



МӘДЕНИ МҰРА
ғылыми журнал

КУЛЬТУРНОЕ НАСЛЕДИЕ
научный журнал

CULTURAL HERITAGE
science journal

ISSN: 2708-3365

№ 3 (102)

Астана
2023

РЕДАКЦИЯ АЛҚАСЫ:

СЫДЫҚОВ Айбек Жексенәліұлы	– PhD докторы (алқа төрағасы) (Қазақстан)
ИБРАЕВА Ақмарал Ғосманқызы	– алқа төрағасының орынбасары, Қазақстан ұлттық жаратылыстану ғылымдары академиясының академигі, тарих ғылымдарының докторы, профессор (Қазақстан)
ТАЙМАҒАМБЕТОВ Жәкен Қожахметұлы	– ҚР ҰҒА академигі, тарих ғылымдарының докторы, профессор (Қазақстан)
САМАШЕВ Зайнолла Самашұлы	– тарих ғылымдарының докторы, профессор (Қазақстан)
АЙМҰХАМБЕТ Жанат Әскербекқызы	– филология ғылымдарының докторы, профессор (Қазақстан)
ҮМІТҚАЛИЕВ Ұлан Үмітқалиұлы	– тарих ғылымдарының кандидаты (Қазақстан)
МЕРЦ Виктор Карлович	– тарих ғылымдарының кандидаты (Қазақстан)
ЖАБАҒИН Мақсат	– тарих ғылымдарының кандидаты (Қазақстан)
БИҒОЖИН Ұлан Зейноллаұлы	– PhD докторы (Қазақстан)
САБИТОВ Жаксылық	– PhD докторы (Қазақстан)
ДЮПЮЙ Пауло	– PhD докторы (Қазақстан)
ҚАРА Әбдуақап	– доктор, профессор (Түркия)
ШАМИЛЬОГЛУ Юлай	– PhD, профессор (АҚШ)
АЙТПАЕВА Гулнара Амановна	– филология ғылымдарының докторы, профессор (Қырғызстан)
РАДИВОЖЕВИЧ Мильяна	– PhD, қауымдастырылған профессор (Ұлыбритания)

EDITORIAL BOARD:

Aibek Sydykov	– Doctor PhD (Chairman of the editorial board) (Kazakhstan)
Akmaral Ibrayeva	– Deputy chairman of the editorial board, Doctor of historical sciences, professor, Academician of the National Academy of Natural Sciences of Kazakhstan (Kazakhstan)
Zhaken Taimagambetov	– Doctor of Historical Sciences, Professor, Academician of NAS RK (Kazakhstan)
Zainolla Samashev	– Doctor of Historical Sciences, (Kazakhstan)
Zhanat Aimukhambet	– Doctor of Philology, Professor (Kazakhstan)
Ulan Umitkaliev	– Candidate of Historical Sciences (Kazakhstan)
Victor Merts	– Candidate of Historical Sciences (Kazakhstan)
Maxat Zhabagin	– Candidate of Historical Sciences (Kazakhstan)
Ulan Bigozhin	– PhD (Kazakhstan)
Zhaxylyk Sabitov	– PhD (Kazakhstan)
Paula Dupuy	– PhD (Kazakhstan)
Kara Abdulvahap	– Doctor, professor (Turkey)
Uli Shamiloglu	– PhD, professor (USA)
Gulnara Aitpaeva	– Doctor of Philology, Professor (Kyrgyzstan)
Radivojevic Miljana	– PhD, Associate professor (UK)

РЕДАКЦИОННАЯ КОЛЛЕГИЯ:

СЫДЫКОВ Айбек Жексеналиевич	– PhD доктор (председатель коллегии) (Казахстан)
ИБРАЕВА Ақмарал Ғосманқызы	– заместитель председателя коллегии, Академик Казахстанской национальной академии естественных наук, доктор исторических наук, профессор (Казахстан)
ТАЙМАҒАМБЕТОВ Жәкен Қожахметұлы	– ҚР ҰҒА академигі, тарих ғылымдарының докторы, профессор (Қазақстан)
САМАШЕВ Зайнолла Самашұлы	– доктор исторических наук, профессор (Казахстан)
АЙМҰХАМБЕТ Жанат Әскербекқызы	– доктор филологических наук, профессор (Казахстан)
ҮМІТҚАЛИЕВ Ұлан Үмітқалиұлы	– кандидат исторических наук, профессор (Казахстан)
МЕРЦ Виктор Карлович	– кандидат исторических наук, профессор (Казахстан)
ЖАБАҒИН Мақсат	– кандидат исторических наук, профессор (Казахстан)
БИҒОЖИН Ұлан Зейноллаұлы	– PhD доктор (Казахстан)
САБИТОВ Жаксылык	– PhD доктор (Казахстан)
ДЮПЮЙ Пауло	– PhD доктор (Казахстан)
ҚАРА Әбдуақап	- Доктор, профессор (Турция)
ШАМИЛЬОГЛУ Юлай	– PhD, профессор (США)
АЙТПАЕВА Гулнара Амановна	- доктор филологических наук, профессор (Кыргызстан)
Радивожевич Мильяна	- PhD, ассоциированный профессор (Великобритания)

МАЗМҰНЫ / CONTENT / СОДЕРЖАНИЕ

Этнология / Ethnology / Этнология

Тоқтабай А.У. Қазақстан территориясындағы суландыру жүйелерінің пайда болуы және дамуы

Toktabay A.U. Emergence and development of systems of irrigation in the territory of Kazakhstan

Тоқтабай А.У. Возникновение и развитие систем орошения на территории Казахстана.....7

Елкей Н.Н. Ұлттық құндылықтарымызды сақтау - ұлттық бірегейліктің негізі

Yelkey N.N. Preservation of national values is the basis of national identity

Елкей Н.Н. Сохранение национальных ценностей - основа национальной идентичности.....19

Музейтану / Museology / Музееведение

Ибраева А.Г. Музей ісінің теориялық-әдіснамалық мәселелері

Ibrayeva A.G. Theoretical and methodological issues of the museum affairs

Ибраева А.Г. Теоретико-методологические проблемы музейного дела.....33

Археология / Archaeology / Археология

Ребекка С. Робертс. Археологиядағы микроорта қалдықтары: фитолиттер мен фекалді сферолиттер және оларды Қазақстанның археологиялық қабаттарындағы адам мен қоршаған ортаның әрекеттесуін зерттеуге қолдану

Rebecca C. Roberts. Micro-environmental remains in archaeology: phytoliths and faecal spherulites and their application for the study of human-environment interactions in archaeological sediments in Kazakhstan

Ребекка С. Робертс. Остатки микросреды в археологии: фитолиты и фекальные сферолиты и их применение для изучения взаимодействия человека и окружающей среды в археологических отложениях Казахстана.....48

Дәрменов Р.Т. Оңтүстік Қазақстан тұрғын үйлеріндегі халық сәулет өнерінің құрылыс материалдары мен конструктивтік әдістері

Darmenov R.T. Construction materials and constructive methods of folk architecture in the dwellings of South Kazakhstan

Дәрменов Р.Т. Строительные материалы и конструктивные приемы народной архитектуры в жилищах Южного Казахстана.....68

Қасенәлі А., Есен С., Мұсырманқұл П., Қызырхан М., Сералиев А. Ұялы қорымында 2023 жылы жасалған зерттеу жұмыстарының алғашқы нәтижелері

Kassenali A., Yessen S., Musyrmsnkul P., Kyzyrhan M., Seraliev A. The first results of research on the Uyaly necropolis in 2023

Касенали А., Есен С., Мусырманкул П., Кызырхан М., Сералиев А. Первые результаты исследований 2023 года на некрополе Уялы.....80

Трещёва С.П. Орталық Қазақстандағы металл өндірісінің тарихы

Trescheva S.P. The origins of big metal in Central Kazakhstan

Трещёва С.П. Истоки большого металла Центрального Казахстана.....92

Филология / Philology / Филология

Шауенова Г.Ә. Абай шәкірттерінің публицистикалық шығармашылығының жанрлық сипаты мен ерекшеліктері

Shaunova G.A. The genre nature and features of the publicistic work of Abay's disciples

Шауенова Г.А. Жанровые черты особенности публицистической деятельности учеников Абая.....106

Бектұрсын А.С. Халық ертегілеріндегі есімдерге филологиялық және этнографиялық талдау

Bektursyn A.S. Philological and ethnographic analysis of names in folk tales

Бектұрсын А.С. Филологический и этнографический анализ имен в народных сказках.....116

Біздің музей / History of our museum / История нашего музея

Ибраева Г.Б. С. Сейфуллин музейі: өткені мен бүгіні

Ibraeva G.B. S. Seifullin museum: past and present

Ибраева Г.Б. Музей С. Сейфуллина: прошлое и настоящее.....129

Рецензия / Review / Рецензия

Жайлыбай Д.Ж., Әшім Б.Ә. Далаева Т.Т., Султанғалиева Г.С. Визуальная антропология новой социальной истории Казахстана XIX – начала XX вв. (Алматы, ИД «Жібек жолы», 2022. 240 с.) монографиясына БУКРЕВЬЮ.....136

Археология / Archaeology / Археология

<https://doi.org/10.47500/2023.v15.i3.04>

МРПТИ 03.41.91

Rebecca C. Roberts^{1,2}

¹McDonald Institute for Archaeological Research, University of
Cambridge, UK

²Fitzwilliam Museum, University of Cambridge, UK
<rcr45@cam.ac.uk>

MICRO-ENVIRONMENTAL REMAINS IN ARCHAEOLOGY: PHYTOLITHS AND FAECAL SPHERULITES AND THEIR APPLICATION FOR THE STUDY OF HUMAN- ENVIRONMENT INTERACTIONS IN ARCHAEOLOGICAL SEDIMENTS IN KAZAKHSTAN

Abstract. This article explores the archaeological information that can be gathered from the study of micro-environmental remains (phytoliths and faecal spherulites) extracted from archaeological sediments, and their application in the analysis of human-environment interactions in the archaeology of Kazakhstan. A brief overview of the history of the study of the two types of micro-environmental remains is given, and assemblage formation and taphonomic processes are considered. Finally, using examples from archaeological sediments in Kazakhstan, the article explores the types of information that can be extracted from phytolith and faecal spherulite analysis, and what this can tell us about human-environment interactions in the past.

Keywords: phytolith, faecal spherulite, archaeobotany, environmental archaeology

Introduction

This article will explore the archaeological information that can be gathered from the study of micro-environmental remains (phytoliths and faecal spherulites) extracted from archaeological sediments, and their application in the analysis of human-environment interactions in the archaeology of Kazakhstan.

Phytoliths are the microscopic three-dimensional amorphous biogenic silica

(opal) infillings of cavities within and between the cells of certain plants (Thorn 2007). This process starts when dissolved monosilicic acid (H_4SiO_4) in groundwater is taken up by the roots of plants and carried up to the aerial organs through the xylem (Piperno 2006). The silica is not metabolised by the plant, and it is deposited as siliceous gel which gradually crystallises into a solid particle (Thorn 2007). While not essential for plant growth, the deposition of silica can increase the plant's

resistance to biotic and abiotic stressors such as water availability, disease and pests (Мырзабаева and Қонысбаева 2018; Strömberg, Di Stilio, and Song 2016)). Once deposited, phytoliths are incredibly durable, and following the death and decay of the plant they are deposited into soils and sediments, forming a fossil record of the plants which formed them (Piperno 2006; Roberts (unpublished thesis)).

Faecal spherulites are a calcium salt formed in the gut of certain species of mammal (Brochier et al. 1992). They are identifiable in archaeological sediments as “minute (typically 5–15 µm) spheres of radially crystallized calcium carbonate surrounded by an organic coating” (Canti 1997). The largest number of faecal spherulites are produced by ruminants (sheep, cow, goat, deer), low numbers are produced by omnivorous and carnivorous species (pig, human, badger, dog, cat, fox), and they are not produced by caecal digesters (horse, rabbit, hare) (Canti 1999).

Of course, many different factors affect the resulting phytolith and faecal spherulite assemblages that may be found in archaeological soils and sediments. This article will consider the different mechanisms and processes that might affect the final phytolith and faecal spherulite assemblage which is analysed in the laboratory. A brief history of phytolith and faecal spherulite research is given, and the formation and taphonomic processes that may affect archaeological phytolith and faecal spherulite assemblages are explored (Roberts (unpublished thesis)). Finally, examples from the territory of Kazakhstan are discussed which highlight the ways in which phytolith and faecal spherulite data can contribute to the understanding of human-environment interactions in the past of Kazakhstan.

Phytoliths

History of the study of phytoliths

The history of the study of phytoliths covers a multitude of disciplines, including archaeology, biology, ecology, botany, plant genetics, geology and soil science (Piperno 2006). The first study of phytoliths was published in 1835 (Powers 1992; Struve 1835), and the earliest taxonomic studies were conducted between 1900-1935 (Bryant 1993), including the identification by Ehrenberg of over sixty-seven phytolith forms from samples of wind-blown dust collected by Darwin from the sails of HMS Beagle in 1833 (Darwin 1909; Piperno 2006). Despite these early observations, Bryant (1993) has highlighted the slow start in the use of phytolith data in archaeobotanical research during the 20th century in contrast to that of pollen. Neolitzky identified phytoliths from wheat and barley in prehistoric sediments from European archaeological sites in 1900 (Neolitzky 1900), and later used phytoliths to prove the use of economically important plants in settlements from other European sites (Powers 1992; Netolitzky 1914). However, these early archaeological studies failed to gain momentum, and it was not until half a century later that detailed archaeobotanical research into phytoliths began in earnest, with the identification of rice, wheat and barley phytoliths demonstrated at archaeological sites in Japan and the Middle East by Watanabe and Helbaek (Bryant 1993; Piperno 2006; Lancelotti and Madella 2018; Watanabe 1955, 1968; Helbaek 1961, 1969). Metcalfe's important publication on the leaf anatomy of grasses provided the basis for further morphological study of phytoliths (Metcalfe 1960; Powers 1992; Lancelotti and Madella 2018), most notably by Twiss et al., who developed a classification system for the discrimination of phytoliths

belonging to the Panicoideae, Pooideae and Chloridoideae subfamilies (Twiss, Suess, and Smith 1969). Rovner further highlighted the potential of phytolith data for palaeobotanical research, in particular demonstrating the complementary role that phytolith and pollen data can play (Pearsall 2016; Rovner 1971). Importantly, for archaeobotanical research, further studies were also made at this time into the morphological characteristics of phytoliths from cereals, such as Parry and Smithson's publications on phytoliths from British grasses and cereals, and Blackman's studies of wheat and rye (Powers 1992; Parry and Smithson 1964, 1966; Blackman 1969; Blackman and Parry 1968). Research into New World cereals was also being conducted, for example with Pearsall using phytolith evidence to demonstrate maize cultivation in Ecuador (Pearsall 1978; Roberts (unpublished thesis)).

Further research into phytolith evidence of prehistoric plant use and domestication in the Americas by researchers such as Steven Bozarth, Dolores Piperno and Deborah Pearsall contributed to the establishment of phytolith research in archaeology (Bozarth 1987; Piperno 1984, 1985a, 1985b, 1988; Pearsall 1982), the real blossoming of which was marked by two publications: the first dedicated publication on the use of phytoliths in archaeology by Piperno (Piperno 1988); and the inclusion by Pearsall of phytolith analysis in her handbook of palaeoethnobotanical procedures (Pearsall 2016, first published 1989). These two publications brought phytolith analysis to the attention of a wide audience, and provided key starting points for interested researchers (Bryant 1993; Roberts (unpublished thesis)).

With the foundation laid by these early pioneers, the number of phytolith researchers has since grown dramatically,

with an increasing diversity of research topics (Hart 2016; Lancelotti and Madella 2018).

Formation and preservation of phytolith assemblages

When analysing any phytolith assemblage, there are a number of factors that must be considered with regard to how the assemblage was formed, and how the depositional environment may have affected the formation and preservation of the phytolith assemblage, leading to biases in the archaeological phytolith record. The first factor to consider is that not all plant families produce phytoliths, and of those that do, only some of the phytoliths produced have significance for taxonomic identification (Piperno 1988, 2006; Strömberg 2003). Those families of primary relevance to the mountainous, semi-arid and arid steppe zones of Central Asia whose phytolith production is both high and phytolith forms have taxonomic significance are: Poaceae (grasses); Cyperaceae (sedges); and Equisetaceae (horsetails, scouring rushes) (Piperno 2006). Additionally, phytoliths have been observed in the Pinaceae which may have diagnostic value, but which are not produced in such abundance (Klein and Geis 1978; Rovner 1971). Klein and Geis note that some species of *Picea* produce silicified endodermal cells, which could be confused with grass bulliforms (Klein and Geis 1978). This may have particular relevance to the analysis of high mountain steppe zones, where the tree line meets the high-mountain grass meadows. In addition to those phytolith morphotypes that have taxonomic value, phytoliths are also produced in wood and twigs which have a distinct form attributable to woody plants, but for which no further attribution is possible (namely globular/ellipsoid

forms, irregular forms with mineral inclusions, and silica aggregates) (Albert et al. 1999; Piperno 2006). Work by Collura and Neumann on West African bark and wood indicated that silica production in bark is much more common than in wood, but that overall production is uneven at different taxonomic levels (Collura and Neumann 2017; Roberts (unpublished thesis)).

In addition to genetically driven species-specific variations in phytolith formation, aspects such as soil chemistry, water availability and evapotranspiration rates have been demonstrated to affect both the amount of available dissolved silica and the rate at which it is taken up by plants (Мырзабаева and Қонысбаева 2018; Piperno 2006). Laboratory studies have shown that the amount of available dissolved silica is an important factor in the rate of phytolith production, with grasses in particular showing a direct positive correlation between amounts of solid silica deposited in the plant and the amount of dissolved silica in the growth medium (Blackman and Parry 1968; Blackman 1969; Parry and Smithson 1964; Jones and Handreck 1965). The amount of silica available in groundwater depends on a complex soil-plant cycle (Cornelis and Delvaux 2016). The rate at which this cycle occurs is governed by the same factors that govern soil formation processes (namely climate, topography, soil parent material, the age of the soil) and biotic factors (vegetation, micro-organisms, and land use) (Alexandre et al. 1997; Cornelis and Delvaux 2016; Strömberg, Di Stilio, and Song 2016). Acidic soil environments are known to have more free silica available, but high concentrations of iron and aluminium oxides can absorb or bind silica to their surfaces, thus removing it from solution (Piperno 2006).

Research into the relationship between water availability and phytolith production in grasses, or more specifically cereals, has indicated that an increase in water supply, whether through rainfall or irrigation, leads to an increase in the production of phytoliths, with Rosen and Weiner noting an increase in the number of conjoined phytoliths (Rosen and Weiner 1994), Madella et al. (Madella et al. 2009) and Jenkins et al. (Jenkins et al. 2016) noting an increased ratio of long cells to short cells (see Figure 1 for an example of conjoined long and short cells). High evapotranspiration rates can also cause an increase in solid silica deposition in the aerial structures of grasses due to the presence of a supersaturated solution of silica leading to the precipitation of solid forms (Jones and Handreck 1965; Piperno 2006; Rosen and Weiner 1994; Roberts (unpublished thesis)).

The second group of factors to consider are the external mechanisms behind the deposition and subsequent taphonomy of the phytolith record. Zurro et al. (2016) identify two major groups of mechanisms that influence the composition of a phytolith assemblage: 1) the origin of the input plant assemblage (whether anthropic, natural or both); and 2) pre- and post-depositional taphonomy (Zurro et al. 2016). The origin of the deposition of plant material in an archaeological sediment can be assumed to be largely deposited by human activity (although periods of no occupation should also be considered for sites with multiple occupancy periods), and therefore phytolith assemblages recovered from various contexts can be expected to reflect different activities around a site, such as crop processing (Harvey and Fuller 2005), craft production (Wendrich and Ryan 2012), bedding (Cabanès et al. 2010), and the burning of fuel (Lancelotti and Madella

2012). Phytolith and spherulite data has

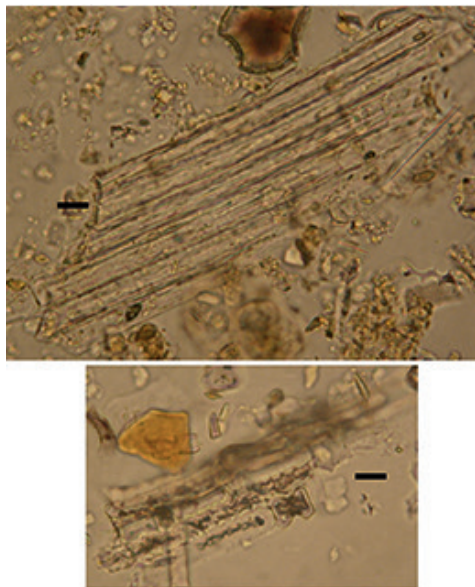


Fig. 1. Multi-celled phytolith from grass leaf or stem from the archaeological site of Tuzusai, Kazakhstan, showing long and short cells in situ (elongate psilate, elongate echinate, elongate sinuate, and bilobe). Scale bar is 10µm (Roberts (unpublished thesis))

the potential to answer some of these questions by identifying, for example, whether a sediment contains evidence for a concentration of crop processing waste or sheep/goat dung, which might indicate a midden, or a phytolith assemblage that is concurrent with surrounding mud brick, indicating that the fill was caused by the collapse of a wall (Katz et al. 2007; Lancelotti and Madella 2012; Portillo, Albert, and Henry 2009)

Pre- and post-depositional taphonomic processes begin with the death of the plant, leading to the release of phytoliths into the surrounding sediment. This can happen through a number of different pathways, for example the natural death and decay of plants within a soil A horizon, through the deliberate burning of plant material (phytolith morphology is preserved at temperatures up to 800C (Parr 2006),

deposition through animal dung (which may also be redeposited by human action for example as fuel or temper (Lancelotti and Madella 2012), and midden deposits to name but a few (Shillito 2011; Piperno 2006). Jenkins (2009) compared the extraction of phytoliths from modern durum wheat plants (*Triticum durum*) using dry ashing and acid digestion methods, and determined that the resulting number of conjoined phytoliths was greatly reduced using the acid digestion method (Jenkins 2009). This not only has implications for future studies using modern plant material, but also illustrates how pre-depositional taphonomic processes might change resulting phytolith assemblage. An example of this might be the destruction of a thatched house through fire compared to a gradual process of disuse and collapse (Roberts (unpublished thesis)).

Madella and Lancelotti (2012) highlight that following the death of the plant, the decay of the plant tissues releases the phytoliths and at this point they may be subject to pre-depositional transport by wind or water which can cause damage, for example through abrasion and chipping. In open, wind-blown environments such as deserts this transport might be significant, however in most cases it is minimal since phytoliths are relatively 'heavy' particles. In archaeological contexts phytoliths might be spread and dislocated through actions such as sweeping a floor, which may also lead to the redeposition of material in a different place to that of its origin (Madella and Lancelotti 2012), for example the clearing and burning of crop processing waste away from a threshing floor.

Post-deposition, phytoliths in both natural and anthropic contexts are exposed to the processes of pedogenesis, fossil diagenesis, and bioturbation (Madella and Lancelotti 2012). A study by Fishkis

et al. (2010) using a fluorescent marker on phytoliths extracted from *Phragmites australis* and added to active soils found that over the course of a year, phytoliths were found to move downwards by an average of 4cm, with smaller phytoliths exhibiting greater movement than larger ones (Fishkis et al. 2010). Cabanes et al. (2011) also determined that root activity and active soil formation on an archaeological site can affect the preservation of phytoliths. Bioturbation is also acknowledged to be a major factor in the post-depositional relocation of phytoliths (Madella and Lancelotti 2012), and is certainly an issue witnessed at the sites in this study, for example pit fills having been used by burrowing mammals and section walls being colonised by tunneling wasps and bees (author's personal observations). These factors mean that one must be very vigilant when sampling a context in order to ensure that the original context is sampled and not an artefact of animal disturbance. In addition to these natural processes, human activity can greatly affect the depositional environment, for example through trampling of floors which might change the rate of water percolation (Madella and Lancelotti 2012), and industrial activity which could affect local soil chemistry for example through the dumping of large quantities of alkaline ash, where highly alkaline soils have demonstrated low phytolith densities (Piperno 1985b). Different pH values in soils and sediments have been proven to affect the dissolution rate of different phytolith morphotypes, with some forms being more sensitive to dissolution than others (Cabanes, Weiner, and Shahack-Gross 2011), with alkaline conditions causing dissolution, and mechanical agitation causing the loss of appendages on certain morphotypes

(Roberts (unpublished thesis)).

Phytolith extraction from sediment, identification, and quantification

Only a small quantity of dried sediment is required to be collected in the field for phytolith and faecal spherulite analysis, equivalent to about a teaspoon (5g). Following the collection of samples in the field, the sediment must be treated in order to isolate the phytoliths, and then once extracted a subsample of phytoliths is mounted to a slide for morphological identification and quantification. Coil et al. (2005) provide a useful comparison of different microfossils that can be extracted from sediments, and how they might be affected by various laboratory processes as well as the strengths and weaknesses of different mounting media, making the point that identifying the end-goal of the extraction and the specific nature of the sediment are important factors to consider when devising a protocol (Coil et al. 2003). There is no single agreed method for the isolation of phytoliths from sediment, nor indeed should there be, since the researcher may be attempting to extract another microfossil at the same time, such as starches (Horrocks 2005). Strömberg (2003) has identified three common steps in all these processing methods: 1) pre-treatment of the sediment to 'free' the phytoliths (disaggregation through the removal of binding agents such as carbonates, and the removal of clays and organics); 2) separation of the phytoliths from the mineral fraction; and 3) preparation of slides. The process for extracting phytoliths depends on the type of information required, the nature of the sediment, and the laboratory equipment available to the researcher (Roberts (unpublished thesis)).

The identification of phytolith

morphotypes can be conducted on two levels: identifying and recording the form of the phytolith, ideally using the standardised nomenclature of the International Code for Phytolith Nomenclature 2.0 (International Committee for Phytolith Taxonomy (ICPT) 2019), and then attributing each morphotype to a particular family or genus (and, where possible, species). Confident identification of family, genus, or species-level phytolith morphotypes is dependent on having locally-obtained plant reference material with which to compare the archaeological samples, since one must also bear in mind that a) local species may be found to produce forms similar to different species in other regions (the problem of redundancy (Rovner 1971)), and b) a single plant may be found to produce a wide range of morphotypes (multiplicity ((Rovner 1971; Piperno 1988)). Not being able to compare local variants in phytolith producing plants is a particular problem in Kazakhstan, and indeed Central Asia more widely, where phytolith work remains a developing discipline (Rosen, Chang, and Grigoriev 2000). Establishment of a reference collection for the varied ecological zones found in Kazakhstan will be an essential next step for continued phytolith research in the country. Regional work in southern West Siberia by Marina Solomonova and colleagues has produced a database of phytolith assemblages for a variety of environments, including steppe, forest, and high-mountains, which serves as a valuable regional reference resource (Соломонова et al. 2019).

Given biases in their production, which leave many plant species either 'silent' or underrepresented in the phytolith record, and the need for further region-specific phytolith work in Kazakhstan, phytoliths are most powerful when employed to

study plant community assemblages as a whole (Strömberg 2003), particularly using multivariate statistical techniques, with the exception of the domesticated cereals, which are discussed below.

The exceptions to the potential problems with identification mentioned above are multi-celled silica skeletons from the seed bracts of domesticated cereals, which have been widely studied in many regions of the world, providing a wealth of comparative material to aid in the identification of these phytoliths in archaeological samples (Rapp and Mulholland 1992; Piperno 2006, 1988; Гольева 2001; Ball et al. 2015), together with online databases. Based on previous macrobotanical and phytolith work in Kazakhstan, cereals of relevance are wheat, barley, millet (*Panicum miliaceum* and *Setaria italica*), and rice (Spengler, Chang, and Tourtellotte 2013; Spengler, Frachetti, and Doumani 2014; Rosen, Chang, and Grigoriev 2000; Баштанник 2007; Гольева 2001; D. A. Gavrillov et al. 2016; Doumani et al. 2015).

In addition to identifying phytolith morphotypes, quantification of phytoliths present in a sample is needed in order to allow the assemblage to be analysed and answer questions about relative abundances of morphotypes and ratios of taxonomically significant phytoliths. As with their extraction and identification, once mounted to a microscope slide there is no single methodology for quantifying the number of phytoliths present (Piperno 2006). However, there is general consensus that the number of single-cell phytoliths that must be counted before a statistically significant representative sample of the assemblage has been recorded is between 200 and 300 diagnostic phytoliths (Rapp and Mulholland 1992; Piperno 1988, 2006). In a study tallying phytolith morphotypes recorded against a high reference count

size of 800 phytoliths, Albert and Weiner (2001) noted that less abundant phytolith morphotypes were lost when fewer than 200 phytoliths were counted (Albert and Weiner 2001). Statistical analysis by Strömberg (2009) of two commonly employed indices, D/P (tree cover index) and Iph (aridity index), determined that while a count of around 200 diagnostic phytoliths appeared to be a good starting point, the value of the index and the number of diagnostic phytoliths together determined the statistical significance of the result. She also argues that for vegetation inference, more skewed samples towards a particular vegetation signature show more statistical significance than evenly distributed assemblages (Strömberg 2009). This serves to demonstrate that, as with extraction methods, effective and statistically valid counting methods depend upon the nature of the assemblage and the number of diagnostic morphotypes that are present, and these factors should be considered both when counting phytoliths and when analysing the subsequent data (Roberts (unpublished thesis)).

Faecal Spherulites

Structure and formation of faecal spherulites

In 1983 Brochier carried out a comparative study of fresh ovicaprine droppings and Neolithic deposits from four caves in France and Greece, and proposed that archaeological deposits of sheep/goat dung could be determined through the presence of faecal spherulites in association with grass phytoliths in sediments (Brochier et al. 1992). Further ethnoarchaeological and geological work in Sicily reinforced these discoveries, and determined that faecal spherulites are always present in sheep droppings but

sometimes absent from goat droppings, and never present in rabbit faeces (Brochier et al. 1992). Through further investigation, Canti determined that the largest number of faecal spherulites are produced by ruminants (sheep, cow, goat, deer), low numbers are produced by omnivorous and carnivorous species (pig, human, badger, dog, cat, fox), and they are not produced by caecal digesters (horse, rabbit, hare) (Canti 1999, 1997).

Faecal spherulites can be identified in sediment samples (and distinguished from calcium oxalate druses) by their size (much smaller than calcium oxalate druses), and the presence of a permanent extinction cross in crossed polarised light (Canti 1997, 1998) (Canti 1997; 1998). Faecal spherulites have a detached inner core, which is frequently visible under plane polarised light, and an organic outer coating.

By sampling sections of sheep intestines, Canti was able to determine that faecal spherulites are absent in the upper acidic small intestine but become abundant in the more alkaline lower sections of the small intestine. The spherulites form when acidic chyme containing Ca^{2+} and Cl^{-} ions from the breakdown by hydrochloric acid of calcium rich plant cell walls, plant calcium oxalates and calcite ingested in soil is neutralised by secretions rich in sodium bicarbonate lower in the small intestine. These conditions are ideal for the formation of calcium carbonate spherulites (Canti 1999; Roberts (unpublished thesis)).

Preservation of faecal spherulites

Experiments have shown that faecal spherulites will dissolve in distilled water if subject to constant stirring, although not in calcareous water, and they are therefore sensitive to water flow through sediment. In simulating leaching

conditions for various pH values (Canti 1999). A pH below 7.7 is detrimental to faecal spherulite preservation, however it is important to note that if the dung has been burned the pH value will be much higher, and therefore the spherulites are more likely to be preserved in dung ash (Canti 1999). Faecal spherulites may be victim to bioturbation if consumed by meso-organisms whose digestive tract would then destroy them (Canti 1999).

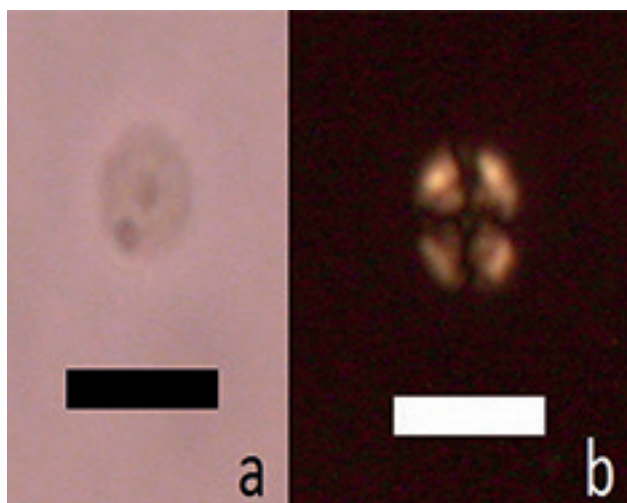


Fig. 2. Photograph of a faecal spherulite under a) plane light, showing dislocated inner core in the centre; and b) crossed polarised light, showing extinction cross. Scale bar is 10µm (Roberts (unpublished thesis)) acidic chyme containing Ca²⁺ and Cl⁻ ions from the breakdown by hydrochloric acid of calcium rich plant cell walls, plant calcium oxalates and calcite ingested in soil is neutralised by secretions rich in sodium bicarbonate lower in the small intestine. These conditions are ideal for the formation of calcium carbonate spherulites (Canti 1999; Roberts (unpublished thesis)).

Discussion: uses of micro-environmental data in understanding human-environment interactions in Kazakhstan

This section will look at some of

the ways in which phytolith and faecal spherulite data have been used to answer archaeological questions. The focus of the literature referenced here will be on those studies which are of direct relevance to the study of human-environment interactions in Kazakhstan, and it is important to note that this is not an attempt to encompass all the many and varied ways in which phytolith data have been employed in archaeology (a comprehensive review can be found in Piperno 2006).

Identification of cereals

As outlined above, many studies have been focused on identifying domesticated cereals in the phytolith record (Rosen, Chang, and Grigoriev 2000; Pearsall 2016; Piperno 2006; Гольева 2001), which means that agricultural activity is identifiable in the archaeological phytolith record in Kazakhstan using existing international reference collections and publications (Figure 3). This also opens the possibility for the calculation of the ubiquity of cereals in the same way as macrobotanical assemblages (Pearsall 2010), allowing for a direct numerical comparison between macrobotanical and phytolith data (Weisskopf, Deng, et al. 2015; Roberts (unpublished thesis)). At the Bronze Age site of Tasbas, Zhetysu, the author identified wheat, barley and millet (*Setaria italica* and *Panicum miliaceum*) (Doumani et al. 2015). At the Iron Age site of Tuzusai, Zhetysu, Arlene Rosen identified wheat, barley, millet and possibly rice (Rosen, Chang, and Grigoriev 2000), with wheat, barley and millet being confirmed in further analyses by the author (Roberts (unpublished thesis)). At the medieval settlement of Jankent, Kyzylorda, wheat was identified in the phytolith record (D. A. Gavrilov et al. 2016), while at the medieval city of Talgar, Zhetysu, millet,

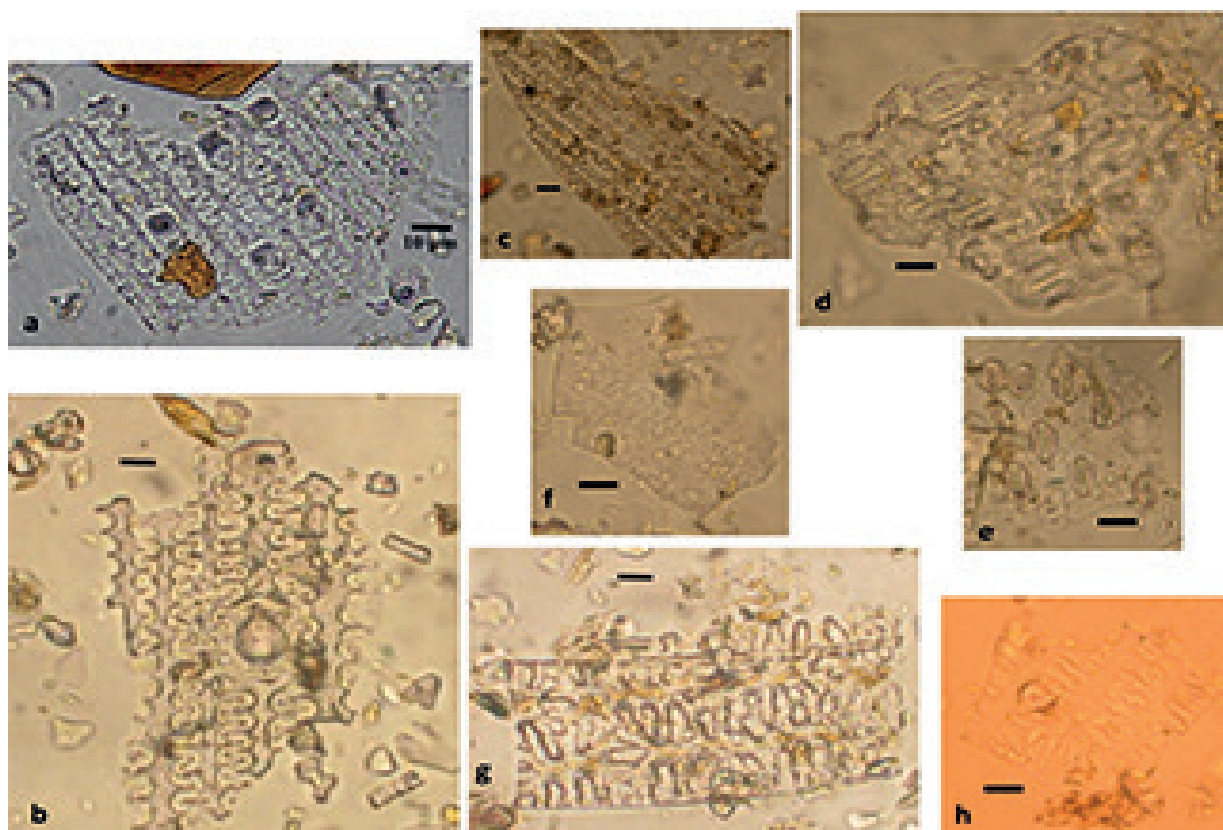


Fig. 3. Multi-celled grass phytoliths from archaeological sites in Kazakhstan that have been identified to genus level or beyond: a) barley husk (*Hordeum* sp.); b) wheat husk (*Triticum* sp.), having large sometimes irregular dendritic wave pattern, papillae having 10-12 pits; c), d) and e) silica skeletons characteristic of *Phragmites australis*, c) stem and d) & e) epidermal layer with many stomata; f) *Setaria italica* husk, having symmetrical rounded dendritic forms; g) & h) *Panicum miliaceum* husk, having asymmetrical 'finger-like' dendritic forms. Scale bar in each photograph is 10 μ m (Roberts (unpublished thesis))

barley, rice, and oats were identified (Гольева 2001 cited in Баштанник 2007).

Agricultural practices

In addition to identifying the types of cereals being cultivated, phytolith data can also be used to indicate agricultural practices. As noted above, research into the identification of irrigation using phytolith assemblages has been carried out by Rosen and Weiner (1994), Madella et al. (2009), Jenkins et al. (2016), and Weisskopf et al. (Weisskopf, Qin, et al. 2015), with results

indicating that changing water availability does have an impact on the nature of phytolith assemblages, meaning that it may be possible to identify cereals which have been irrigated through the ratio of 'fixed' and 'sensitive' phytolith forms which respond to water availability, or (as argued by Rosen and Weiner 1994) through an increased number of conjoined phytoliths (Roberts (unpublished thesis)). Analysis of medieval irrigated soils from Bozok archaeological district, North Kazakhstan by M. Khabdulina and D. Gavrilov

employed multivariate statistical analysis of phytolith assemblages in combination with soil chemistry analysis to reveal that ancient irrigated soils can be identified in the archaeological record (D. Gavrilov and Khabdulina 2018). Phytoliths also have the potential to provide information about crop processing. Harvey and Fuller (2005) propose a model whereby phytolith forms attributable to different parts of the plant, such as leaves and stems, and husks, can be used to identify different stages of crop processing. This has the potential to inform about the differing use of space in an archaeological site, and the use and disposal of crop processing waste, for example as temper or fuel, such as in the mud brick at Tasbas (see below) (Doumani et al. 2015). At Talgar, a lack of phytoliths specific to the stems of rice was noted, leading to the conclusion that rice was an imported cereal, as opposed to the other cereals which appear to have been cultivated nearby due to the presence of stem fragments (Гольева 2001).

Identification of fuel sources, land use, building materials

Analysis of the ratio of woody dicotyledenous plants to grasses (D/P^o ratio) can provide an indication of the amount of wood material brought to the site relative to that from grasses, which may indicate aspects such as choices in fuel types (wood versus dung) (Piperno 2006). Environmentally indicative species, such as wetland species like *Phragmites* sp. can add further information about the use of plant matter in craft and construction, such as choices in building materials. At the Bronze Age settlement of Ajtman, Ustyurt plateau, wetland species were identified in the phytolith assemblage, indicating that its inhabitants harvested plant matter such as reeds from a nearby freshwater source

such as a spring or lake, now non-existent in the area, a conclusion reinforced by the presence of sponge spicules, diatoms and flax fibre (Лошакова and Гаврилов 2015).

In a recent study of the kurgans at Koy-Gunzhar cemetery, North Kazakhstan, the identification of phytoliths from *Phragmites* sp., together with co-occurring aquatic micro-remains such as diatoms and sponge spicules was combined with analysis of soil chemistry to conclude that soils from nearby wetland environments were favoured in the construction of the mounds (D. A. Gavrilov et al. 2022). This observation of the use of wetland/marshy sods in the construction of kurgans has also been recorded by Z.S. Samashev at the burial ground of Eleke Sazy, East Kazakhstan (Samashev 2021). The analysis of phytoliths preserved in mud bricks can also shed light on the technology and 'recipes' behind this construction material. At Tuzusai, two different colours of mud of mud brick were observed in the Iron Age phases of the settlement. Analysis of the plant matter used as temper in their creation found that both types of mudbrick had similar compositions in terms of the relative percentages of different morphotypes in the phytolith assemblages, however the smaller yellow mud bricks associated with internal walls and floors had a far lower density of phytoliths than the larger red-brown mud bricks that were associated with foundations, indicating that mud bricks were made to different 'recipes' according to structural need (Chang and Beardmore 2016). At Tasbas, both whole grains and chaff of barley were found to have been included in the mud brick surrounding a hearth (Doumani et al. 2015).

Where preserved, faecal spherulites indicate the presence of dung, and as Canti (1999) pointed out, dung which has been

turned to ash is more likely to preserve spherulites. This is particularly useful for answering questions about the use of animal dung for fuel, since the presence of spherulites in a hearth context indicates the presence of dung as fuel (Lancelotii and Madella 2012), and this information is likely to be preserved due to the alkaline nature of ash. In an experimental archaeology study on deposits from Butser Ancient Farm, Macphail reported variable preservation of spherulites depending on the pH of the deposit, which demonstrates that spherulites will not necessarily be found in contexts where dung was deposited, and therefore their absence does not indicate the absence of dung (Macphail et al. 2004). As an exploratory exercise to test the potential of archaeological sediments from Kazakhstan, the author mounted a known mass of archaeological sediment (c.2mg) directly to slides from the archaeological sites of Tuzusai (Iron Age), Tasbas (Bronze Age), and Turgen II (Iron Age) in the Zhetysay region. Faecal spherulites were present in samples from all 3 sites. At Tuzusai and Turgen in particular, there was a marked difference between presence of faecal spherulites in ashy contexts vs. floor contexts, indicating that further studies in combination with phytolith analysis have the potential to explore the history of the use of animal dung as fuel and building material in Kazakhstan (Roberts (unpublished thesis)).

Climate reconstruction

Phytolith data have been used to indicate past climate and land use through the calculation of two climatic indices using single cell morphotypes that are particular to the Pooid, Panicoid and Chloridoid subfamilies of grasses, as identified by Twiss et al. (1969). These are the climatic index, Ic, and the aridity index Iph

(Alexandre et al. 1997; Piperno 2006, 32–34; Strömberg 2009). In addition, vegetation cover can be indicated through the ratio of phytoliths from woody dicotyledonous plants to those from grasses (D/P°) (Piperno 2006; Roberts (unpublished thesis)). The climatic indices have the potential to inform about trends in climate over time, particularly for archaeological sites that have a long occupation history. At Tasbas, the climatic index (Ic) indicated the increasing exploitation of warmer environments over time, with a return to cooler environments in the later phase, while the ratio of phytoliths from woody dicotyledonous plants to those from grasses (D/P°) fell over time and the aridity index (Iph) indicated the increasing presence of dry-adapted grasses over the same period (Doumani et al. 2015). Further such studies could shed light on localised responses to large-scale climatic trends across the territory of Kazakhstan.

Conclusion

The overview presented here brings together the history, background, and methods in the study of two different types of micro-environmental remains from archaeological sediments: phytoliths and faecal spherulites. It has been demonstrated that there is now a solid foundation of micro-environmental work in Kazakhstan, but that there is great scope to build the discipline in the country. The need for a national reference database has been highlighted, and it is hoped that such an initiative could be achieved through an international collaborative effort. The study of micro-environmental remains in archaeological sediments provides novel insights into past agriculture, craft, construction, climate, and human-animal interactions on the territory of Kazakhstan, and further

studies can only add to our understanding of the rich and complex ways in which

people interacted with their environments in the past.

Acknowledgements. *The author wishes to acknowledge the Arts and Humanities Research Council (UK), who funded this research. With thanks to A.A. Goryachev, C. Chang, and P. Doumani Dupuy for access to the archaeological sediments discussed in this paper.*

References

1. Albert, Rosa Maria, Ofer Lavi, Lara A. Estroff, Steve Weiner, Alexander Tsatskin, Avraham Ronen, and Simcha 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: P.1249–1260.
2. Albert, Rosa Maria, and Stephen Weiner. 2001. Study of Phytoliths in Prehistoric Ash Layers from Kebara and Tabun Caves Using a Quantitative Approach. *Phytoliths: Applications in Earth Sciences and Human History*. P. 251–266.
3. Alexandre, A., J.-D. Meunier, A.-M. Lézine, A. Vincens, and D. Schwartz. 1997. Phytoliths: Indicators of Grassland Dynamics during the Late Holocene in Intertropical Africa. *Palaeogeography, Palaeoclimatology, Palaeoecology* 136 (1): P. 213–229. doi:10.1016/S0031-0182(97)00089-8.
4. Ball, Terry, Karol Chandler-Ezell, Ruth Dickau, Neil Duncan, Thomas Hart, Jose Iriarte, Carol Lentfer, et al. 2015. Phytoliths as a Tool for Investigations of Agricultural Origins and Dispersals around the World. *Journal of Archaeological Science* In Press (December). doi:10.1016/j.jas.2015.08.010.
5. Bashtannik S.V. 2007. *Zemledel'cheskaya kul'tura Yuzhnogo Kazakhstana epochi srednevekov'a* [Agricultural culture of Southern Kazakhstan of the Middle Ages]. Kemerovo: Kemerovskiy gosudarstvenny universitet iskusstv (KemGUKI) <https://lib.biblioclub.ru/?page=book&id=227786&razdel=10467>. [in Russian].
6. Blackman, Elizabeth. 1969. Observations on the Development of the Silica Cells of the Leaf Sheath of Wheat (*Triticum Aestivum*). *Canadian Journal of Botany* 47 (6). NRC Research Press Ottawa, Canada: P. 827–838.
7. Blackman, Elizabeth, and D. Wynn Parry. 1968. Opaline Silica Deposition in Rye (*Secale Cereale* L.). *Annals of Botany* 32 (1). Oxford University Press: P. 199–206.
8. Bozarth, Steven R. 1987. Diagnostic Opal Phytoliths from Rinds of Selected Cucurbita Species. *American Antiquity* 52 (3). Cambridge University Press: P. 607–615.
9. Brochier, Jacques E, Paola Villa, Mario Giacomarra, and Antonio Tagliacozzo. 1992. Shepherds and Sediments: Geo-Ethnoarchaeology of Pastoral Sites. *Journal of Anthropological Archaeology* 11 (1): P. 47–102. doi:10.1016/0278-4165(92)90010-9.
10. Bryant, V. M. 1993. Phytolith Research: A Look toward the Future. *MASCA Research Papers in Science and Archaeology* 10: P. 175–181.
11. Cabanes, Dan, Carolina Mallol, Isabel Expósito, and Javier Baena. 2010. Phytolith Evidence for Hearths and Beds in the Late Mousterian Occupations of Esquilieu Cave (Cantabria, Spain). *Journal of Archaeological Science* 37 (11): P. 2947–2957. doi:10.1016/j.jas.2010.08.010.

jas.2010.07.010.

12. Cabanes, Dan, Steve Weiner, and Ruth Shahack-Gross. 2011. Stability of Phytoliths in the Archaeological Record: A Dissolution Study of Modern and Fossil Phytoliths. *Satellite Remote Sensing in Archaeology: Past, Present and Future Perspectives* 38 (9): P. 2480–2490. doi:10.1016/j.jas.2011.05.020.

13. Canti, M.G. 1997. An Investigation of Microscopic Calcareous Spherulites from Herbivore Dungs. *Journal of Archaeological Science* 24 (3): P. 219–231. doi:10.1006/jasc.1996.0105.

14. Canti, M.G. 1998. The Micromorphological Identification of Faecal Spherulites from Archaeological and Modern Materials. *Journal of Archaeological Science* 25 (5): P. 435–444. doi:10.1006/jasc.1997.0210.

15. Canti, M.G. 1999. The Production and Preservation of Faecal Spherulites: Animals, Environment and Taphonomy. *Journal of Archaeological Science* 26 (3): P. 251–258. doi:10.1006/jasc.1998.0322.

16. Chang, Claudia, and Rebecca Beardmore. 2016. The Tale of a Mud Brick : Lessons from Tuzusai and de-Assembling an Iron Age Site on the Talgar Alluvial Fan in Southeastern Kazakhstan. In *Incomplete Archaeologies: Assembling Knowledge in the Past and Present*, edited by Emily Miller Bonney, Kathryn J. Franklin, and James A. Johnson. Oxbow Books.

17. Coil, James, M. Alejandra Korstanje, Steven Archer, and Christine A. Hastorf. 2003. Laboratory Goals and Considerations for Multiple Microfossil Extraction in Archaeology. *Journal of Archaeological Science* 30 (8): P. 991.

18. Collura, Lucia Veronica, and Katharina Neumann. 2017. Wood and Bark Phytoliths of West African Woody Plants. 9th International Meeting of Phytolith Research (IMPR) 434 (April): P. 142–159. doi:10.1016/j.quaint.2015.12.070.

19. Cornelis, Jean-Thomas, and Bruno Delvaux. 2016. 'Soil Processes Drive the Biological Silicon Feedback Loop'. *Functional Ecology* 30 (8): P. 1298–1310. doi:10.1111/1365-2435.12704.

20. Darwin, Charles. 1909. *Journal of Researches into the Natural History and Geology of the Countries Visited during the Voyage Round the World of HMS "Beagle" under Command of Captain Fitz Roy, RN.* J. Murray.

21. Doumani, Paula N., Michael D. Frachetti, Rebecca Beardmore, Tekla M. Schmaus, Robert N. Spengler, and Alexei N. Mar'yashev. 2015. 'Burial Ritual, Agriculture, and Craft Production among Bronze Age Pastoralists at Tasbas (Kazakhstan)'. *Archaeological Research in Asia* 1–2 (January): P. 17–32. doi:10.1016/j.ara.2015.01.001.

22. Fishkis, O., J. Ingwersen, M. Lamers, D. Denysenko, and T. Streck. 2010. 'Phytolith Transport in Soil: A Laboratory Study on Intact Soil Cores'. *European Journal of Soil Science* 61 (4): P. 445–455. doi:10.1111/j.1365-2389.2010.01257.x.

23. Gavrilov, Denis A., Maria A. Bronnikova, Maral K. Khabdulina, and Alexey N. Sviridov. 2022. 'Soil-Archaeological Studies of Koy-Gunzhar Scythian Tumuli (Kazakhstan) - Estudios de Suelo y Arqueológicos de Los Túmulos Escíticos de Koy-Gunzhar (Kazajistán)'. *Boletín de La Sociedad Geológica Mexicana* 74 (3). Sociedad Geológica Mexicana & Instituto de Geología UNAM: P. 1–18.

24. Gavrilov, Denis A., Гаврилов Д. А, L. S. Shumilovskikh, Шумиловских Л. С, E. Sh Amirov, Амиров Е. Ш, I. R. Kamaldinov, and Камалдинов И. Р. 2016. 'Microbiomorph studies on the cultural layers of Jankent (AD X-XIII), Southern Kazakhstan'. *Environmental*

Dynamics and Global Climate Change 7 (1): P. 54–62. doi:10.17816/edgcc7154-62.

25. Gavrillov, Denis, and Maral Khabdulina. 2018. 'Ancient Irrigated Soils of the Bozok Archaeological District, Northern Kazakhstan (11th to 12th Centuries)'. *Archaeology Ethnology and Anthropology of Eurasia* 46 (December): P. 83–93. doi:10.17746/1563-0102.2018.46.4.083-093.

26. Gol'eva, A. A. 2001. *Fitolity i ih informacionnaya rol' v izuchenii prirodnyh i arkhologicheskikh ob'ektov* [Phytoliths and their informational role in the study of natural and archaeological objects]. Moskva: POLTEKS. <https://istina.msu.ru/publications/book/49473050/>.

27. Hart, Thomas C. 2016. 'Issues and Directions in Phytolith Analysis'. *Journal of Archaeological Science* 68 (April): P. 24–31. doi:10.1016/j.jas.2016.03.001.

28. Harvey, Emma L., and Dorian Q Fuller. 2005. 'Investigating Crop Processing Using Phytolith Analysis: The Example of Rice and Millets'. *Journal of Archaeological Science* 32 (5): P. 739–752. doi:10.1016/j.jas.2004.12.010.

29. Helbaek, Hans. 1961. 'Studying the Diet of Ancient Man'. *Archaeology* 14 (2). JSTOR: 95–101.

30. Helbaek, Hans.. 1969. 'Plant Collecting, Dry-Farming and Irrigation Agriculture in Prehistoric Deh Luran'. *Prehistory and Human Ecology of the Deh Luran Plain*. Mem. Mus. Anthropol., No. 1. Univ. Michigan Ann Arbor, MI, P. 383–426.

31. 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): P. 1169–1175. doi:10.1016/j.jas.2005.02.014.

32. International Committee for Phytolith Taxonomy (ICPT). 2019. 'International Code for Phytolith Nomenclature (ICPN) 2.0'. *Annals of Botany* 124 (2): P. 189–199. doi:10.1093/aob/mcz064.

33. Jenkins, Emma. 2009. 'Phytolith Taphonomy: A Comparison of Dry Ashing and Acid Extraction on the Breakdown of Conjoined Phytoliths Formed in Triticum Durum'. *Journal of Archaeological Science* 36 (10): P. 2402–2407. doi:10.1016/j.jas.2009.06.028.

34. Jenkins, Emma, Khalil Jamjoum, Sameeh Nuimat, Richard Stafford, Stephen Nortcliff, and Steven Mithen. 2016. 'Identifying Ancient Water Availability through Phytolith Analysis: An Experimental Approach'. *Journal of Archaeological Science* 73 (September): P. 82–93. doi:10.1016/j.jas.2016.07.006.

35. Jones, Lloyd H. P., and K. A. Handreck. 1965. 'Studies of Silica in the Oat Plant'. *Plant and Soil* 23: P. 79–96.

36. Katz, Ofir, Isaac Gilead, Pua Bar (Kutiel), and Ruth Shahack-Gross. 2007. 'Chalcolithic Agricultural Life at Grar, Northern Negev, Israel: Dry Farmed Cereals and Dung-Fueled Hearths'. *Paléorient* 33 (2). [Paleorient and CNRS Editions, CNRS Editions]: P. 101–116.

37. Klein, R.L., and J.W. Geis. 1978. 'BIOGENIC SILICA IN THE PINACEAE'. *Soil Science* 126 (3). https://journals.lww.com/soilsci/Fulltext/1978/09000/BIOGENIC_SILICA_IN_THE_PINACEAE.3.aspx.

38. Lancelotti, Carla, and M. Madella. 2018. *Phytoliths and the Human Past: Archaeology, Ethnoarchaeology and Palaeoenvironmental Studies*. McDonald Institute for Archaeological Research. <https://www.repository.cam.ac.uk/handle/1810/291129>.

39. Lancelotti, Carla, and Marco Madella. 2012. 'The "invisible" Product: Developing Markers for Identifying Dung in Archaeological Contexts'. *Journal of Archaeological*

Science 39 (April): P. 953–963. doi:10.1016/j.jas.2011.11.007.

40. Loshakova, T.N., D.A. Gavrilov. 2015. Mikrobiomorfnye issledovaniya kul'turnogo sloya poseleniya Aytman (Plato Ustyurt) [Microbiomorph studies of the cultural layer of the Aitman settlement (Ustyurt Plateau)] VAAE. 2015. №2 (29). URL: <https://cyberleninka.ru/article/n/mikrobiomorfnye-issledovaniya-kulturnogo-sloya-poseleniya-aytman-plato-ustyurt> (Accessed: 19.09.2023). [in Russian].

41. Macphail, Richard I, G.M. Cruise, Michael J Allen, Johan Linderholm, and Peter Reynolds. 2004. 'Archaeological Soil and Pollen Analysis of Experimental Floor Deposits; with Special Reference to Butser Ancient Farm, Hampshire, UK'. Journal of Archaeological Science 31 (2): P. 175–191. doi:10.1016/j.jas.2003.07.005.

42. Madella, M., M.K. Jones, P. Echlin, A. Powers-Jones, and M. Moore. 2009. 'Plant Water Availability and Analytical Microscopy of Phytoliths: Implications for Ancient Irrigation in Arid Zones'. Perspectives on Phytolith Research: 6th International Meeting on Phytolith Research 193 (1): P. 32–40. doi:10.1016/j.quaint.2007.06.012.

43. Madella, M., and Carla Lancelotti. 2012. 'Taphonomy and Phytoliths: A User Manual'. Site Formation and Postdepositional Processes In Archaeology (International Workshop, Barcelona, 2–4 June 2010) 275 (October): P. 76–83. doi:10.1016/j.quaint.2011.09.008.

44. Metcalfe, Charles Russell. 1960. 'Anatomy of the Monocotyledons. 1. Gramineae.' Anatomy of the Monocotyledons. 1. Gramineae. Oxford: Clarendon Press.

45. Myrzabayeva, M.T., D.T. Konysbayeva. 2018. Osimdikterdegi abiotikalyq jane biotikalyq stress jagdaylaynda kremniy elementinin biologialyq manyzy (Biological function of silicon in plants under biotic and abiotic stress conditions). Semey qalasynyn Shakarim atyndagy memlekettik universitetinin habarshysy 4 (84): 174–79. [in Kazakh]

46. Netolitzky, Fritz. 1914. Die Hirse Aus Antiken Funden. Hölder in Komm.

47. Parr, Jeff F. 2006. 'Effect of Fire on Phytolith Coloration'. Geoarchaeology 21 (2): P. 171–185. doi:<https://doi.org/10.1002/gea.20102>.

48. Parry, D. Wynn, and F. Smithson. 1964. 'Types of Opaline Silica Depositions in the Leaves of British Grasses'. Annals of Botany 28 (1). Oxford University Press: P. 169–185.

49. Parry, D. Wynn, and F. Smithson.. 1966. 'Opaline Silica in the Inflorescences of Some British Grasses and Cereals'. Annals of Botany 30 (3). Oxford University Press: P. 525–538.

50. Pearsall, Deborah M. 1978. 'Phytolith Analysis of Archeological Soils: Evidence for Maize Cultivation in Formative Ecuador'. Science 199 (4325). American Association for the Advancement of Science: P. 177–178.

51. Pearsall, Deborah M.. 1982. 'Phytolith Analysis: Applications of a New Paleoethnobotanical Technique in Archeology'. American Anthropologist 84 (4). JSTOR: P. 862–871.

52. Pearsall, Deborah M. 2016. Paleoethnobotany: A Handbook of Procedures. Abingdon, Oxon: Routledge. <https://www.taylorfrancis.com/books/e/9781315423098>.

53. Piperno, D. R. 1984. 'A Comparison and Differentiation of Phytoliths from Maize and Wild Grasses: Use of Morphological Criteria'. American Antiquity 49 (2). Cambridge University Press: P. 361–383.

54. Piperno, D. R.. 1985a. 'Phytolith Analysis and Tropical Paleo-Ecology: Production and Taxonomic Significance of Siliceous Forms in New World Plant Domesticates and Wild Species'. Review of Palaeobotany and Palynology 45 (3–4). Elsevier: P. 185–228.

55. Piperno, D. R.. 1985b. 'Phytolith Taphonomy and Distributions in Archeological

Sediments from Panama'. *Journal of Archaeological Science* 12 (4). Elsevier: P. 247–267.

56. Piperno, D. R.. 1988. 'Phytolith Analysis: An Archaeological and Geological Perspective. San Diego: Academic Press'.

57. Piperno, D. R.. 2006. *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. Lanham, Md: AltaMira Press.

58. Portillo, Marta, Rosa Maria Albert, and Donald O. Henry. 2009. 'Domestic Activities and Spatial Distribution in Ain Abū Nukhayla (Wadi Rum, Southern Jordan): The Use of Phytoliths and Spherulites Studies'. *Perspectives on Phytolith Research: 6th International Meeting on Phytolith Research* 193 (1): P. 174–183. doi:10.1016/j.quaint.2007.06.002.

59. Powers, Alix H. 1992. 'Great Expectations: A Short Historical Review of European Phytolith Systematics'. In *Phytolith Systematics: Emerging Issues*, edited by George Rapp and Susan C. Mulholland, P. 15–35. Boston, MA: Springer US. doi:10.1007/978-1-4899-1155-1_2.

60. Rapp, George Robert, and Susan C Mulholland. 1992. *Phytolith Systematics : Emerging Issues / Edited by George Rapp, Jr. and Susan C. Mulholland*. New York: Society for Archaeological Sciences (U.S.).

61. Roberts, Rebecca. (unpublished thesis). 'Late Bronze Age to Iron Age Land Use and Subsistence Strategies in the Semirech'ye Region of Kazakhstan'. London: University College London.

62. Rosen, Arlene Miller, Claudia Chang, and Fedor Pavlovich Grigoriev. 2000. 'Palaeoenvironments and Economy of Iron Age Saka-Wusun Agro-Pastoralists in Southeastern Kazakhstan'. *Antiquity* 74 (285). Cambridge University Press: P. 611–623. doi:10.1017/S0003598X00059974.

63. Rosen, Arlene Miller, and Stephen Weiner. 1994. 'Identifying Ancient Irrigation: A New Method Using Opaline Phytoliths from Emmer Wheat'. *Journal of Archaeological Science* 21 (1): P. 125–132. doi:10.1006/jasc.1994.1013.

64. Rovner, Irwin. 1971. 'Potential of Opal Phytoliths for Use in Paleoecological Reconstruction'. *Quaternary Research* 1 (3). Cambridge University Press: P. 343–359.

65. Samashev, Zainolla Samashevich. 2021. 'Eleke Sazy, Kurgan 4'. In *Gold of the Great Steppe*, edited by Rebecca Roberts, P. 69–101. PHP.

66. Shillito, Lisa-Marie. 2011. 'Simultaneous Thin Section and Phytolith Observations of Finely Stratified Deposits from Neolithic Çatalhöyük, Turkey: Implications for Paleoecology and Early Holocene Palaeoenvironment'. *Journal of Quaternary Science* 26 (6): P. 576–588. doi:10.1002/jqs.1470.

67. Solomonova M.Yu., Speranskaya N.Yu., Elesova N.V., Silant'eva M.M., Blinnikov M.S. 2019. *Fitolitnye spektry fitocenzov yuga Zapadnoy Sibiri [Phytolith spectra of phytocenoses of the south of Western Siberia.]*. August. <http://phytolith.asu.ru/>. [in Russian].

68. Spengler, Robert N., Claudia Chang, and Perry A. Tourtellotte. 2013. 'Agricultural Production in the Central Asian Mountains: Tuzusai, Kazakhstan (410–150 b.c.)'. *Journal of Field Archaeology* 38 (1). Routledge: P. 68–85. doi:10.1179/0093469012Z.00000000037.

69. Spengler, Robert N., Michael D. Frachetti, and Paula N. Doumani. 2014. 'Late Bronze Age Agriculture at Tasbas in the Dzhungar Mountains of Eastern Kazakhstan'. *Quaternary International, The Bridging Eurasia Research Initiative: Modes of mobility and sustainability in the palaeoenvironmental and archaeological archives from Eurasia*,

348 (October): P. 147–157. doi:10.1016/j.quaint.2014.03.039.

70. Strömberg, Caroline A. E. 2003. *The Origin and Spread of Grass-Dominated Ecosystems during the Tertiary of North America and How It Relates to the Evolution of Hypsodonty in Equids*. University of California, Berkeley.

71. Strömberg, Caroline A. E., Verónica S. Di Stilio, and Zhaoliang Song. 2016. 'Functions of Phytoliths in Vascular Plants: An Evolutionary Perspective'. *Functional Ecology* 30 (8): P. 1286–1297. doi:10.1111/1365-2435.12692.

72. Strömberg, Caroline A. E. 2009. 'Methodological Concerns for Analysis of Phytolith Assemblages: Does Count Size Matter?' *Perspectives on Phytolith Research: 6th International Meeting on Phytolith Research* 193 (1): P. 124–140. doi:10.1016/j.quaint.2007.11.008.

73. Struve, Gustav Adolf. 1835. *De Silicia in Plantis Nonnullis*. Nietackianis.

74. Thorn, Vanessa. 2007. 'Phytoliths in Palaeoecology'. *Geology Today* 23 (4): P. 153–157. doi:https://doi.org/10.1111/j.1365-2451.2007.00624.x.

75. Twiss, Page C., Erwin Suess, and Ron M. Smith. 1969. 'Morphological Classification of Grass Phytoliths'. *Soil Science Society of America Journal* 33 (1). Wiley Online Library: P. 109–115.

76. Watanabe, N. 1955. 'Ash in Archaeological Sites'. In *Rengo-Taikai Kiji. Proceeding of the Joint Meeting of the Anthropological Society of Nippon and Japan Society of Ethnology (Japanese)* 9: 169. Vol. 171.

77. Watanabe, N.. 1968. 'Spodographic Evidence of Rice from Prehistoric Japan'. *Jour. Fac. Sci. Univ. Tokyo* 3: P. 217–235.

78. Weisskopf, Alison, Zhenhua Deng, Ling Qin, and Dorian Q Fuller. 2015. 'The Interplay of Millets and Rice in Neolithic Central China: Integrating Phytoliths into the Archaeobotany of Baligang'. *Archaeological Research in Asia* 4 (December): P. 36–45. doi:10.1016/j.ara.2015.10.002.

79. Weisskopf, Alison, Ling Qin, Jinglong Ding, Pin Ding, Guoping Sun, and Dorian Q Fuller. 2015. 'Phytoliths and Rice: From Wet to Dry and Back Again in the Neolithic Lower Yangtze'. *Antiquity* 89 (347). Cambridge University Press: P. 1051–1063. doi:10.15184/aqy.2015.94.

80. Wendrich, Willeke Z., and Philippa Ryan. 2012. 'Phytoliths and Basketry Materials at Çatalhöyük (Turkey): Timelines of Growth, Harvest and Objects Life Histories'. *Paleobiology* 38: P. 55–63.

81. Zurro, Débora, Juan José García-Granero, Carla Lancelotti, and M. Madella. 2016. 'Directions in Current and Future Phytolith Research'. *Journal of Archaeological Science* 68 (April): P. 112–117. doi:10.1016/j.jas.2015.11.014.

Ребекка С. Робертс^{1,2}

¹Макдональд археологиялық зерттеулер институты
Кембридж университеті, Ұлыбритания

²Фицвильям мұражайы, Кембридж университеті
Ұлыбритания
<rcr45@cam.ac.uk>

АРХЕОЛОГИЯДАҒЫ МИКРООРТА ҚАЛДЫҚТАРЫ: ФИТОЛИТТЕР МЕН ФЕКАЛДІ СФЕРОЛИТТЕР ЖӘНЕ ОЛАРДЫ ҚАЗАҚСТАННЫҢ АРХЕОЛОГИЯЛЫҚ ҚАБАТТАРЫНДАҒЫ АДАМ МЕН ҚОРШАҒАН ОРТАНЫҢ ӘРЕКЕТТЕСУІН ЗЕРТТЕУГЕ ҚОЛДАНУ

Аннотация. Бұл мақалада археологиялық зерттеу қабаттарынан табылған микроорта қалдықтарын (фитолиттер мен фекалді сферолиттер) зерттеу нәтижесінде жинақталатын археологиялық материалдар және олардың Қазақстан археологиясындағы адам мен қоршаған ортаның өзара әрекеттесуін талдауда қолданылуы қарастырылады. Микроорта қалдықтарының екі түрінің зерттелу тарихына қысқаша шолу жасалып, жинақталу процестері мен тафономикалық процестер де қарастырылады. Қазақстандағы археологиялық қабаттардан алынған мысалдарды пайдалана отырып, мақалада сол кездегі адам мен қоршаған ортаның өзара әрекеттесулері туралы түсінік беретін фитолиттер мен фекалді сферолиттерді талдаудан алынған ақпарат түрлерін зерттейді.

Кілт сөздер: фитолит, фекалді сферолит, археология, экологиялық археоботаника.

Ребекка С. Робертс^{1,2}

¹Институт археологических исследований Макдональда,
Кембриджский университет, Великобритания

²Музей Фицуильяма, Кембриджский университет
Великобритания
<rcr45@cam.ac.uk>

ОСТАТКИ МИКРОСРЕДЫ В АРХЕОЛОГИИ: ФИТОЛИТЫ И ФЕКАЛЬНЫЕ СФЕРОЛИТЫ И ИХ ПРИМЕНЕНИЕ ДЛЯ ИЗУЧЕНИЯ ВЗАИМОДЕЙСТВИЯ ЧЕЛОВЕКА И ОКРУЖАЮЩЕЙ СРЕДЫ В АРХЕОЛОГИЧЕСКИХ ОТЛОЖЕНИЯХ КАЗАХСТАНА

Аннотация. В этой статье исследуются археологические материалы, которые могут быть собраны в результате изучения остатков микросреды (фитолитов и фекальных сферолитов), извлеченных из археологических отложений, и их применение при анализе взаимодействия человека и окружающей среды в археологии Казахстана. Дан краткий обзор истории изучения двух типов остатков микросреды, а также рассмотрены процессы формирования скоплений и тафономические процессы. Используя примеры из археологических отложений в Казахстане, в статье

исследуются типы информации, которые могут быть извлечены из анализа фитоли-
тов и фекальных сферолитов, которые позволят узнать о взаимодействии человека и
окружающей среды в прошлом.

Ключевые слова: фитолит, фекальный сферолит, археоботаника, экологи-
ческая археология.

Information about authors:

Rebecca C. Roberts, PhD, McDonald Institute for Archaeological Research, University
of Cambridge, UK; Fitzwilliam Museum, University of Cambridge, UK.

Автор туралы мәлімет:

Ребекка С. Робертс, PhD, Макдональд археологиялық зерттеулер институты,
Кембридж университеті, Ұлыбритания; Фицвильям мұражайы, Кембридж
университеті, Ұлыбритания.

Сведения об авторе:

Ребекка С. Робертс, PhD, Институт археологических исследований
Макдональда, Кембриджский университет, Великобритания; Музей Фицуильяма,
Кембриджский университет, Великобритания.