2016. Sonication improves the efficiency, efficacy and safety of phytolith extraction. *Review of Palaeobotany and Palynology* 235, 1–5.

Lu, H., J. Zhang, N. Wu, K.B. Liu, D. Xu & Q. Li, 2009. Phytoliths analysis for the discrimination of foxtail millet (*Setaria italica*) and common millet (*Panicum miliaceum*). *PLoS One* 4(2), e4448.

Madella, M., 1997. Phytoliths from a Central Asia loess-paleosol sequence and modern soils: their taphonomical and palaeoecological implication, in *The State of the Art of Phytoliths in Soils and Plants*, eds. A. Pinalla, J. Juan-Tresserras & M.J. Machado. (Monografias del Centro de Ciencias Medioambientales.) Madrid: Consejo Superior de Investigaciones Cientificas, 49–58.

Madella, M., A. Alexandre & T. Ball, 2005. International code for phytolith nomenclature 1.0. *Annals of botany* 96(2), 253–60.

Madella, M., J.J. Garcia-Granero, W. Out, P. Ryan & D. Usai, 2014. Microbotanical evidence of domestic cereals in Africa 7000 years ago. *PLoS One* 9(10), e110177.

Madella, M., M.K. Jones, P. Echlin, A. Powers-Jones & M. Moore, 2009. Plant water availability and analytical microscopy of phytoliths: implications for ancient irrigation in arid zones. *Quaternary International* 193(1), 32–40.

Madella, M. & C. Lancelotti, 2012. Taphonomy and phytoliths: a user manual. *Quaternary International* 275, 76–83.

Madella, M., C. Lancelotti & J.J. García-Granero, 2016. Millet microremains – an alternative approach to understand cultivation and use of critical crops in prehistory. *Archaeological and Anthropological Sciences* 8(1), 17–28.

Madella, M., A.H. Powers-Jones & M.K. Jones, 1998. A simple method of extraction of opal phytoliths from sediments using a non-toxic heavy liquid. *Journal of Archaeological Science* 25(8), 801–3.

Mbida, C., H. Doutrelepont, L. Vrydaghs, *et al.*, 2001. First archaeological evidence of banana cultivation in central Africa during the third millennium before present. *Vegetation History and Archaeobotany* 10, 1–6.

McClaran, M.P. & M. Umlauf, 2000. Desert grassland dynamics estimated from carbon isotopes in grass phytoliths and soil organic matter. *Journal of Vegetation Science* 11(1), 71–6.

McMichael, C.H., M.B. Bush, M.R. Silman, *et al.*, 2013. Historical fire and bamboo dynamics in western Amazonia. *Journal of Biogeography* 40, 299–309.

Meister, J., Jan. Krause, B. Müller-Neuhof, M. Portillo, T. Reimann & B. Schütt, 2017. Desert agricultural systems at EBA Jawa (Jordan): integrating archaeological and paleoenvironmental records. *Quaternary International* 434, 33–50.

Mercader, J., F. Runge, L. Vrydaghs, H. Doutrelepont, C.E. Ewango, & J. Juan-Tresseras, 2000. Phytoliths from archaeological sites in the tropical forest of Ituri, Democratic Republic of Congo. *Quaternary Research* 54(1), 102–12.

Mercader, J., T. Bennett, C. Esselmont, S. Simpson & D. Walde, 2009. Phytoliths in woody plants from the Miombo woodlands of Mozambique. *Annals of Botany* 104(1), 91–113.

Metcalfe, C.R., 1960. *Anatomy of the Monocotyledons. I. Gramineae.* London: Oxford University Press.

Middleton, W.D. & I. Rovner, 1994. Extraction of opal phytoliths from herbivore dental calculus. *Journal of Archaeological Science* 21(4), 469–73.

Mobius, M., 1908. Über die Festlegung der Kalksaltze und Kieselkörper in den Pflanzenzellen. *Berichte der Deutschen Botanischen Gesellschaft* 26a, 29.

Mulholland, A.C. & G. Rapp Jr, 1992. Phytolith systematics: an introduction, in *Phytolith Systematics: Emerging issues*, eds. G. Rapp, Jr & S.C. Mulholland. (Advances in Archaeological and Museum Science 1.) Boston (MA): Springer, 1–13.

Mulholland, S.C., G. Rapp Jr & A.L. Ollendorf, 1988. Variation in phytoliths from corn leaves. *Canadian Journal of Botany* 66(10), 2001–8.

Netolitzky, F., 1900. Mikroskopische Untersuchung gänzlich verkohlter vorgeschichtlicher Nahrungsmittel aus Tirol. *Zeitschrift für Untersuchung der Nahrungs- und Genussmittel* 3, 401–7.

Netolitzky, F., 1914. Die Hirse aus antiken Funden. *Sitzbuch der Kaiserliche Akademie für Wissenschaft der Mathematisch-Naturwissenschaften* 123, 725–59.

Neumann, K., A.G. Fahmy, N. Müller-Scheeßel & M. Schmidt, 2017. Taxonomic, ecological and palaeoecological significance of leaf phytoliths in West African grasses. *Quaternary International* 434, 15–32.

Nogué, S., K. Whicher, A.G. Baker, S.A. Bhagwat & K.J. Willis, 2017. Phytolith analysis reveals the intensity of past land use change in the Western Ghats biodiversity hotspot. *Quaternary International* 437, 82–9.

Novello, A. & D. Barboni, 2015. Grass inflorescence phytoliths of useful species and wild cereals from sub-Saharan Africa. *Journal of Archaeological Science* 59, 10–22.

Ollendorf, A.L., 1992. Toward a classification scheme of sedge (Cyperaceae) phytoliths, in *Phytolith Systematics: Emerging issues*, eds. G. Rapp Jr & S.C. Mulholland. (Advances in Archaeological and Museum Science 1.) Boston (MA): Springer, 91–111.

Ollendorf, A.L., S.C. Mulholland & G. Rapp Jr, 1987. Phytoliths from some Israeli sedges. *Israel Journal of Botany* 36(3), 125–32.

Out, W.A. & M. Madella, 2016. Morphometric distinction between bilobate phytoliths from *Panicum miliaceum* and *Setaria italica* leaves. *Archaeological and Anthropological Science*s 8(3), 505–21.

Out, W.A. & M. Madella, 2017. Towards improved detection and identification of crop by-products: morphometric analysis of bilobate leaf phytoliths of *Pennisetum glaucum* and *Sorghum bicolor*. *Quaternary International* 434, 1–14.

Parr, J.F., 2002. A comparison of heavy liquid floatation and microwave digestion techniques for the extraction of fossil phytoliths from sediments. *Review of Palaeobotany and Palynology* 120(3), 315–36.

Parr, J.F. & L.A. Sullivan, 2005. Soil carbon sequestration in phytoliths. *Soil Biology and Biochemistry* 37(1), 117–24.

Pearsall, D.M., 2015a. *The Phytoliths in the Flora of Ecuador Project: Order tables*. Online resource: http://phytolith.missouri.edu

Pearsall, D.M., 2015b. *Paleoethnobotany. A handbook of procedures* (3rd edition). Walnut Creek (CA): Left Coast Press.

Piperno, D.R., 1984. A comparison and differentiation of phytoliths from maize and wild grasses: use of morphological criteria. *American Antiquity* 49(2), 361–83.

Piperno, D.R., 2006. *Phytoliths: A comprehensive guide for archaeologists and paleoecologists*. Lanham/New York/Toronto/Oxford: AltaMira.

Piperno, D.R., 2009. Identifying crop plants with phytoliths (and starch grains) in Central and South America: a review and an update of the evidence. *Quaternary International* 193, 146–59.

Piperno, D.R., 2011. The origins of plant cultivation and domestication in the New World tropics. *Current Anthropology* 52(S4), S453–S470.

Piperno, D.R., 2012. New archaeobotanical information on early cultivation and plant domestication involving microplant (phytolith and starch grain) remains, in *Biodiversity in Agriculture – Domestication, evolution, and sustainability*, eds. P. Gepts, T.R Famula, R.L. Bettinger, S.B. Brush, A.B. Damania, P.M. McGuire & C.O. Qualset. Cambridge: Cambridge University Press, 136–59.

Piperno, D.R., 2016. Phytolith radiocarbon dating in archaeological and paleoecological research: a case study of phytoliths from modern Neotropical plants and a review of the previous dating evidence. *Journal of Archaeological Science* 68, 54–61.

Piperno, D.R., T.C. Andres & K.E. Stothert, 2000. Phytoliths in Cucurbita and other neotropical Cucurbitaceae and their occurrence in early archaeological sites from the lowland American tropics. *Journal of Archaeological Science* 27(3), 193–208.

Piperno, D.R., I. Holst, L. Wessel-Beaver & T.C. Andres, 2002. Evidence for the control of phytolith formation in Cucurbita fruits by the hard rind (Hr) genetic locus: archaeological and ecological implications. *Proceedings of the National Academy of Sciences* 99(16), 10923–8.

Piperno, D.R. & D.M. Pearsall, 1993. Phytoliths in the reproductive structures of maize and teosinte: implications for the study of maize evolution. *Journal of Archaeological Science* 20(3), 337–62.

Portillo, M., T. Ball & J. Manwaring, 2006. Morphometric analysis of inflorescence phytoliths produced by *Avena sativa* L. and *Avena strigosa* Schreb. *Economic Botany* 60(2), 121–9.

Portillo, M., S. Kadowaky, Y. Nishiaki & R.M. Albert, 2014. Early Neolithic household behavior at Tell Seker al-Aheimar (Upper Khabur, Syria): a comparison to ethnoarchaeological study of phytoliths and dung spherulites. *Journal of Archaeological Science* 42, 107–18.

Portillo, M., M.C. Belarte, J. Ramon, N. Kallala, J. Sanmartí & R.M. Albert, 2017. An ethnoarchaeological study of livestock dung fuels from cooking installations in northern Tunisia. *Quaternary International* 431, 131–44.

Powers, A.H., 1992. Great expectations: a short historical review of European phytolith systematics, in *Phytolith Systematics: Emerging issues*, eds. G. Rapp, Jr & S.C. Mulholland. (Advances in Archaeology and Museum Science 1.) Boston (MA): Springer, 15–35.

Powers, A.H. & D.D. Gilbertson, 1987. A simple preparation technique for the study of opal phytoliths from archaeological and Quaternary sediments. *Journal of Archaeological Science* 14(5), 529–35.

Radomski, K. & K. Neumann, 2011. Grasses and grinding stones: inflorescence phytoliths from modern West African Poaceae and archaeological stone artifacts, in *Windows on the African Past: Current approaches to African archaeobotany*, eds. A. Fahmy, S. Kahlheber & A.C. D'Andrea. Frankfurt: Africa Magna Verlag, 153–66.

Rosen, A.M., 1992. Preliminary identification of silica skeletons from Near Eastern archaeological sites: an anatomical approach, in *Phytolith Systematics: Emerging issues*, eds. G. Rapp Jr & S.C. Mulholland. (Advances in Archaeological and Museum Science 1.) Boston (MA): Springer, 129–47.

Rosen, A.M. & S. Weiner, 1994. Identifying ancient irrigation: a new method using opaline phytoliths from emmer wheat. *Journal of Archaeological Science* 21(1), 125–32.

Rovner, I., 1971. Potential of opal phytoliths for use in paleoecological reconstruction. *Quaternary Research* 1, 345–59.

Ruiz-Pérez, J., C. Lancelotti, B. Rondelli, M. Madella, J.J. García-Granero & L. Peña-Chocarro, 2016. Sickles and forks: traditional rural knowledge of agricultural practices and its possible applications in archaeology, in *The Intangible Elements of Culture in Ethnoarchaeological Research*, eds. S. Biagetti & F. Lugli. Cham: Springer International, 241–52.

Runge, F. & J. Runge, 1997. Opal phytoliths in East African plants and soils, in *The State of the Art of Phytoliths in Soils and Plants*, eds. A. Pinalla, J. Juan-Tresserras & M.J. Machado. (Monografias del Centro de Ciencias Medioambientales.) Madrid: Consejo Superior de Investigaciones Cientificas, 71–81.

Santos G.M. & A. Alexandre, 2017. The phytolith carbon sequestration concept: fact or fiction? A comment on 'Occurrence, turnover and carbon sequestration potential of phytoliths in terrestrial ecosystems by Song *et al.* doi: 10.1016/j.earscirev.2016.04.007'. *Earth-Science Reviews* 164, 251–5.

Santos, G.M., A. Alexandre & C. Prior, 2016. From radiocarbon analysis to interpretation: a comment on 'Phytolith radiocarbon dating in archaeological and paleoecological research: a case study of phytoliths from modern Neotropical plants and a review of the previous dating evidence. *Journal of Archaeological Science* 68, pp. 54–61', by Dolores R. Piperno. *Journal of Archaeological Science* 71, 51–8.

Schellenberg, H.C., 1908. Wheat and barley from the North Kurgan, Anau, in *Exploration in Turkestan* vol. 3, ed. R. Pumpelly. Washington (DC): Carnegie Institution, 471–3.

Shahack-Gross, R., A. Shemesh, D. Yakir & S. Weiner, 1996. Oxygen isotopic composition of opaline phytoliths: potential for terrestrial climatic reconstruction. *Geochimica et Cosmochimica Acta* 60(20), 3949–53.

Shahack-Gross, R., F. Marshall & S. Weiner, 2003. Geo-ethnoarchaeology of pastoral sites: the identification of livestock enclosures in abandoned Maasai settlements. *Journal of Archaeological Science* 30(4), 439–59.

Shahack-Gross, R., F. Marshall, K. Ryan & S. Weiner, 2004. Reconstruction of spatial organization in abandoned Maasai settlements: implications for site structure in the Pastoral Neolithic of East Africa. *Journal of Archaeological Science* 31(10), 1395–1411.

Sobolik, K.D., 1996. Lithic organic residue analysis: an example from the Southwestern Archaic. *Journal of Field Archaeology* 23(4), 461–9.

Song, Z., K. McGrouther & H. Wang, 2016. Occurrence, turnover and carbon sequestration potential of phytoliths in terrestrial ecosystems. *Earth-Science Reviews* 158, 19–30.

Strömberg, C.A., 2009. Methodological concerns for analysis of phytolith assemblages: does count size matter? *Quaternary International* 193(1), 124–40.

Strömberg, C.A., L. Werdelin, E.M. Friis & G. Saraç, 2007. The spread of grass-dominated habitats in Turkey and surrounding areas during the Cenozoic: phytolith evidence. *Palaeogeography, Palaeoclimatology, Palaeoecology* 250(1), 18–49.

Tripathi, D.K., S. Mishra, D.K. Chauhan, S.P. Tiwari & C. Kumar, 2013. Typological and frequency based study of opaline silica (phytolith) deposition in two common Indian Sorghum L. species. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* 83(1), 97–104.

Tsartsidou, G., S. Lev-Yadun, R.M. Albert, A. Miller-Rosen, N. Efstratiou & S. Weiner, 2007. The phytolith archaeological record: strengths and weaknesses evaluated based on a quantitative modern reference collection from Greece. *Journal of Archaeological Science* 34(8), 1262–75.

Tsartsidou, G., S. Lev-Yadun, N. Efstratiou & S. Weiner, 2008. Ethnoarchaeological study of phytolith assemblages from an agro-pastoral village in Northern Greece (Sarakini): development and application of a Phytolith Difference Index. *Journal of Archaeological Science* 35(3), 600–13.

Tsartsidou, G., S. Lev-Yadun, N. Efstratiou & S. Weiner, 2009. 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. *Journal of Archaeological Science* 36(10), 2342–52.

Tubb, H.J., M.J. Hodson & G.C. Hodson, 1993. The inflorescence papillae of the Triticeae: a new tool for taxonomic and archaeological research. *Annals of Botany* 72, 537–45.

Twiss, P.C., E. Suess & R.M. Smith, 1969. Morphological classification of grass phytoliths. *Soil Science Society of America Proceedings* 33, 109–15.

van Heerwaarden, J., J. Doebley, W.H. Briggs, *et al.*, 2011. Genetic signals of origin, spread, and introgression in a large sample of maize landraces. *Proceedings of the National Academy of Sciences* 108, 1088–92.

Vrydaghs, L., T. Ball, H. Volkaert, I. van den Houwe, J. Manwaring & E. De Langhe, 2009. Differentiating the volcaniform phytoliths of bananas: Musa acuminata. *Ethnobotany Research and Applications 7*, 239–46.

Vrydaghs, L. & E. De Langhe, 2003. Phytoliths: an opportunity to rewrite history, in *INIBAP Annual Report 2002*. Montpellier (France): International Network for the Improvement of Banana and Plantain, 14–17.

Wallis, L.A., 2001. Environmental history of northwest Australia based on phytolith analysis at Carpenter's Gap 1. *Quaternary International* 83, 103–17.

Wang, C. & H. Lu, 2012. Research progress of fan shaped phytoliths of rice and relevant issues. *Quaternary Sciences* 32, 269–81. (In Chinese)

Watanabe, N., 1955. Ash in archaeological sites, Rengo-Taikai Kiji. *Proceedings of the Joint Meeting of the Anthropological Society of Nippon and Japan Society of Ethnology* 9, 169–71. (In Japanese)

Watanabe, N., 1968. Spodographic evidence of rice from prehistoric Japan. *Journal of the Faculty of Science of the University of Tokyo* 3(3), 217–34.

Watanabe, N., 1970. A spodographic analysis of millet from prehistoric Japan. *Journal of the Faculty of Science of the University of Tokyo* 3(5), 357–59.

Watling, J., J. Iriarte, B.S. Whitney, *et al.*, 2016. Differentiation of neotropical ecosystems by modern soil phytolith assemblages and its implications for palaeoenvironmental and archaeological reconstructions II: Southwestern Amazonian forests. *Review of Palaeobotany and Palynology* 226, 30–43.

Webb, E.A. & F.J. Longstaffe, 2000. The oxygen isotopic compositions of silica phytoliths and plant water in grasses: implications for the study of paleoclimate. *Geochimica et Cosmochimica Acta* 64(5), 767–80.

Weisskopf, A., 2016. Elusive wild foods in South East Asian subsistence: modern ethnography and archaeological phytoliths. *Quaternary International*. https://doi.org/10.1016/j.quaint.2016.09.028

Yongji, L.H.W., 1991. A study on phytoliths in loess profile and paleoenvironmental evolution at Heimugou in Luochuan, Shaanxi province since late Pleistocene. *Quaternary Sciences* 1, 8.

Zhang, J., H. Lu, N. Wu, X. Yang & X. Diao, 2011. Phytolith analysis for differentiating between foxtail millet (*Setaria italica*) and green foxtail (*Setaria viridis*). *PLoS One* 6(5), p.e19726.

Zhang, J.P., H.Y. Lu, N.Q. Wu, X.G. Qin & L. Wang, 2013. Palaeoenvironment and agriculture of ancient Loulan and Milan on the Silk Road. Holocene 23, 208–17.

Zhao, Z. & D.R. Piperno, 2000. Late Pleistocene/Holocene environments in the middle Yangtze River Valley, China and rice (*Oryza sativa*) domestication: the phytolith evidence. *Geoarchaeology* 15, 203–22.

Zurro, D., 2017. One, two, three phytoliths: assessing the minimum phytolith sum for archaeological studies. *Archaeological and Anthropological Sciences* 10(7), 1673–91.

Zurro, D., J. Negre, J. Ruiz-Pérez, M. Álvarez, I. Briz Godino & J. Caro, 2017. An ethnoarchaeological study on anthropic markers from a shell-midden in Tierra del Fuego (southern Argentina): Lanashuaia II. *Environmental Archaeology* 22, 394–441.