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Late Pleistocene humans in Sri Lanka used plant resources: a phytolith record from Fahien Rock Shelter

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Abstract

Little is known of the human use of rainforest plant resources of prehistoric Sri Lanka due to the lack of preservation of organic material and the effects of various destructive taphonomic processes. Phytoliths recovered from a AMS radiocarbon and OSL dated sequence at Fahien Rock Shelter indicate interactions of anatomically modern humans with the lowland rainforests of south-western Sri Lanka from 44,952-47,854 cal. BP to 11,991-12,402 cal. BP. During this period, the Rock Shelter occupants extracted their livelihood from a number of wild plants including bananas, rice, breadfruits, durians, canarium and species of palm and bamboo. These taxa are associated with present-day disturbed lowland rainforests. Gathering and processing of plant resources by existing modern rainforest foragers cannot directly be compared with the subsistence activities of the Late Pleistocene Rock Shelter occupants.

Key words: Excavation; Stratigraphy; Taphonomy; Rainforests; Rice; Wild Banana

1. Introduction

Tropical environments are reputed to be amongst the most challenging for human colonisation (Friesem et al., 2016). Until recently, many anthropologists held that it was impossible for hunter-gatherers to live in rainforest environments if they could not exchange forest resources with adjacent agricultural populations (Headland and Bailey, 1991). Ethnohistorical, geomorphological, palaeoecological, archaeological and archaeobotanical evidence is important to examine questions concerning the antiquity of rainforest colonization by humans on a global scale (Cosgrove et al., 2007; Barker et al., 2007, 2017). However, there is emerging archaeobotanical evidence (e.g. phytoliths, pollen and macro-plant remains) to indicate that humans were able to colonise and exploit rainforest environments in Island South East Asia, Melanesia, Australasia, Sri Lanka and Africa from the late Pleistocene and in doing so, they utilised fire to manage rainforest vegetation (e.g. Premathilake, 2003, 2006; Barker et al., 2007, 2017; Petraglia et al., 2009; Clarkson et al., 2009; Lentfer et al., 2010; Summerhayes et al., 2010; Perera, 2010; Perera et al., 2011; Hunt et al., 2012; Castillo and Fuller, 2015; Roberts and Petraglia, 2015; Roberts et al., 2015, 2017).

Phytoliths - minute silica bodies produced by plants (Piperno, 1988) - are one of the most promising lines of evidence in tropical environments. These environments are often highly oxidizing, with frequent free iron, aluminium oxides and other clay minerals and thus with poor preservation of organic materials such as pollen, plant macrofossils and wood. This has major implications in reporting the history of use of rainforest plant resources (Deraniyagala, 1992; Goldberg and Bar-Yosef, 1998; Bowdery, 1999; Albert et al., 1999; Denham et al., 2003; Premathilake, 2003, 2006; Fuller and Harvey 2006; Vrydaghs et al., 2009; Castillo and Fuller, 2010; Perera 2010; Perera et al., 2011; Madella and Lancelotti, 2012; Castillo and Fuller, 2015; Friesem et al., 2016; Bates et al., 2017; Premathilake et al., 2017a,b). We report the results of phytolith analysis from the deposits at Fahien Rock Shelter, one of the oldest prehistoric sites in South Asia, which contains a sequence containing evidence for habitation by rainforest hunter-gatherers through the second half of the late Pleistocene and into the Holocene.

2. Fahien Rock Shelter environment

Fahien Rock Shelter, one of the largest caves in Sri Lanka, is situated at 6° 38' 55'' N 80° 12' 55'' E and 130 m above sea-level close to Yatagampitiya village, near Bulathsinhala in the Kalutara District, southwest Sri Lanka (Fig. 1). It is a complex of interconnected Rock Shelters developed in coarse crystalline gneiss rock faces (Cooray, 1984). The mouth has a width of 30 m and average height above the floor of 20 m. The interior is about 10 m deep and slopes down west to east. Data from the meteorological station in Sinharaja, in lowland rainforest some 10 km away (06°23′22″N 80°30′05″E) indicate that the regional climate is humid-tropical with a mean annual temperature of 26°C and annual average rainfall of 4300 mm (Zoysa and Raheem, 1987; Gunatillake et al., 2004). Today, the landscape around the site is characterized by disturbed lowland rainforest, with paddy fields present in the slightly incised valley below the Rock Shelter.

3. Material and methods

The Rock Shelter was excavated over several seasons between 1986 and 2012 by scholars from the Department of Archaeological Survey, Sri Lanka (Deraniyagala, 1992; Wijeyapala, 1997; Perera, 2010, 2015; Oshan, 2011). The excavation area (4 x 5 m) is located in the east of the main chamber of the Rock Shelter, and a detailed stratigraphical study was undertaken. The depiction of the stratigraphic succession with its contained archaeological contexts at the Rock Shelter was made according to the standard Harris Matrix tool (cf. Premathilake and Hunt, 2018).

3.1. Lithostratigraphy

The excavation penetrated ca. 2.40 m of heterogeneous clast-rich loamy sediments which can be subdivided into five major stratigraphic units, 10 archaeological phases (I-X) and approximately 250 archaeological contexts (C). This paper considers the lithological records from units L5 and L4/L3, including phases I-VI of the archaeological sequence, where the most significant late Pleistocene archaeological evidence was found. This includes the oldest microlith toolkits known to South Asia, associated with the contexts from C-92 to C-87 (Fig. 2; Table 1).

3.2. Chronostratigraphy

Nine AMS dates were obtained from charred materials, charred wood, charcoal, *Canarium* cf. *zylanicum* nut and freshwater shells deposited throughout the investigated southern section. Two sediment samples (SUTL2327, SUTL2326) from context C-92 were used for OSL dating. Radiocarbon dates were produced using Accelerator Mass Spectrometry at the CHRONO Centre at Queen's University, Belfast and the Beta Analytic Laboratory in the USA. The dates were calibrated using Calib 6.11 (Reimer et al., 2009). The radiocarbon dates indicate that the studied sediments were laid down between 44,950-47,854 cal. BP and 11,991-12,402 cal. BP (Table 2; Fig. 2). The oldest microlith toolkits known to South Asia are associated with the contexts from C-92 to C-87, which are dated to between 44,950-47,854 cal. BP and 27,860-29,089 cal. BP. OSL dating (Kinnaird & Sanderson, 2010) appears to be broadly consistent with the radiocarbon chronology (Premathilake and Hunt, 2018).

3.3. Biostratigraphy

Table 1 includes macro-botanical and zoological remains reported through the stratigraphy. This comprises shell beads, animal teeth (e.g. *Semnopithecus priam*, *Ratufa macroura*, *Parradoxurus* sp., *Trachypithecus vetulus* and *Macaca sinica*), human bones, burnt and unburnt shells (e.g. *Acavus* sp. and *Pila* sp.), charcoal, wild breadfruit (*Artocarpus nobilis*), epicarps, *Canarium* nuts and coprolites. Human remains include several internments; some coated with red ochre and are associated with the first microlith and osseous technologies anywhere in South Asia. The layer is dated on charcoal and charred materials to 39,852-35,768 cal. BP (Table 2). Phase VI in the sequence has been characterised as a period of intensive human habitation at the site, as indicated by the presence of a highly fragile and fragmentary human skeleton (Perera, 2010, 2015; Perera et al., 2011). This has recently been dated to around 12,000 cal. BP. (cf. Perera, 2015). The stratigraphy also contains well-preserved ashy hearths.

3.4. Sample selection and sediment processing

Twelve 30x10x8 cm monoliths were taken from the southern profile of the Rock Shelter. These covered five major layers (L3-L5) including archaeological phases I-VI; (Table 1) (Wijeyapala, 1997; Perera, 2010, 2015; Oshan, 2011). Six subsamples (C-92 - C-81) from the lowermost sediments of late Pleistocene age including L5 and L4/L3 were selected for detailed phytolith analysis on the basis of their archaeological and chronological significance (cf. Premathilake and Hunt, 2018). The detailed techniques used for phytolith extraction (Lentfer and Boyd, 1998), microscopy and phytolith percentage diagram construction are presented in SOM 1.

3.5. Phytolith taxonomy

Classification and taxonomic identifications of phytoliths from archaeological samples were made using modern and archaeological phytolith collections housed at the Laboratory for Palaeoecology, Postgraduate Institute of Archaeology, University of Kelaniya, Sri Lanka and the French Institute of Pondicherry, India (IFP). In our procedures, the most common morphological characteristics, general occurrence and appearance of key archaeological phytoliths were comparatively studied (Figs. 3, 4, 5, 6). Additional support received from several published works and details of taxonomic separation are presented in SOM 1 and 2.

4. Results

4.1. Phytoliths stratigraphy

Phytolith assemblages are shown in Fig. 7 and Table S3. All samples contained high counts of well-preserved phytoliths. In a very few samples, some phytoliths are pitted, displayed a few relatively large micro-channels, mineralized micro-structures or were broken. More than 60 phytolith morphotypes were identified. Monocotyledonous phytoliths were dominant in comparison to the dicotyledonous types. The detailed results are given in Table S3. Phytolith counts decrease from the Late to Terminal Pleistocene samples.

Phytoliths from seeds and leaves of wild *Musa* banana commonly occur (SOM 2; Table S3). Phytoliths from several other economically-important taxa e.g. species of Palmae, *Artocarpus* cf. *nobilis* (wild breadfruit) and *Durio* occur in relatively low percentages. One terminal Pleistocene sample contained a few phytoliths of Burseraceae. The presence of phytoliths from *Oryza* sp. (wild rice) seeds and leaves is reported in varying percentages (SOM 2; Table S3). Phytoliths from Poaceae (grass) occur in all samples, with Pooid regular short cells relatively common compared with Chloridoid saddles and Panicoid bilobates. All samples contain bulliforms derived from Poaceae. Rondel phytoliths are common in all the samples.

Many of them are distinctly taller than width (corn-like rondel), most possibly derived from Bambusoid species. A few samples contain Cyperaceae phytoliths.

Phytoliths blackened by fire (reported as burnt phytoliths) are common. Many of the burnt phytoliths are from Poaceae, Palmae (identified as Palmae 1 and 2 based on size variation), *Oryza* sp., *Durio* sp. and *Artocarpus* cf. *nobilis*.

Freshwater diatom (*Navicula* cf. *leistikowii* and *Aulacoseria* cf. *granulata*) counts increase from the Late to the terminal Pleistocene samples. A few brackish/marine diatoms (*Navicula* cf. *gregaria*, *Amphora* cf. *coffeaeformis* and *Achnanthes* cf. *hauckiana*) occur in several samples (Table S3).

5. Discussion

5.1. Reliability of Rock Shelter stratigraphy

Understanding of the litho-stratigraphy is imperative for interpreting the Rock Shelter phytoliths, although many challenges still lies ahead of investigations of how sediment stratigraphies can develop (Gilbertson et al. 2005; Butzer, 2008; Hunt et al., 2010; Friesem, 2016; Zurro et al., 2016; Barker et al, 2007, 2017). The sediments of Fahien Rock Shelter are heterogeneous and analysis of the ca. 250 contexts suggests the occurrence of very complex sedimentary processes (Perera, 2010, 2015; Kourampas et al., 2009; Oshan, 2011). Nevertheless, all of the radiocarbon dates are in good stratigraphic order, suggesting sequential deposition and little post-depositional disturbance.

The chronology suggests that significant depositional hiatuses occur within the excavated sequence between the late Pleistocene and early Holocene (Fig. 2; Table 2). The oldest sample, from context 92; just above the date of 44,952-47,854 cal BP contains a very high number of phytoliths suggesting significant human activity (Premathilake and Hunt, 2017). A major hiatus extended from C-87 to C-81 (27,860-29,089 to 11,991-12,402cal. BP) and is marked by the reduction of phytolith sums (Fig. 7).

These hiatuses can be explained by climatic phases causing erosion of the Rock Shelter sediments. Multi-proxy investigations (Premathilake and Risberg, 2003; Petraglia et al., 2009; Premathilake, 2006, 2012ab, 2015a) indicate Inter Tropical Convergence Zone (ITCZ) -

induced monsoon intensification events with high rainfall at 17,650-16, 200, 13,700-12,800, 10,400-9,900 and 9,200-8,800 cal. BP, contemporary with periods of increased rainfall-driven landslide frequency in the landscape around the Rock Shelter (Gunathilaka, 2007; Kourampas et al., 2009; Premathilake and Hunt, 2018). These alternate with desiccation from millennial to multi-century scale arid/semi-arid phases of monsoon failure, identified from peat and sedimentary archives in southern Asia between 24,000 cal. BP and 8,100 cal. BP (Premathilake and Risberg, 2003; Premathilake and Gunathilaka, 2013). Phases of erosion of the Rock Shelter sediments (Fig. 2) seem to be contemporary with the high-rainfall episodes, suggesting that the impact of climate was the dominant factor forming the litho-stratigraphy throughout the late Pleistocene. We argue that accumulation of clast-rich loam sediment layers (Table 1) continued because of the combined effect of the prominent mode of semi-arid climate and human activities including biomass burning and foraging associated with lowland and upper montane rain forests (Perera et al., 2011, Kourampas et al., 2009, Premathilake, 2003, 2006). It seems that anthropogenic sedimentation, particularly accumulation of human habitation debris and sediment entrained by human action was prominent during the late Pleistocene, but the accumulation rate varied very markedly between and within major layers through this time (Fig. 2). Detailed geo-archaeological research (soil micromorphology) with additional radiocarbon dates will provide more information that will further enhance and clarify the current understanding of the depositional history of the sequence (Friesem et al., 2016).

5.2. Reliability of phytolith assemblages

Seeds, epicarps, charcoal and wood recovered from several rock shelter deposits in south western Sri Lanka have been used to address archaeological issues including subsistence activities of the rock shelter occupants and understanding site environments but, phytoliths have not been discussed in detail. Understanding the late Pleistocene rock shelter sites is often difficult because of poor preservation of organic materials and the effect of various taphonomic processes (Deraniyagala, 1992; Perera, 2010; Perera et al., 2011; Kourampas et al., 2009; Roberts et al., 2015, 2017). In the case of Fahien Rock Shelter, taphonomic investigation was essential to understand how phytoliths reached the site and how they were deposited and preserved. The presence of phytoliths in the Rock Shelter sediments provides information about the depositional processes in several ways (1) *in situ* plant decay leading to phytolith deposition on surfaces (2) alluvial or colluvial re-deposition of phytoliths along with their associated sediments (3) wind deposition (4) cultural deposition of phytoliths through plant materials used by Rock Shelter occupants for food and other cultural purposes (Behrensmeyer et al., 2000; Hunt et al., 2016).

The lack of macro botanical evidence – fruits, leaves, stems etc. - of living plants of taxa such as Poaceae, Palmae and Musaceae and the lack of organic litter in the Rock Shelter suggest a minimal deposition of *in situ* phytoliths. Abundant phytoliths from these monocot taxa in the samples suggest that the effect of horizontal and vertical movements through alluvial and/or colluvial processes may have played a limited role in phytolith re-deposition. Due to the presence of a drip-line, rain water penetration into the Rock Shelter is minimal. Wind deposition is rare due to the particular geomorphology of Rock shelter in the humid tropical environment.

The main process, therefore, of phytolith deposition in the Rock shelter is most likely to have been through human or animal vectors. Common animals in the vicinity of the Rock Shelter, such as bats, birds, and insects, are rather unlikely to play a role in phytolith deposition, however. The variable phytolith counts through the sequence (Fig. 7) and selective distribution of phytoliths from wild bananas suggest that most phytoliths were brought into the cave by people and remain *in-situ* (cf. Premathilake and Hunt, 2018). Hunt et al. (2016) suggested that similar strong patterning at Niah Cave was evidence for anthropogenic deposition. Thus, it is inferred that humans are the most likely agents for phytolith deposition – with materials from economically significant plants such as wild banana, breadfruit and palms from plants characteristically growing in disturbed lowland rainforest near to the Rock Shelter (most likely within a few kilometers at most). Abundant phytoliths from grasses and sedges - are identified as from economically-useful taxa, but may also be evidence for forest disturbance. The occurrence of freshwater and brackish-marine diatom species throughout is not surprising in habitation deposits (Hunt et al. 2016) and is consistent with a number of human activities involving activity in wetlands and the carrying of material encrusted with diatoms into the Rock Shelter (Kanthilatha et al., 2017).

In the majority of samples, abundant banana seed and leaf phytoliths together with the lack of taphonomic markers (such as breakage, corrosion, microchannels, regulation, dissolution pits, mineralized microstructures, cut marks and pitted patterns) indicate excellent preservation conditions and selective distribution of phytoliths from wild bananas used by the Rock Shelter occupants. This suggests high phytolith compositional fidelity in the samples. Excellent preservation conditions are further attested by the high number of non-durable phytoliths (e.g. globular echinate, volcaniforms, trichome, elongate sinuous and bilobate) and very few phytoliths with isolated cavities, with occluded carbon. A few phytoliths contain cavities that may be due to the natural silicification process, as evidenced by the modern phytolith collections and are not related to taphonomic processes such as diagenetic dissolution. The presence of well-preserved phytoliths throughout the sequence suggests these impacts were minimal (Alexandre et al., 1997; Behrensmeyer et al., 2000; Fredlund and Tieszen, 1997; Albert et al., 1999, 2006; Farmer et al., 2005; Piperno, 2006; Gérard, et al., 2008; Loucaides et al., 2008, 2010; Osterrieth, et al., 2009; Karkanas, 2010; Borrelli et al., 2010; Cabanes et al., 2011, 2012; Alexandre et al., 2015). Alkaline conditions are thought to contribute to phytolith dissolution (Loucaides et al., 2010; Cabanes et al., 2011; Fraysse et al., 2006, 2009) with an increase in solubility of silica at pH > 7.8. In the iron (Fe) rich fine-grained Fahien Rock Shelter sediments solubility is limited as indicated by pH measurements of 6.5-7.3 in all the sediment samples studied (cf. Piperno, 1988). Facetate and sclereid phytoliths from woody dicotyledonous (e.g. forest taxa) are rare in the Late Pleistocene and Holocene samples, which might possibly due to dissolution (Piperno, 2006), but given the circumneutral sediments it is more likely that few phytoliths from woody materials were incorporated. We acknowledge that the production of facetates and sclereids from modern forest plant species is relatively high, but they are very unlikely to be preserved in much older samples (Premathilake et al., 2017b).

Except in the very uppermost parts of the sequence, the absence of post-depositional disruption through root penetration, roof fall, vertical sediment cracks, human digging and animal burrowing and the lack of evidence for disruption within the clay- and silt-rich, highly-compacted and multi-layered sediments indicates likely very limited vertical movement of phytoliths (Perera, 2010; 2015). The distribution of the smallest phytoliths (e.g. small rectangles from wild banana seeds and globular nodules from Bombacaceae) and fine-grained sediments suggests the minimal impact of illuviation of clay minerals, reported as a common process in some rock shelter stratigraphies (Butzer 2008; Kourampas, 2009; Alexandre et al., 1997). All these minimized sources of bias indicate that spatial and temporal fidelity is relatively high in this Rock Shelter phytolith stratigraphy (Behrensmeyer et al., 2000). Therefore phytoliths buried in deep stratigraphic levels are likely to be securely *in-situ* and unaffected by bioturbation, suffusion, infiltration or corrosion (Premathilake and Hunt, 2018).

5.3. Late Pleistocene plant exploitation

The Rock Shelter phytolith assemblages provide a potentially more complete botanical record than that provided by macrofossils (Table 1). The significant phytolith counts of economically important plants - wild bananas (*Musa accuminata* and *Musa balbisiana*), wild rice (*Oryza* spp), breadfruit (*Artocarpus* cf. *nobilis*), *Durio*, sp. Palmae and grasses - suggests that the Rock Shelter occupants used those plants. Significant late Pleistocene archaeological evidence is associated with contexts C-87 to C-92; which are dated to between 44,950-47,854 and 27,860-29,089 cal. BP. The deposits in those contexts yielded high counts of phytoliths from economic plants. Key taxa are discussed below.

5.3.1. Wild bananas

Today, more than 50 *Musa* species are recorded in tropical and subtropical regions (Cheesman, 1947; Simmonds, 1956, 1962; Constantine, 1999-2008; Fuller and Madella, 2009; Häkkinen and Väre, 2008). In Sri Lanka, the perennial species *M. acuminata* and *M. balbisiana* commonly grow in disturbed lowland rainforest from sea-level up to 900 m, and they are used for food and various cultural purposes by local people (Chandraratne and Nanayakkara, 1951; Perera, 2017). The Pali chronicle '*Mahavamsa*', written in the 5th century A.D., reported wild banana (*attikehel*) with its various uses. Ethnobotanical investigations indicate that immature and mature fruits with or without seeds, leaves, young leaf sheaths, the male inflorescence bud, male flowers, fruit peels, pseudostem, sucker/shoots, rhizome and ash of wild banana were widely used for plates, wrapping foods, medicine, stimulants, textiles, clothing, packaging, paper-making, craft industry, ornaments and also ceremonial, magic and ritual activities in the countries of south and southeast Asia (Christiansen, 2002; Fuller and Madella, 2009; Simmonds, 1956, 1962; Kennedy, 2009).

High counts of wild *Musa* banana seed and leaf phytoliths (Table S1, S2, S3) indicate that the Rock Shelter occupants exploited wild bananas throughout the late Pleistocene. The banana phytoliths in the late Pleistocene samples are identical to those found in modern *M. accuminata* and *M. balbisiana* populations in Sri Lanka (Premathilake, 2016; Perera, 2017; Premathilake and Hunt, 2018; SOM 2; Fig. 8). This suggests that these two species existed as natural populations in association with open semi-natural habitats in heavily human-impacted lowland rainforest of south western Sri Lanka (Fuller and Madella, 2009; De Langhe, 2009; Roberts et al., 2015, 2017). The suggestion of open habitats is consistent with the abundant wild banana seeds and scarcity of woody dicotyledonous phytoliths at Fahien **(**Fig. 7). The antiquity of wild banana use, previously known from charred seeds from the terminal Pleistocene at Beli-lena rock shelter (Kajale, 1989), has been pushed back into the late Pleistocene and the date of 44,950-47,854 cal. BP by this study. The variety of wild banana phytoliths at Fahien is consistent with multiple uses including the fruits for starchy food, leaves for ethnographically-attested uses such as plates and clothing, stems for fuel. The common occurrence of burnt (blackened) banana seed phytoliths associated with ashy deposits, charcoal and bone fragments from hearths (Perera, 2010; Fig. 7; Table 1; Table S3); suggests perhaps that the roasting and inadvertent burning of banana fruits may have released blackened phytoliths, suggesting possible employment of food processing techniques (Heyne 1950; Perera, 2010; Kanthilatha et al., 2017). However, the available phytolith evidence is not enough to understand the relationship between the phytolith assemblages yielded by processing techniques and the phytoliths found in Rock Shelter floors (Kanthilatha et al., 2017). It is possible given the evidence for behavioural richness of the occupants, including the use of shark vertebra, marine shells as beads and a shell pendant at 38,000 cal. BP (Perera, 2010; Perera et al., 2011; Roberts and Petraglia 2015) that some part of the banana plant could have been used for ritual purposes, as happens ethnographically today, but additional investigations on this particular issue are required to support such a suggestion.

5.3.2. Wild rice

Comparison with multiple rice phytolith reference samples suggests strongly that Rock Shelter rice phytoliths were derived from *Oryza nivara* and/or *O. rufipogon* (SOM 2), but the criteria used here cannot fully separate the perennial *rufipogon* from the annual *nivara* (Fig. 9). Understanding the ecology of wild rice provides an opportunity to explore the relationship between human activity and the presence of wild rice in the archaeological context. The ecology of the wild rice species clearly indicates differing modes of wild rice exploitation for food since the prehistoric in South Asia (Munasinghe, 2007; Vaughan et al., 2008; Fuller and Qin, 2009; Fuller, 2011). *O. nivara* commonly grows in dry habitats and has large-scale seed production and so could have been easily gathered by prehistoric people. On the other hand, *O. rufipogon* prominently grows in aquatic habitats in relatively small isolated patches, not in genetically uniform stands and has a much lower seed production, so would have been more difficult to gather in quantity (Claridge et al. 1982; Vaughan, 1994; Vaughan and Morishima, 2003; Vaughan et al., 2008; Fuller and Qin, 2009).

In Marine Isotope stage 3 (MIS3), the elevated $\delta^{13}C$ and $\delta^{18}O$ from Batadomba-lena rock shelter faunal remains (Roberts et al., 2017) and Himalayan ice cores (Thompson et at., 2000) indicate that during the period 36,000-29,000 cal. BP the lowland rainforests of Southern Asia were more open, with decreased canopy cover as a result of decreased rainfall and temperature (cf. Mercader, 2002). Then, prior to the Last Glacial maximum (LGM), humid environments appear to have prevailed in the Indian subcontinent (Rajagopalan et al., 1997; Patnaik et al., 2008; Kumaran et al., 2013). Paleoclimatic records suggest that atmospheric cooling by 3-4°C occurred in the Tropics (Farrera et al., 1999), with a remarkable drop in precipitation during the LGM much greater than during any of the earlier (e.g. middle Pleistocene) glaciations (Robert et al., 2017). Palaeclimate data from Sri Lanka suggest a drier LGM punctuated by short sharp climatic ameliorations (Premathilake, 2012ab, 2015a). It is probable that climatic fluctuations within prevailing dry conditions during the late Quaternary may have resulted in a number of climatically adapted wild rice populations (cf. Premathilake, 2003; Premathilake and Risberg, 2003; Fuller, 2011). Gathering by prehistoric humans could have modified *O. nivara* populations leading to a more reliable wild grain source for human use, especially when they were already widely growing in ideal habitats associated with prolonged dry conditions long before the domesticated forms arose (Fuller et al., 2007; Fuller and Qin, 2009, Fuller et al., 2009; Fuller et al., 2010). During early rice exploitation, it is worth noting that high microcharcoal, and pollen and phytolith core records indicate regular anthropogenic burning from the Terminal Pleistocene (14,500-13,000 cal. BP) through the early-middle Holocene in the archaeological sites from Ganges plains, India (Singh, 2005; Saxena et al., 2006). Several archaeological sites in the Yangzte valley in China, dating from 17,000 cal. BP through the Terminal Pleistocene yielded *O. nivara* phytoliths (Zhijun, 1998; Chi, 2002; Lu, 2006; Liu et al., 2007; Zong et al., 2007). Sediment and peat core records from the Horton Plains, central Sri Lanka yielded *Oryza* spp. phytoliths and other evidence including pollen, charcoal, mineral magnetics, stable carbon and diatoms suggesting that burning and disturbance were associated with dry climate in montane environments occurred between 15,900-13,800 cal. BP (Premathilake, 2003, 2006; 2015a; Premathilake and Gunathilaka, 2013). Those records indicate that wild rice was present in human economies from the late Pleistocene into the Holocene in South and East Asia. We argue that wild rice exploited by late Pleistocene hunter-gatherers in Sri Lanka was *O. nivara* (rather than *O. rufipogon*) as an adaption to the predominantly dry climate. The antiquity of human use of wild rice species, probably *O. nivara* at Fahien is remarkably early at 44,952-47,854 cal. BP, compared with the evidence for rice foraging in other known South Asian sites (Fuller, 2006; Premathilake, 2015b; Fuller et al., 2007).

5.3.3. Wild rice (Oryza spp.)

Leaf and seed (glum) phytolith evidence of wild rice, together with low counts of chlorodoid (e.g. *Cynodon* sp.), panicoid (e.g. *Panicum* sp.), and sedge (Cyperaceae), taxa which are recurrent weeds in dry rice fields with *O. nivara* (Table S1, S3; Weisskopf, et al., 2014; Huan et al., 2015; Jenkins et al., 2017) suggest that dry wild rice stands located near to the Rock Shelter were exploited. The samples analyzed yielded low aumbers of phytoliths of dicotyledons and relatively high numbers of burnt phytoliths. These Rock Shelter phytolith records appear to be indicative of the conditions associated with anthropogenic activity, perhaps removal of competing vegetation and burning (cf. Jenkins et al., 2017).

The common husk phytoliths (single and double peaked forms, glumes, dendriforms) make it highly likely that wild rice seeds were exploited for food. The occurrence of burnt bulliforms and bilobates from the rice leaves and phytoliths from rice husks in association with ash deposits throughout the sequence (Table 1; Table S1, S3) suggests that rice straw was imported into the Rock Shelter. The presence of some bulliform type B, elongate psilate, elongate echinate, pooid, chloridoid and panicoid phytoliths in these assemblages indicates that wild grasses were also brought into the Rock Shelter. It is possible that wild rice and contaminant grassy plants were imported for threshing, but these may alternatively have been gathered for bedding, flooring, mat-making, thatching, ritual or other purposes (Tsartsidou et al., 2007; Pearsall, 2015; Bates et al., 2017; Premathilake et al., 2017a; Jenkins et al., 2017). From these primary uses, some may have ended up as fuel for domestic fires or may have been burnt to discourage insect pests, analogous with *fumier* deposits in Mediterranean caves (Angelucci et al. 2009).

The Rock Shelter rice phytolith assemblages thus may reflect human activities related to the model of prehistoric rice exploitation (e.g. Harvey and Fuller, 2005; Fuller and Qin, 2009; Fuller et al., 2011).

5.3.4. Wild breadfruit (*Artocarpus nobilis*)

Samples from the Rock Shelter sediments contained phytoliths of wild breadfruit. In modern times, breadfruit is an important economic crop in South and Southeast Asia. (Dassanayake and Fosberg, 1981; Jarrett, 1959; Blench, 2004). Wild breadfruit, *Artocarpus nobilis.* is endemic to Sri Lanka, occuring in disturbed lowland rainforest from 600 to 800 m asl (Bandaranaike and Sultanbawa, 1991). Seeded wild breadfruit is an excellent source of carbohydrates and also contains significant amounts of geranylated phenolic compounds which have strong antioxidant properties (Jayasinghe et al., 2006). The seeds contain an especially high percentage of oil, which is commonly used in traditional medical practices. Since historic times seeded fruits have been one of the staple starchy foods in the traditional diet, providing a secure food source (Rajapaksha, 1998). The processing and preservation techniques for wild breadfruit include roasting, boiling and drying. The wood of the plant is also commonly used for fuel and for building material.

Charred tissues from fruits and seeds of wild breadfruit have been found from 36,000 cal. BP through to the terminal Pleistocene in the Batadomba-lena and Beli-lena rock shelters (Kajale, 1989; Deraniyagala, 1992; Perera et al., 2011). At Fahien, phytoliths suggest that the late Pleistocene rainforest hunter gatherers exploited seedy fruits of wild breadfruit as early as 44,952-47,854 cal. BP. (Fig. 10). Burnt phytoliths associated with charcoal and ash deposits recovered from the Rock Shelter clearly indicate that material from *Artocarpus* cf. *nobilis* was probably used as fuel (Perera, 2010; Table 1; Table S1, S3). We contrast the phytoliths of wild breadfruit at Fahien, with the morphologically different forms from two other breadfruit species, *Artocarpus altilis* (rata del), which was probably domesticated in New Guinea (Blench, 2004) and *Artocarpus heterophyllus* (kos), native to Western part of India (Rajapaksha, 1998). Both species are commonly cultivated in Sri Lanka today.

5.3.5. Durian (*Durio zibethius*)

This is a lowland rainforest species, usually utilized as desert fruits, very delicious to some people, although the wood is also valued for construction. It is widely cultivated throughout Sri Lanka, Indonesia, Malaysia, India and Burma, and contains significant amounts of carbohydrates, proteins, fats, calcium, phosphorus, vitamins (A, B1, B2, C and E) and fibre (Rajapaksha, 1998). *Durio zibethius* perhaps originated in Borneo (Blench, 2004, 2008), and spread throughout the Malayan peninsula during the pre-European period and then to a number of other countries in South and Southeast Asia during the nineteenth century. It is interesting to note that no phytolith and other archaeobotanical evidence of *Durio* spp. from any cave and rock shelter excavation sites in South and Southeast Asia has been reported (cf. Blench, 2004, 2008). Phytolith evidence for *Durio* cf. *zibethius* was identified in later Pleistocene samples (Fig. 10) and pollen from *Durio* sp. was also found in all the samples analyzed (to be published elsewhere). However, phytolith evidence of *Durio* cf. *zibethius* at Fahien Rock Shelter is somewhat striking compared to the available records (Blench, 2004, 2008), requiring additional investigations on a number of well-dated sites to gain a better understanding the archaeobotany of *Durio* cf. *zibethius* in the rainforests of South and Southeast Asia. Nevertheless, evidence for this economically-important plant is consistent with finds of phytoliths of other food plants.

5.3.6. *Canarium sp*. nuts

Phytoliths classified as from the Buseraceae are closely consistent with the modern phytoliths and macro archaeobotanical remains of *Canarium* sp. nuts suggesting that this was part of the subsistence pattern of the Rock Shelter occupants (Table 1; Table S1, S3; Fig. 7; Fig. 10). *Canarium zeylanicum* (Burseraceae family), an endemic tree species commonly grows in the lowland rainforest of Sri Lanka (Gunatilleke et al., 2008). Seeds of the species found in Batadomba-lena rock shelter (Deraniyagala 1992; Perera 2010; Perera et al. 2011) and Beli-lena (Kajale, 1989; Deraniyagala 1992) were dated to 16,000 cal. BP and the terminal Pleistocene age respectively. Records of *Canarium* sp. dated through late Pleistocene to early Holocene (14,000-10,000 cal. BP) from Sepik-Ramu in New Guinea (Latinis, 2000), Con Moong cave in Vietnam (Viet, 2001), Spirit cave in Thailand (Gorman, 1970) and the older record ~45,000 cal. BP from Niah Cave in Sarawak (Paz, 2005) suggest that *Canarium* spp. was integral to subsistence Near Oceania , South and Island Southeast Asia. In an environmental context, the appearance of Burseraceae phytoliths at Fahien and an increasing occurrence of *Canarium* sp. nuts at other Sri Lankan sites indicates an expansion of the lowland rainforest (Roberts et al., 2017), which corresponds to the strengthening of southwest monsoon rains through the terminal Pleistocene to the early Holocene (cf. Premathilake, 2003, 2006, 2012ab; 2015a; Premathilake and Gunathilaka, 2013; Perera et al., 2011).

5.3.7. Species of Palmae

An abundance of Palmae phytoliths, identified as Palmae 1 and 2 based on morphological variations, indicates that the Rock Shelter occupants brought the vegetative parts of palms into the Rock Shelter. Palmae 1 are spheroid-elliptical (around 10-30 μm), densely echinate phytoliths while Palmae 2 includes spheroid-elliptical (5-10 μm) phytoliths with nodular obtuse tip projections (Fig. 10). In our reference collection, phytoliths of Palmae 1 are broadly similar to the phytoliths derived from *Borassus* sp., while Palmae 2 is similar to the phytoliths from *Areca* sp., *Caryota* sp., *Cocos* sp. and *Phoenix* sp. However, the morphological differences within these two groups are difficult to apply to species level identification. It is possible to suggest that blackened and non-blackened Palmae phytoliths in association with ash deposits throughout the sequence were released from palm leaves, bark and stems used by Rock Shelter occupants, possibly for fire, food, vessels and construction as early as 44,952-47,854 cal. BP.

In modern times, several palm species are frequently associated with human activity (Henderson, 2009). Eighteen native species are found in Sri Lanka, ten of which are endemic and several native palms grow in the disturbed lowland rainforest, e.g. at Sinharaja Forest Reserve (Henderson, 2009). Ethno-archaeological studies indicate that palm leaves are traditionally used for baskets, fishing nets, containers, mats, sleeping platforms (Premathilake et al., 1994). In south and southeast Asia, *Borassus flabellifer* (Palmyra palm) is now commonly used for roofing, sugar, toddy (naturally alcoholic sap of the palm) and writing (using the dried leaves), but the origins and original uses of the species during prehistoric times are disputed (Blench, 2005). Three palms, *Areca catechu*, *Caryota urens* and *Cocos nucifera* are among the most common economic crops. The first two grow naturally in disturbed lowland rainforest in Sri Lanka, India, Malaysia, Myanmar and Nepal. The third commonly grows in tropical and subtropical coastlands. Its origins are much disputed (Blench, 2005), however, linguistic studies suggest that it was carried to Sri Lanka and India prior to the second century BC (Mahdi, 1998). Harris (1990) suggests that coconut originated in Malaysia and its general distribution pattern is a relic of the splitting-up of Gondwanaland, highlighting the complexity of its botanical origins. Blench (2004, 2008) reports *Areca catechu* was in use for chewing at 13,000 cal. BP in Malaysia, and *Cocos nucifera* and *Areca catechu* occurred as part of an early agricultural system in Papua New Guinea at 6,000-6,950 cal. BP (Denham, 2004; Fairbairn and Swadling, 2005). Two coastal sites located in south- and north-western Sri Lanka yielded pollen evidence of *Cocos nucifera* dating to 7,500 cal. BP and 3,400 cal. BP respectively (Manawadu, 2016; Dilrukshi, 2017), confirming the antiquity of the accounts of coconut (Mahdi, 1998). Phytolith and starch grains from archaeological contexts dated to 5,000 cal. BP suggest that sago palms were an important plant food prior to rice in south subtropical China (Yang et al., 2013), and the Fishtail Palm (*Caryota* sp.) has been mentioned by Ki Han during the Jin Dynasty (AD 290-307) (Ruddle et al., 1978). Archaeobotanical records from North Gujarat (India) suggest that the progressive weakening of the south west monsoon around 7,000 cal. BP, compelled human populations to adapt seminomadic pastoralism which involved the cultivation of fast-maturing crops, and the gathering of a number of wild plants including *Phoenix sylvestris* (García-Granero et al., 2016). In Sri Lanka, ashy deposits at the Batadomba-lena Rock Shelter identified as hearths yielded round echinate Palmae phytoliths, suggesting the use of Palmae-based artefacts (e.g. matting, thatching and woven ware) after the LGM (Perera et al., 2011).

5.3.8. Bamboo

Phytoliths from the Fahien sediments imply that bamboos were abundant in the lowland rainforest. It is likely that Rock Shelter occupants may have used them for tools, containers, construction, fuel and other purposes as evidenced by an abundance of burned and un-burned rondel and large saddle phytoliths (Fig. 10) identical to those of modern Bambusoideae (**SOM 2**) Bamboos are perennial evergreen plants found in diverse climates from cold mountains to hot tropical regions and are especially common in lowland disturbed rainforest in Sri Lanka. They are of great cultural and economic significance, and are used as materials for various types of construction, tool making, baskets, vessels, mats, food, medicine, textiles and wood throughout South, East and Southeast Asia (Roach, 2013). Bulmer (1975) reported the presence of bamboo in early- to middle-Holocene archaeological contexts at Yuku, Papua New Guinea. Archaeological excavations in Japan uncovered bamboo baskets dating to the Late Jomon Period 4000-3000 cal. BP (Piper et al., 2017)

5.39. Diatoms

The freshwater diatoms may indicate human activities; for instance from faeces, having been incorporated from aquatic microflora in drinking water, or from external contamination of the Rock Shelter occupants who have visited freshwater habitats for fishing and/or bathing, or on plants or animals taken from freshwaters (cf. Perera, 2010). Alternatively, the diatoms might represent the construction of floors using mud from flood plains or rivers in the vicinity of the Rock Shelter, although if this is the case no other evidence for this practice survives. Infrequent visits to the brackish/marine environment for fishing and salt collection may account for the discontinuous record of marine diatoms and is consistent with the finds of shark teeth and vertebra and marine shell beads through the late Pleistocene sequence at the Rock Shelter (Perera, 2010).

6. Conclusions

Understanding the human history of the rainforests of Sri Lanka is poor because of the lack of preservation of organic materials and effect of taphonomic processes. The Late Pleistocene archaeological sequence dating back to 44,952-47,854 cal. BP at the Fahien Rock Shelter in lowland southwest Sri Lanka was an excellent opportunity to supplement our understanding using siliceous phytoliths. The phytolith evidence indicates that the Rock Shelter occupants exploited wild bananas (*Musa acuminata* and *Musa balbisiana*), wild rice (most possibly *Oryza nivara*), wild breadfruit (*Artocarpus nobilis*), durians (*Durio* cf. *zibethius*), *Canarium* sp. and a number of species of palm and bamboo. Most of these are commonly associated with disturbed lowland rainforests. These results are of great importance as the oldest evidence for late Pleistocene rainforest plant exploitation from South Asia. This is relatively younger, however, than the earliest evidence from the Niah Cave, Sarawak dating to 53,000 cal. BP (Barker, 2011; Barker and Farr, 2016; Hunt et al., 2016; Barker et al, 2017). An uncertainty left by the current work is whether the earliest deposits sampled here actually relate to the first modern anatomical human presence in Sri Lanka. We assume that further excavation of the very lowermost layers at the Rock Shelter is likely to produce additional evidence in due course, and it would be most interesting to investigate the use of rainforest plants by earlier colonists.

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Table 1

Layers (Wijeyapala (1997)	**Thick ness (m)**	**Contexts**	**Archaeogical phases**	**Litho-stratigraphy**	**Colour**	**Biotic remains and archaeological finds**	**Cultural density**
Bedrock	NA	95	I	NA	NA	NA	NA
NA	0.40	92	II	Consolidated clast-rich loam	Yellowish brown	Ashy habitation deposits (hearths), human bone, wood charcoal, fragments of shells and fragments of microlithic flakes	Relatively low
L5	0.15	90, 91, 89	III	Moderately unconsolidated clast-rich loam	Pinkish grey to greyish brown	Ashy habitation deposits, charcoal, fragment of small mammals and human bones, burnt shells, fragments of *Canarium* nuts, hearths, microliths	Relatively high
L4	1.00	89, 88, 87	IV	Moderately unconsolidated clast-rich loam	Dark grey to brown	Ashy habitation deposits, charcoal, burnt shells, unburnt shell, human bones, *Canarium* nuts, microliths, red ochre, grindstones, postholes	High
NA		70	V				
L3	0.25	12/42/72	VI	Moderately unconsolidated loam	Brown	Charcoal rich habitation deposits, ashy, *Canarium* nuts, carnivore coprolites, bones, shells, unburnt shells, carnivores coprolites, wood, microliths. Fragmentary human skeleton found from the context 81, which has been directly dated to around 12,000 BP.	Relatively high
L3		10, 11, 38, 48,	VI				
NA		50, 62, 81	VI				

Table 2

Layers	**Context (2010-2012 excavation)**	**Archaeological phase**	**Lab number**	**Lab age (BP)**	**$\delta^{13}C$**	**Calibrated dates BP (2σ)**	**Date range BC**	**Materials**	**Reference**
Bedrock	95	I							Wijeyapala (1997)
	92	II	Beta-354918	43,030 ± 720	-27.0	44,952-47,854	45,905-43,003	Charred	Perera (2015)
L5	91	III	Beta-354920	34,610 ± 320	-25.7	38,477-39,852	37,903-36,528	Charred	Perera (2015)
	91	III	Beta-33294	33,070±630	NA	35,768-38,716	36,767-33,819	Charcoal	Wijeyapala (1997)
	91	III	Beta-354914	32,890±240	-26.9	36,263-37,844	35,895-34,314	Charred	Perera (2015)
L4	88	IV	Beta-33296	32,060±630	NA	34,688-37,753	35,804-32,739	Charcoal	Wijeyapala (1997)
	87	IV	Beta-33299	30,060±290	NA	33,674-34,644	32,695-31725	Charcoal	Wijeyapala (1997
	87	IV	Beta-33295	24,470±290	NA	27,860-29,089	27,140-25,911	Charcoal	Wijeyapala (1997)
NA	81	VI	UBA-19332	10,402±45	-12.3	12,071-12,426	10,477-10,122	Freshwater shell	This paper
NA	81	VI	UBA-19331	10,344±52	-29.7	11,991-12,402	10,453-10,042	Charred wood	This paper

Figure and Table captions:

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Figures

Fig. 1. A: Location of the Fahien rockshelter in Sri Lanka. Area marked by dark green color receives relatively high rainfall (>2,500 mm/yr) from the South West Monsoon while area marked by light green color receives relatively low (< 2,500 mm/yr) rainfall from the North East Monsoon. **B:** Contour map of the Rock Shelter.

Fig. 2. X: Plan of the rockshelter with excavated area. **Y:** Stratigraphy with the archaeological layers (L5-L3). Chronology of the Pleistocene sequence from the excavated area is shown. Contexts are marked by numbers. Locations of the monoliths and subsamples taken for phytolith analysis are indicated.

Fig. 3. Phytolith morphotypes from modern plants. Asteraceae (1-3): armed segmented hair cells with straight tips. Cyperaceae (4-10): 4-6: polyhedral conical projections, 7: polyhedral decorated cells, 8-9: three-four edge psilate-pitted (blocky), 10: epidermal cells. Panicoideae grass (11-15): 11: polylobate, 12-14: bilobate, 15: cross. Chloridoideae grass (16-19): saddle. Poideae grass (20-23): 20: elliptical psilate, 21-22: rectangle psilate, 23: round psilate. Bambusoideae (24-36): 24-31: rondel, 32-34: bulliform type B with angular-triangular flared keystone widely flared thin top symmetrical morphology. 35: elongate psilate. 36: large saddle. Poaceae (37-47): 37: elongate psilate, 38-39: elongate echinate, 40: elongate psilate, 41: bulliform type B with widely flared keystone thin top asymmetrical base morphology, 42-44: four edged smooth (blocky psilate), 45: double outline non-armed non-curved (trichome), 46-47: elongate pitted. Scale bar =10 µm.

Fig. 4. Phytolith morphotypes from modern plants. Moraceae/ *Artocarpus nobilis* (1-7), 1: double outline armed with acute tip attached to epidermal base, 2-4: double outline armed acute tip (trichome), 5-6: double outline armed acute tip attached to a round epidermal base with polyhedral cells, 7: epidermal polyhedral smooth cell. Bombacaceae/*Durio zibethius* (8-15): spheroidal-elliptical with nodular obtuse tip projections. Arecaceae/Palmae (15-21): 15: spheroidal-elliptical echinate from *Areca catchu*, 16-18: spheroidal echinate from *Borasus* sp., 19: spheroidal spinulose from *Caryota urans*, 20: spheroidal-elliptical spinulose from *Cocos nucifera*, 21: spheroidal echinate from *Phoenix zylanica*. 22: faceted from Moraceae/*Artocarpus nobilis*. 23-25: multi-faceted from Diterocarpaceae/*Shorea* sp. 26: Stomata from *Artocarpus nobilis*. Scale bar = 10 µm.

Fig. 5. Phytolith morphotypes from modern plants. Seed phytoliths of *Musa accuminata* (1-9): 1-2: rectangular and square base with less protuberances, 3-6: irregular faceted and elongate with irregular short grooves, 7-9: faceted with nodule. Seed phytoliths of *Musa balbisiana* (10-17), 10-11: variable base with more protuberances. 12-15: irregular faceted with elongate well defined regular long grooves. 16-17: faceted with nodule. Volcaniform variants (V1-V8) from leaf of *Musa accuminata* (18) and *Musa balbisiana* (19). Crater, basal and protuberances of volcaniform are marked. Scale bar = 10 µm. (cf. Ball et al., 2006).

Fig. 6. Phytolith morphotypes from modern rice plants. Bulliform type C phytoliths from domesticated rice leaves (1-7). 1: flared keystone moderately flared incurving sides, 2-4: flared keystone widely flared wide top asymmetrical base, 5: flared keystone moderately flared side not incurving, 6-7: keystone widely flared wide top with symmetrical base. 7: burnt bulliform. Diagnostic phytolith morphotypes of domesticated rice are marked with ψ symbol. 8: burnt scooped bilobate from ash sample (black color indicates burning), from traditional rice fields in Sri Lanka. 9-15: glume cell with various projections occurring on deeply serrated cells from traditional rice processing sites (e.g. named as *kamatha* in Sinhala language) in Sri Lanka. 16-17: glume cell with small projections occurring on deeply serrated cells from the archaeological context dated to 5/6th century BC and 12-13th century AD in southern India and Sri Lanka. Rice husks commonly produce these glume phytoliths. 18: large single-peaks, 19-20: double-peaks from domesticated rice husks. 21: double outlined non-armed with acute tip (trichome) from domesticated rice husks. 22: double outline non-armed curved small base with acute tips (trichome) from *Oryza* spp. 23: elongate cells with various projections (dendriforms) from *Oryza* spp. 24: epidermal non-curvilinear striate phytoliths from domesticated rice husks. 25: large single and double peaks from *Oryza rufipogon* husks. 26: flared keystone moderately flared wide top symmetrical base from *Oryza rufipogon* leaves. 27-28: flared keystone moderately flared wide top with symmetrical base, and scooped bilobate and cross from *O. nivara* leaves. 29-30: large single peaks and 31: double peaks from *O. nivara* husks. Scale bar = 10 μm.

Fig. 7. Phytolith percentages of the major economic plant taxa identified from the Rock Shelter samples analyzed.

Fig. 8. Wild banana phytoliths from Fahien Rock Shelter. 1-21: volcaniform variants (V1, V2, V3, V5 and V6) derived from wild banana leaves. 22-24: phytoliths from *Musa balbisiana* seeds. 25-26: phytoliths from *Musa accuminata* seeds; 27-28: small volcaniform phytoliths derived from wild banana seed. Scale bar = 10 μm.

Fig. 9. Wild rice phytoliths from Fahien Rock Shelter. 1-5: flared keystone moderately flared wide top symmetrical base and flared keystone moderately flared incurving sides. Black color indicates burning. 6-14: glume cell with projections occurring on deeply serrated cells. 15-18: large single peaks. 19-22: large double peaks. Black color indicates burning. 23: glume cell with small projections. 24-25: double out lined non-armed curved small base with acute tips (trichome). 26: elongate echinate. 27-28: bilobate. Scale bar = 10 μm.

Fig. 10. Phytoliths from Fahien Rock Shelter. Cyperaceae (1-6): 1-2: polyhedral base with conical projections (corn-shaped), 3-6: polyhedral decorated cells. Asteraceae (7): armed segmented hair cells with straight tips. Poaceae/Panicoideae (8): bilobate and polylobate. Poaceae/Chloridoideae (9-10): saddle. Bambusoideae (11-14): rondel. Arecaceae/Palmae (15-25): 15-18: spheroidal echinate, 19: spheroidal-elliptical spine, 20-21: spheroidal spinulose, 22-23: spheroidal-elliptical spinulose, 24-25: spheroidal spinulose. *Artocarpus* cf. *nobilis* (26-37): 26-32: double out lined armed with acute tip (trichome), 33-34: double outline armed acute tip attached round epidermal base, 35-37: round epidermal base comprised of polyhedral cells without arms. Bombacaceae/*Durio* cf zibethius (38-40): spheroidal-elliptical nodular with obtuse

tip projections. Poaceae/grass (41-46): 41-43: bulliform types C, 44: elongate pitted, 45: elongate echinate, 46: double outlined non-armed with blunt tip. 47: large saddle from Bambusideae. 48: faceted. Burseraceae (49-50): faceted/scalloped elliptical (cf. Fig. 3 and 4). Scale bar = 10 µm.

Table captions:

Table. 1. Summary of archaeology and stratigraphy described from the Fahien Rock Shelter (after Wijeyapala, 1997; excavation directed by Dr. Nimal Perera and Dr. Deraniyagala from the Department of Archaeology, Sri Lanka, 2010-2012). NA = Not available.

Table. 2. Chronology of the Fahien Rock Shelter (after Wijeyapala, 1997; Perera, 2015). NA = Not available.

Supplementary Online Materials

Supplementary Tables:

Table S1. Detailed stratigraphy of Fahien Rock Shelter

Table S3: Full phytolith raw data found from Fahien Rock Shelter

1. SOM 1

1.1. Fossil phytolith extraction

Sediment samples of 10-15 g were dried at 40º C and passed through 2 mm sieves. $CaCO_3$ was removed from the fraction passing the sieve using 10% HCl at 40º C. The material was centrifuged at 2000 rpm for 5 minutes. The supernatant was decanted and the remaining suspension checked with 1% $AgNO_3$ solution to ensure removal of $CaCO_3$. The material was oxidized in 40 ml of 30% H_2O_2 at 80-90º C in an oven for 2-3 hours. After cooling, a few drops of Ammonia solution were added to check for excess H_2O_2. The resulting suspension was passed through a150 µm sieve to remove coarse sand. The fraction less than 150 µm was mixed with 20 ml 0.5% sodium hexametaphosphate. Clay particles were removed using density gradient techniques based on Stoke's Law. The silty fraction was removed and dried. 0.5 g of dry materials were mixed with 10 ml $ZnBr_2$ solution (density exactly adjusted to 2.35 gcm^3) in a centrifuge tube. It was allowed to settle for 30 minutes and centrifuged at 2000 rpm for 30 minutes. The phytolith fraction was removed, mixed with 1N HCl and centrifuged at 2000 rpm for 5 minutes. The final phytolith fraction was mounted in Canada Balsam and observed at a magnification of x 400 under the Olympus BX51 microscope. Images critical to phytolith identification were documented at a magnification of x 1000. Micrographs were taken using the F-View Soft Imaging System. Target counts were at least 250 (>250) and this was usually achieved. Counts of other siliceous microfossils (diatom) were also included. In order to understand the reliability of the archaeological phytolith assemblages in each sample and to trace vegetation signals, the relative abundance of each phytolith was calculated (Piperno, 1988). In this procedure, raw counts were transferred to percentage values (relative abundance) based on Tilia program. The basic sum included phytoliths derived from Poaceae. Other taxa were excluded from the sum. Phytolith diagrams were constructed using TILIA (Grimm, 1991-1993).

1.2. Modern phytoliths

Modern samples (reference samples) from Sri Lanka and southern India were used. Taxonomic assignment of the reference samples were confirmed with the available Herbarium records at the Laboratory for Palaeoecology, Postgraduate Institute of Archaeology, French Institute of Pondicherry, India and Royal Botanic Garden, Kew (cf. Perera, 2017). Phtolith extraction from the samples was carried out both by ashing (Jenkins, 2009; Issaharou-Matchi et al., 2016) and chemical digenesis methods (Geiss, 1973 and Carter, 2007), because the results from those methodologies reflect the possible impact of such stresses on phytoliths at the field over a long period of time and during the laboratory processing as well. Plant samples of 25 g were cleaned using a bleaching agent (Alconox) and dried in a ceramic crucible at 50º C for five hours in order to remove adhered minerals. Subsamples of 1g of dry plant materials were taken for ashing and another subsample of 1 g was taken for chemical digenesis. In ashing method the materials were incinerated at 500° C for 5 hours in a ceramic crucible using a muffle furnace. Siliceous residues were further treated with 1N HCl, centrifuged at 2000 rpm for 5 minutes (centrifuging shall, hereafter, indicate this speed and time). The residual pellet was cleaned with distilled water and centrifuged. The pellet was treated with 5 ml of concentrated HNO_3 keeping in a water bath at 65° C for 2 hours and centrifuged. The pellet was cleaned with distilled water, centrifuged and then dried at 60° C. In the chemical digenesis method, the materials were treated with concentrated H_2SO_4 (Sulphuric acid) at 80° C in a water bath for 4 hours until they dissolved. Then, the mixture was treated with 30% H_2O_2 on a hot plate at 150° C for 2-3 hours till it turned colourless. The obtained residue was cleaned with distilled water and the pellet was air-dried. A known weight of dry residue containing phytoliths obtained from both methods was separately mounted in both Canada balsam and Benzyl benzoate media.

2. SOM 2

2.1. Phytolith taxonomy and modern plants

Knowledge from the modern phytolith collections facilitated the fossil phytolith identification. In this collection, type slides were made from various plant parts (e.g., leaves, sheaf; seeds/husks, spikes, inflorescence/culm, roots and twigs) from a large number of traditional and modern cultivated and wild plants. This includes *Oryza nivara*, O. *rufipogon*, *Leersia* sp. *Oryza sativa*, *Panicum* sp., *Musa*-banana, *Artocarpus nobilis*, *Artocarpus* spp., *Durio zibethius*, bamboo, species from Asteraceae and Cyperaceae, Palmae, wild grasses, Dipterocarpaceae, Euphorbiaceae, Fabaceae, Verbenacae and Burseraceae. The reference collection also contained phytolith type slides made from well preserved domesticated rice grains retrieved from archaeological contexts dating to the 6th and 3rd century BC and 12-13th century AD in southern India and Sri Lanka (Premathilake et al., 2017ab). To achieve additional knowledge on taxonomic identification, phytoliths were extracted from the samples obtained from several sites where traditional cereal processing activities (e.g. winnowing, de-husking and burning) was carried out in southern India and Sri Lanka. In our procedures, the most common morphological characteristics, general occurrence and appearance of key phytoliths, e.g. bulliforms, bilobates, saddles, rondel, elongate echinate, elongate sinuous, elongate projections, globular echinate, globular nodular spheroidal-elliptical nodular, double out line armed acute tips (trichome) double out line non-armed acute tip (trichome) and volcaniforms were comparatively studied (**Table S1**). The terminology was according to Madella et al. (2005), Pearsall and Dinan, 1992-2012 and Pearsall, 2015. Additional data from published works were used to differentiate taxa (e.g., Twiss et al., 1969; Bozarth et al. 1992; Pearsall and Dinan, 1992-2012; Fujiwara, 1993; Rapp and Mullholland, 1992; Mulholland, 1993; Pearsall et al., 1995; Houyuan et al., 1997; Zhijun, 1998; Zhao et al., 1998, Kealhofer and Penny, 1998; Runge, 1999; Zhao and Pearsall, 2000; Lu and Liu, 2000; Zheng et al., 2003; Thorn, 2004; Harvey and Fuller, 2005; Madella et al., 2005; Piperno, 2006; Saxena et al., 2006; Lejju et al., 2006; Ball et al., 2006, 2015; Bamford et al., 2006; Davey et al. 2007; Albert et al., 2009; Lu et al., 2009; Vrydaghs et al., 2003, 2009; Lentfer, 2009; Huang and Zhang, 2009; Mercader et al., 2010; Lippi et al., 2011; Weisskopf and Lee, 2013; Weisskopf, 2014; Weisskopf et al., 2014, 2015ab; Yang et al., 2013; Lisztes-Szabó et al., 2014; Zurro et al., 2016; Bates et al., 2017).

Table S1: Phytoliths from modern taxa

Taxa	**Phytolith morphotypes**	**Botanical parts**
Banana (domesticated/wild)	Volcaniform (described in Table S4)	Leaf
Banana (wild)	Irregular faceted with elongated grooves	Seeds
Artocarpus nobilis	Double out line armed with acute tip (trichome)	Leaf
Artocarpus nobilis	Trichome base with polyhedral cells	Leaf
Durio zibethius	Globular-elliptical nodular obtuse tip projections (> 20µm)	Fruits and seeds
Canarium zeylanicum (Burseraceae)	Facetate/scalloped elliptical	Leaf
Burseraceae	Epidermal tissue polyhedral cells	Leaf
Wild rice (*O. nivara*/*rufipogon*	Small double-peak glume cell (25-30µm)	Husk
Wild rice (*O. nivara*/*rufipogon*	Large single-peak glume cell (20-30µm)	Husk
Wild rice (*O. nivara*/*rufipogon*	Small bumpy projections occurring on deeply serrated cells	Husk
Wild rice (*O. nivara*/*rufipogon*	Double out line non-armed with prominent base acute tip (trichome).	Husk and Inflorescence
Wild rice (*O. nivara*/*rufipogon*	Bulliform types-A. Flared keystone moderately flared deeply incurving side (1) and flared keystone widely flared wide top symmetrical base (2)	Leaf
Panicoid grass	Bilobate (rounded to square lobes)	Leaf and Inflorescence

Wild rice (*O. nivara*/*rufipogon*	Plate like epidermal (non-curvilinear with non-striate surface)	Husk
Pooid grass	Round to oblong	Leaf and Inflorescence
Pooid grass	Rectangle psilate	Leaf and Inflorescence
Pooid grass	Elliptic psilate	Leaf and Inflorescence
Pooid grass	Elongate sinuous	Leaf and Inflorescence
Chloridoid grass	Saddle	Leaf and Inflorescence
Poaceae (grass)	Plate like epidermal (non-curvilinear edge with smooth-pitted)	Husk
Poaceae (grass)	Elongate psilate and elongate potted	Leaf
Poaceae (grass)	Elongate echinate	Leaf
Poaceae (grass)	Elongate granulate	Leaf
Poaceae (willd grass)	Bulliform types-B: flared keystone slightly flared angular (1); flared keystone slightly flared rounded (2); flared keystone widely flared thin top symmetrical-asymmetrical base (3). Scale-like decorations < 9	Leaf
Pooid and Bambusoideae	Rondel	Leaf and trunk
Cyperaceae	Polyhedral decorated cell (achene)	Leaf
Cyperaceae	Polyhedral conical projection (hat shaped phytoliths)	Leaf
Cyperaceae	Blocky psilate-pitted	Leaf
Domesticated rice (*O.*	Bulliform types-C: flared keystone	Leaf

sativa)	moderately flared weakly incurving side (1); flared keystone widely flared wide top asymmetrical base (2). Scale-like decorations > 9	
Domesticated rice (*O. sativa*)	Scooped bilobate	Leaf and Inflorescence
Domesticated rice (*O. sativa*)	Small double-peak glume cell (45-55 µm)	Husk
Domesticated rice (*O. sativa*)	Large single-peak glume cell (30-45 µm)	Husk
Domesticated rice (*O. sativa*)	Small bumpy projections occurring on deeply serrated cells	Husk
Domesticated rice (*O. sativa*)	Double out line non-armed with acute tip attached to a weakly developed base (trichome).	Husk and Inflorescence
Domesticated rice (*O. sativa*)	Bottle-like psilate and glob with short neck psilate	Husk
Domesticated rice (*O. sativa*)	Plate like epidermal (non-curvilinear with striate surface)	Husk and Inflorescence
Asteraceae	Multicellular segmented hair cells	Leaf
Poaceae (wild grass)	Plate-like epidermal (non-curvilinear four edges with smooth-pitted) and blocky psilate bodies, double outline non-armed non-curved (trichome)	Leaf
Palmae	Globular echinate	Leaf and Inflorescence
Euphorbiaceae, Anacardiaceae and Annonaceae	Facetate	Leaf
Santalaceae and Zingiberaceae	Relatively large globular with projections	Leaf and Inflorescence

Euphorbiaceae, Anacardiaceae and Annonaceae	Sclereids	Leaf
Commelinaceae, Combretaceae, Cyperaceae, Poaceae and Fabaceaeae	Irregular shape blocky bodies with various projections	Leaf

2.1.2. Rice taxa identification

Comparative studies indicate that glume phytoliths i.e. double peak, single peak, elongate small round bumpy projection (glume cells), bumpy projections arising deeply serrated glume cells and elongate very deeply serrated sinuous edges glume cells classified into rice throughout the archaeological samples are broadly similar in to those from lemma, palea and rachilla i.e. seeds/husks samples from modern *Oryza nivara* and *O. rufipogon*. Bulliform phytoliths described as flared keystone moderately flared deeply incurving side (1) and flared keystone widely flared wide top symmetrical base (2) from modern *Oryza nivara* and *O. rufipogon* are similar to bulliform type A. The comparative studies indicate that on the lateral side of the bulliform type A from these wild rice species have less than 9 characteristic scale-like decorations (Table S1). These decorations are irregular and highly variable (cf. Wu et al., 2002). These species also produce regular short cell bilobate, epidermal non-curvilinear with non-striate surface and double out line non-armed with acute tip attached to a prominent base (trichome-1) phytoliths. The phytolith morphologies are consistent with the archaeobotanical evidence of rice. These key phytoliths are morphologically distinct from other wild rice i.e. *Leersia* sp. and wild grass populations studied. Many published works supported identification of rice (cf. Fujiwara, 1993; Harvey and Fuller, 2005; Huang and Zhang, 2009; Lippi et al., 2011; Tomber et al., 2011; Wang and Lu, 2012; Gu et al., 2013; Hu et al., 2013; Weisskopf, et al., 2014; Weisskopf et. al., 2015ab; Ball et al., 2016; Bates et al., 2017).

2.1.3. Wild Musa banana identification

Two groups of wild banana were recognized based on the morphology of seed phytoliths compared to the modern wild banana records (**Table S2**). In these groups, *Musa*-type 1 (crater width = 1-2.5µm; basal length =8-10 µm; shape = rectangle and square base with less protuberances, and irregular faceted with elongate very irregular short grooves) and *Musa*-type 2 (crater width = 1-2.5µm; basal length = 3-7 µm; shape = variable base with more protuberances, and irregular faceted with elongate well defined regular long grooves) found in the late Pleistocene samples. The morphology of *Musa*-type 1 and 2 is closely similar to the morphology found from the modern seeds and leaves of *M. accuminata* and *M. balbisiana* respectively (**Table S2** and cf. Perera, 2017). However, based on morphometric evidence, leaf phytolith (volcanifrm variants V1-V8) morphology of those two wild banana groups do not support the differentiation between *Musa*-type 1 and 2 (**Table S2**).

Table S2: Morphology of wild banana seed and leaf phytoliths. Total individual counts (N) per sample = 100

Modern wild banana seeds				
M. accuminata	1.97±0.30 range: 1-3.2	10.75±2.18 range: 8-18	Irregular faceted with elongate very irregular short grooves. Rectangle and square base with few verrucae.	
M. balbisiana	1.8±0.35 range: 1-3.2	8.62±2.25 range: 6-12	Irregular faceted with elongate well defined regular long grooves. Variable base with more verrucae.	
Modern wild banana leaf				
	Crater (µm)	Basal (µm)		
M. accuminata	7.07±0.89 range: 6.18-7.96	15.31±3.76 range:11.55-9.07	Cone is visible with variants. V1 (84-85%), V3 (11-16%), V6 (1%), V5 (3-4%) are reported. V2, V4, V7, V8 are absent. Rectangle and square base with more protuberances dominate at the base of V6. Psilate-granulate with very few verrucate found.	Not available
M. balbisiana	7.62±1.06 range: 5.96-8.22	16.20±4.73 range:11.46-21.24	Cone is visible with variants. V1 (67-85%), V3 (12-23%), V5 (1-12%), V6 (1-5), V8 (1-3), V4 (1) are reported. V2 and V7 are absent. Rectangle and square base with more protuberances dominate at the base of V6. Psilate-granulate with very few verrucate found.	Not available

Phytolith morphotypes and their affinities to botanical parts and plant taxa (cf. Table S1, S2)			Analysed Sample					
Morphotype	**Botanical parts**	**Taxa**	**C-81**	**C-87**	**C-88**	**C-89**	**C-91**	**C-92**
Volcaniform	Banana leaves	Mucaceae/*Musa* spp	18	31	130	31	60	65
Faceted	Banana seeds	Mucaceae/*Musa* spp	1000	310	1173	1100	275	2620
Bulliform type-A	Rice leaves	*Oryza* sp.	6	1	15	2	5	18
Glume cell (single peak)	Rice husk	*Oryza* sp.		1	12	3	20	15
Glume cell (double peak)	Rice husk	*Oryza* sp.			15	3	7	25
Gluem cell (deeply serrated sinuous edges)	Rice husk	*Oryza* sp.		2	25	3	29	42
Glume cell (deeply serrated sinuous/striate edges: plate-like)	Rice husk	*Oryza* sp.			12	1	2	2
Elongate dendritic	Rice husk/Inflorescence	*Oryza* sp.		1	6		7	7
Trichome (non-armed relatively round base acute tip)	Rice husk/Inflorescence	*Oryza* sp.			3		13	16
Glob with short neck psilate-granulate	Rice husk/Inflorescence	*Oryza* sp.					1	
Bottel-like psilate	Rice husk/Inflorescence	*Oryza* sp.						1
Bilobate convex ends	Leaves/Inflorescence	Panicoid		3				
Bilobate concave ends	Leaves/Inflorescence	Panicoid			5		2	5
Bilobate straight ends	Leaves/Inflorescence	Panicoid			2		2	3
Polylobate	Leaves/Inflorescence	Panicoid						2
Rounded psilate	Leaves/Inflorescence	Pooid	4	10	9	1	1	13
Elliptical psilate	Leaves	Pooid	3		1			3
Elongate sinuous	Leaves/Inflorescence	Pooid	5	15	30	2		2
Rectangle psilate	Leaves/Inflorescence	Pooid	150	25	300	100	100	209
Small saddle	Leaves/Inflorescence	Chloridoid			10		1	
Trichome (armed base not apparent straight edges acute tip)	Grass husk/Inflorescence	Poaceae/ (rice?)					5	1
Bulliform type-B	Grass leaves	Poaceae			3	3		5
Elongate deeply sinuous edges rounded bump	Grass/leaves Inflorescence	Poaceae			5	2		7
Elongate psilate	Grass leaves	Poaceae	25	10	45	2	10	45

Elongate wavy (echinate) symmetry	Grass leaves	Poaceae	1		5		20	13
Elongate wavy (echinate) asymmetry	Grass leaves	Poaceae			3			
Elongate echinate-baculate asymmetry	Grass leaves	Poaceae					5	2
Elongate granulate	Grass leaves	Poaceae	18		50		3	6
Rectangle-type granulate	Grass leaves	Poaceae	3	1	1	1	2	1
Elongate striate	Grass leaves	Poaceae			8	1		
Tabular trapizoid spine 60-70 µm	Grass leaves	Poaceae						3
Tabular trapizoid scrobiculate 60-70 µm	Grass leaves	Poaceae					1	
Undif.	Undif.	Poaceae	11	7	5	8	2	10
Large saddle	Leaves/steam	Bambusoideae	3		2			
Cone-like	Leaves/steam	Bambusoidea	36	12	20	15	12	17
Tabular trapizoid spine-scrobiculate 100-150 µm	Leaves	Dicot					1	
Globular-elliptical nodular obtuse tip projections	Seeds	*Durio* sp.	50	13	59	60		
Trichome (armed acute tip)	Leaves	*Artocarpus nobilis*	1	25	11	5	15	20
Trichome-base with polyhedral cell	Leaves	*Artocarpus nobilis*	1	4			3	10
Trichome (non-armed cone-like acute tip)	Leaves	Moraceae			3		15	23
Epidermal-type1: rectangle-squre shaped/striate	Leaves	cf. *Artocarpus* sp.	3	3	10		1	25
Globular echinate >15 µm	Leaves	*Borass* spp	1	4	40	10		7
Globular echinate 7- 15 µm	Leaves/fruit	*Phonex* spp	100	90	230	300	31	160
Globular echinate < 7 µm	Leaves/steam	Palmae	16		11	50	10	50
Facetate (scalloped)	Undif.	Burseraceae	3					
Achene	Leaves	Cyperaceae			11		10	25
Globular psilate-verrucate	Undif.	Dicot		1	2		3	10
Globular irregular projection	Undif.	Dicot			6	1	10	20
Globular verruvate-baculate	Undif.	Dicot			1	1	1	2
Globular spine-baculate	Undif.	Woody dicot			4		1	5
Globular psilate 5 µm	Undif.	Dicot			1	1	2	2
Irregular facetate	Undif.	Woody dicot			4		9	12
Tabular facetate	Undif.	Dicot			2		10	5
Stomata	Undif.	Undif.					1	

Epidermal-type2 (hexagonal)	Undif.	Undif.			5		1	
Epidermal-type3 (honey comb)	Undif.	Undif.						1
Epidermal-type4 (elongate)	Leaves	Poaceae			2		1	8
Epidermal-type5 (Jigsaw-puzzle)	Leaves	Dicot			1		3	5
Undif. epidermal-types	Undif.	Undif.	1	1			1	6
Sclereids (tabular-like)	Undif.	Woody dicot					15	20
Blocky body perforate	Undif.	Dicot/monocot					2	3
Blocky body spine projection	Undif.	Dicot/monocot					5	2
Blocky body (irregular shaped) spinulose	Undif.	Dicot/monocot					3	2
Undif. (Dicot)	Undif.	Dicot	12		4		12	24
Tracheid	Undif.	Dicot/monocot			15	5		10
Burnt phytolith (bilobate/cross/bullifom/trichome/spherical echinate)	Leave/seed/husk	*Artocarpus*/*Musa*/ *Oryza* spp/Palmae	80	15	130	5	50	200
Fallacia sp	Diatom	Freshwater	2		2			
Nitzschia cf. *taylorii*	Diatom	Freshwater		1				3
Surirella sp.	Diatom	Freshwater						3
Aulacoseria cf. *granulata*	Diatom	Freshwater			7		2	2
Melosira cf. *lineata*	Diatom	Freshwater	2	4		7		2
Navicula cf. *leistikowii*	Diatom	Freshwater	200	10	5			
Navicula cf. *cryptotenella*	Diatom	Freshwater	20	1	9	2		3
Navicula sp.	Diatom	Freshwater	22		115	22	50	105
Pinularia spp	Diatom	Freshwater		1	7			4
Eunotia sp.	Diatom	Freshwater	1	1	4			
Gomphonema sp.	Diatom	Freshwater		1		1		
Navicula cf. *gregaria*	Diatom	Brackish/marine				1	1	1
Achnanthes cf. *hauckiana*	Diatom	Marine			30			10
Amphora cf. *coffeaeformis*	Diatom	Marine			1			

Table. S3. Detailed records of phytolith raw data found from the Fahien Rock Shelter.

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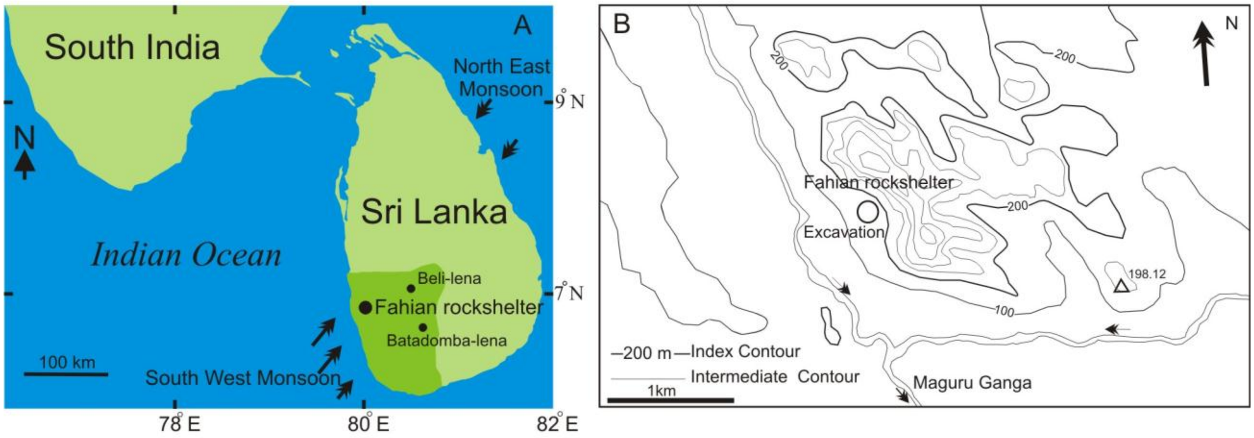

Fig. 1

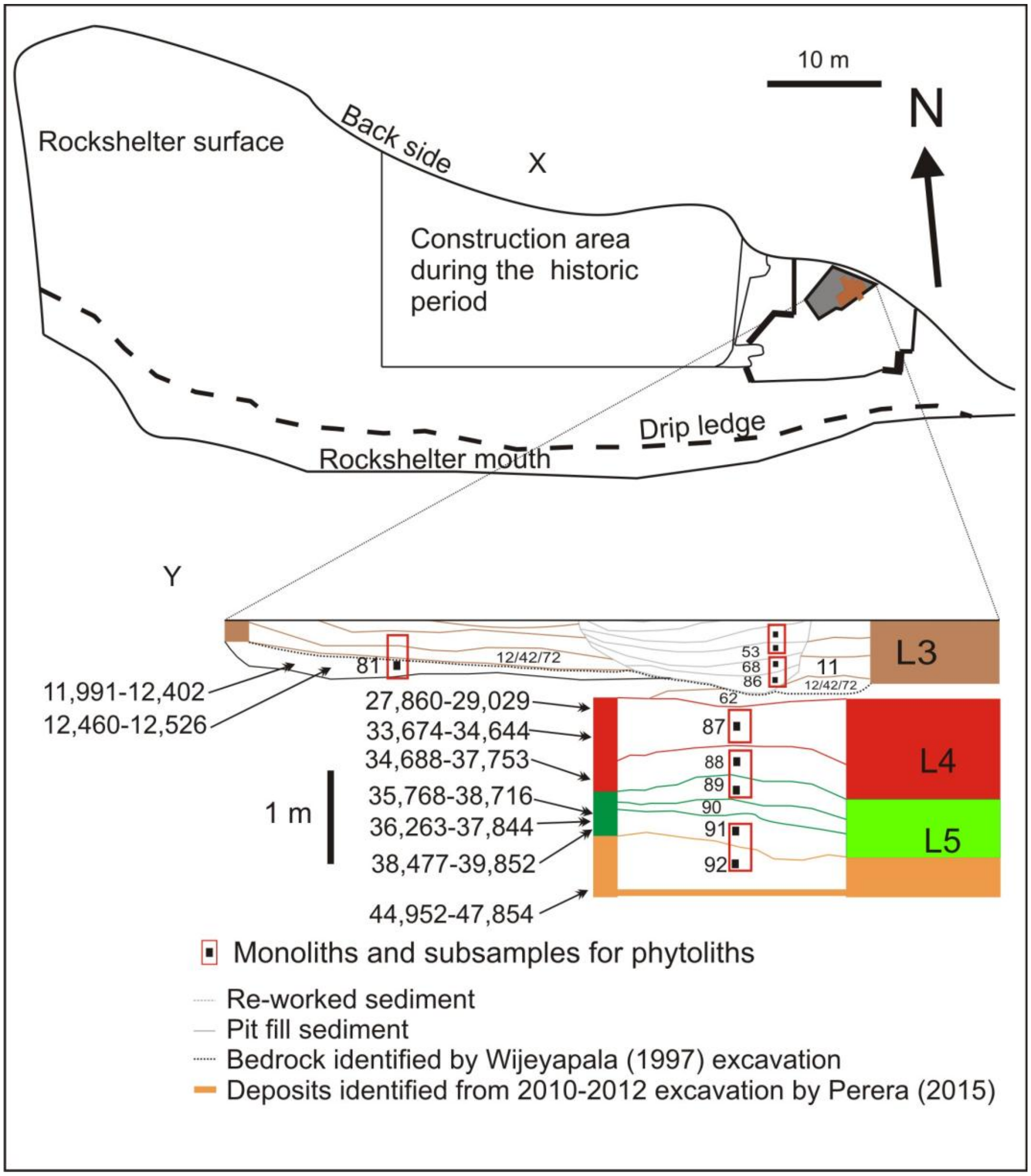
10 m
N
Rockshelter surface
Back side
X
Construction area during the historic period
Drip ledge
Rockshelter mouth
Y
L3
L4
L5
1 m
81
12/42/72
53
68
86
11
12/42/72
62
87
88
89
90
91
92
11,991-12,402
12,460-12,526
27,860-29,029
33,674-34,644
34,688-37,753
35,768-38,716
36,263-37,844
38,477-39,852
44,952-47,854
Monoliths and subsamples for phytoliths
Re-worked sediment
Pit fill sediment
Bedrock identified by Wijeyapala (1997) excavation
Deposits identified from 2010-2012 excavation by Perera (2015)

Fig. 2

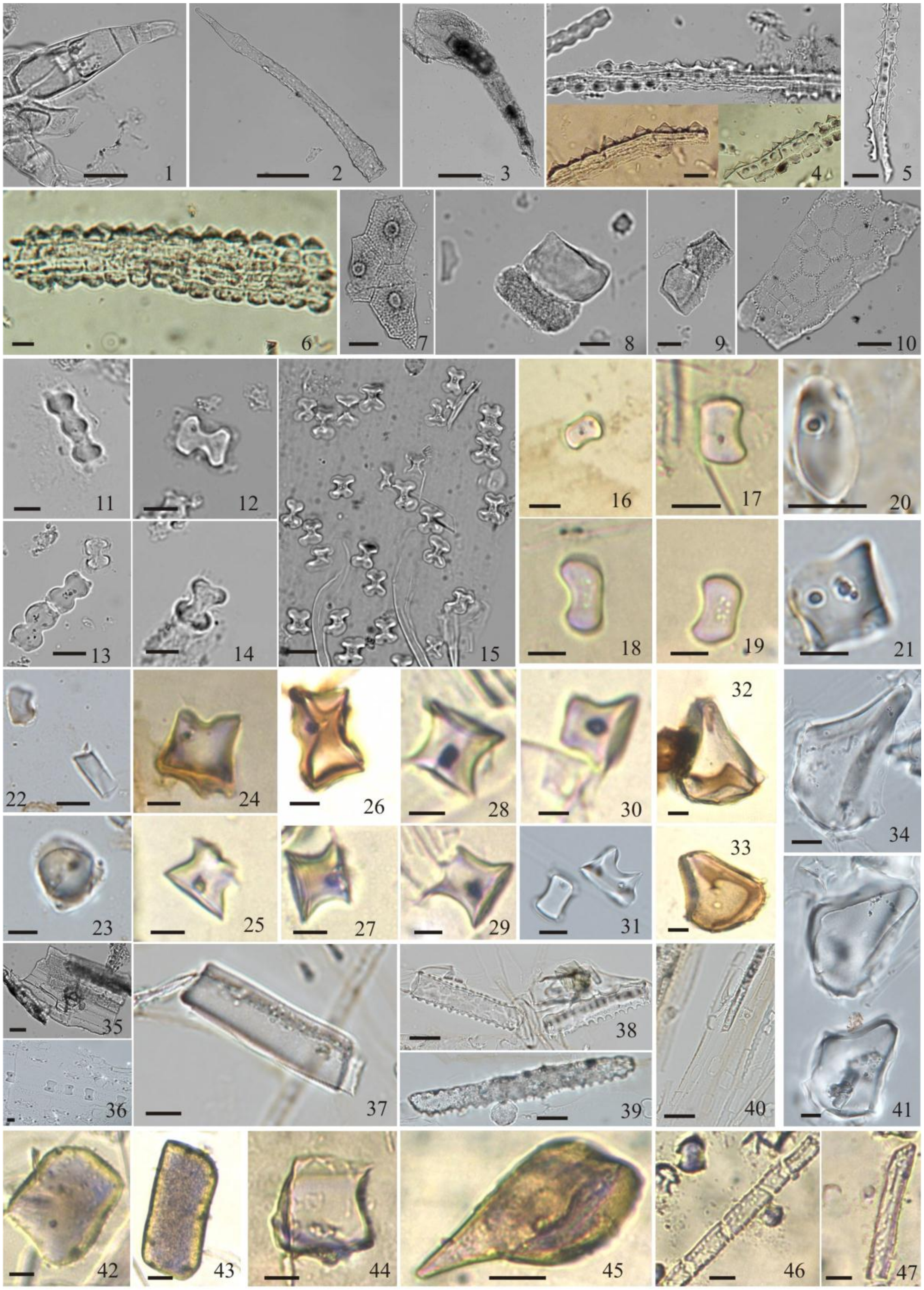
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Fig. 3.

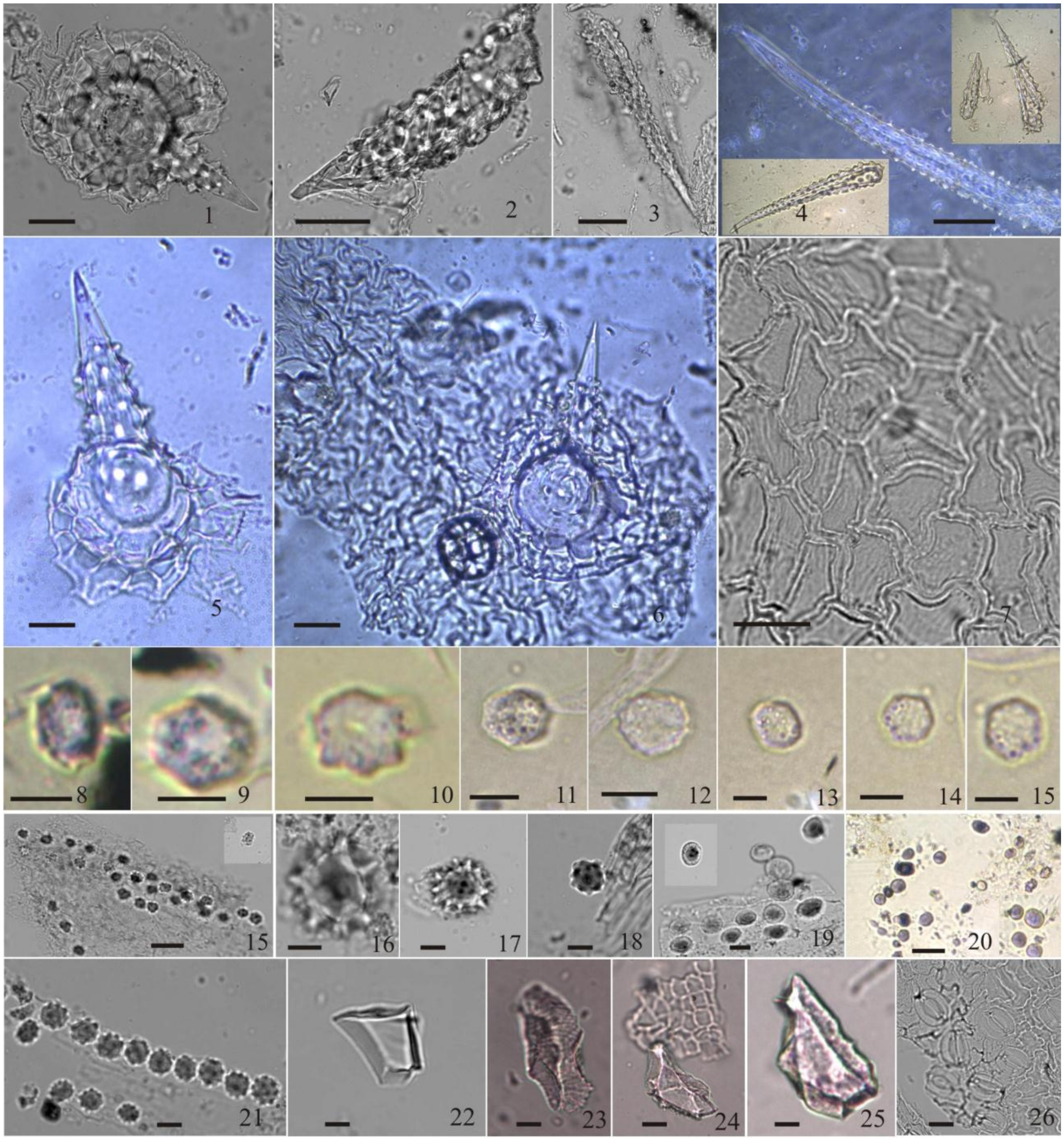
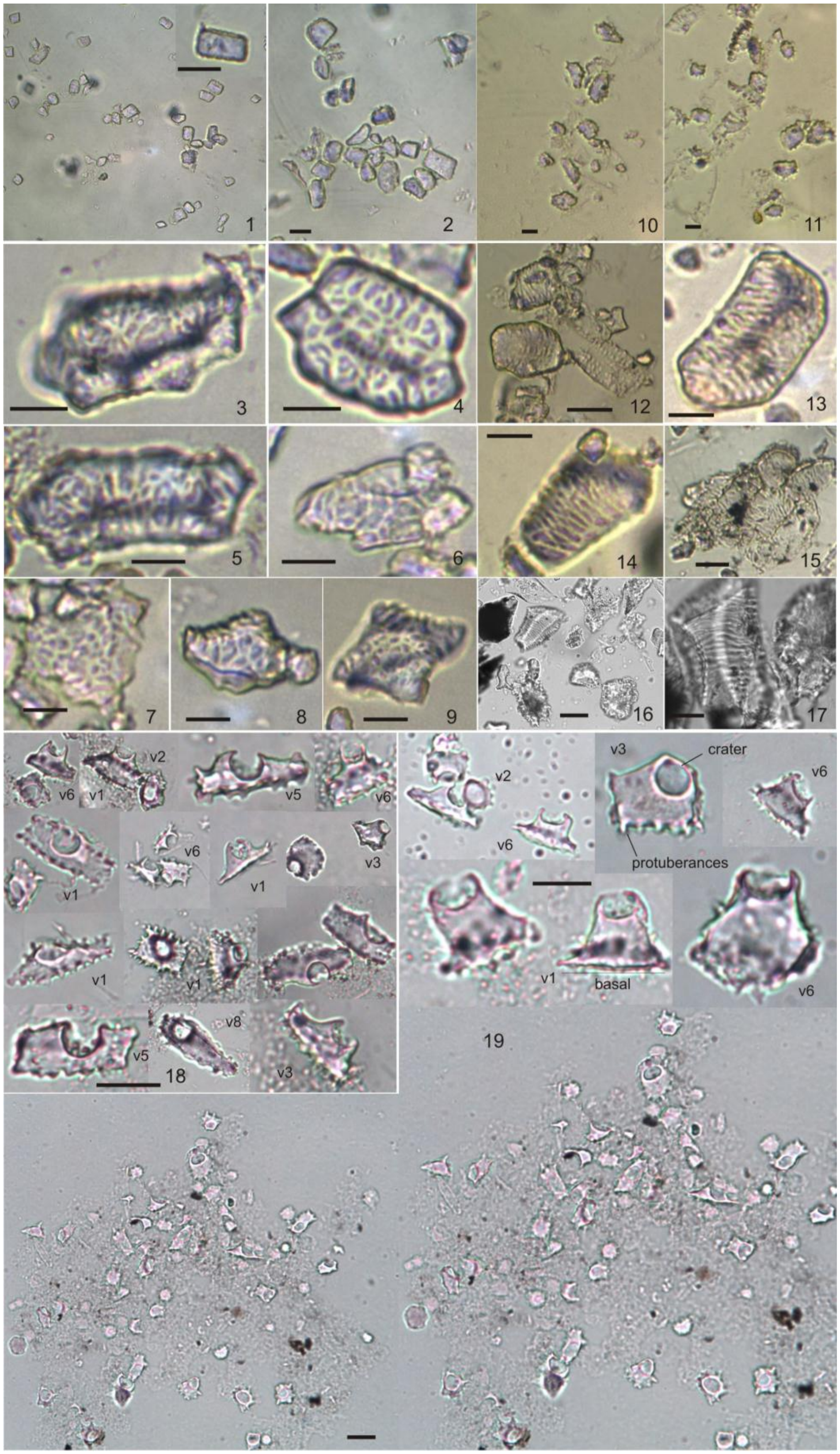


Fig. 4.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crater
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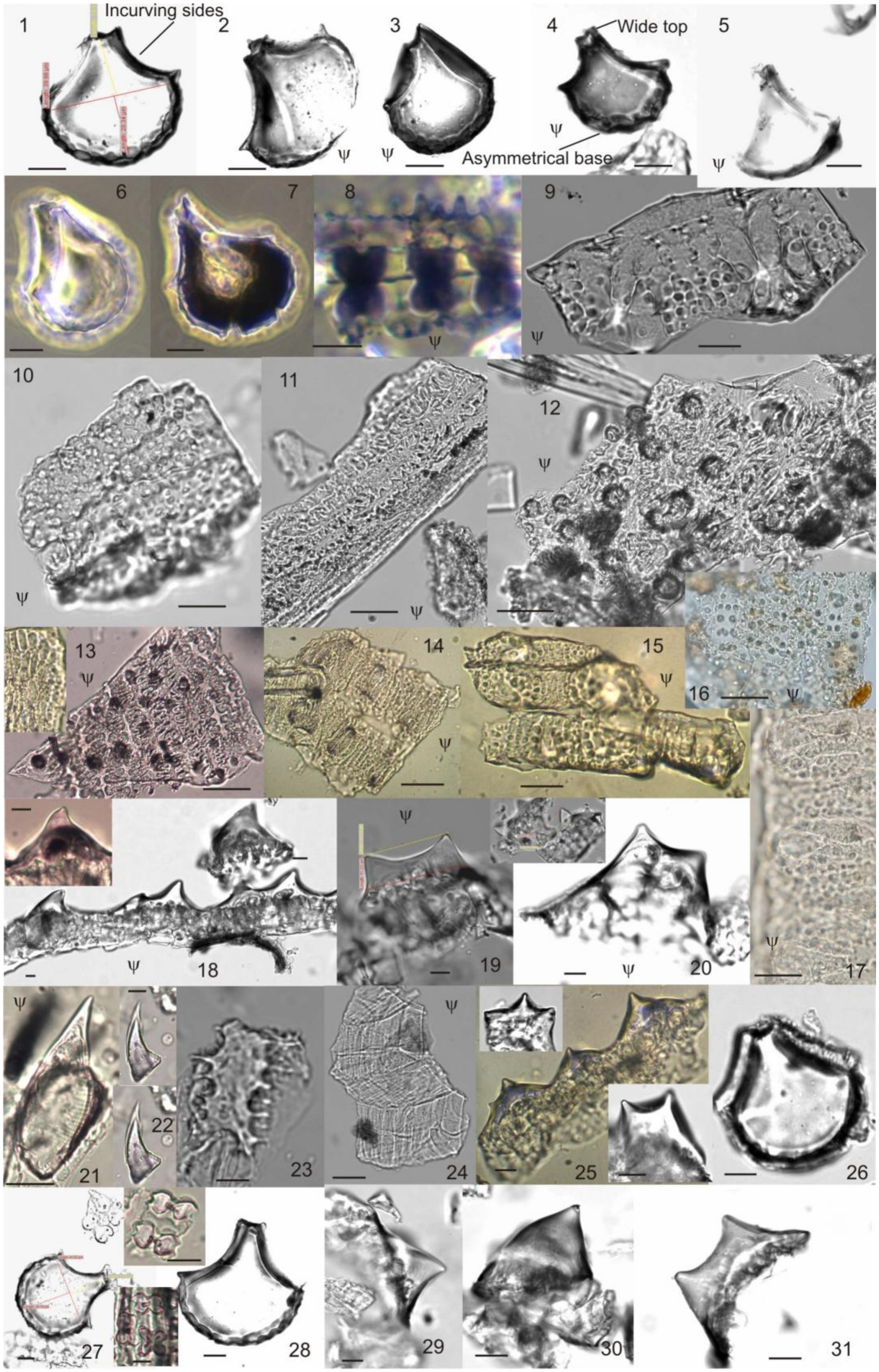
protuberances
v1
basal
v6
19

Fig.5.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Wide top
Asymmetrical base
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Fig.6

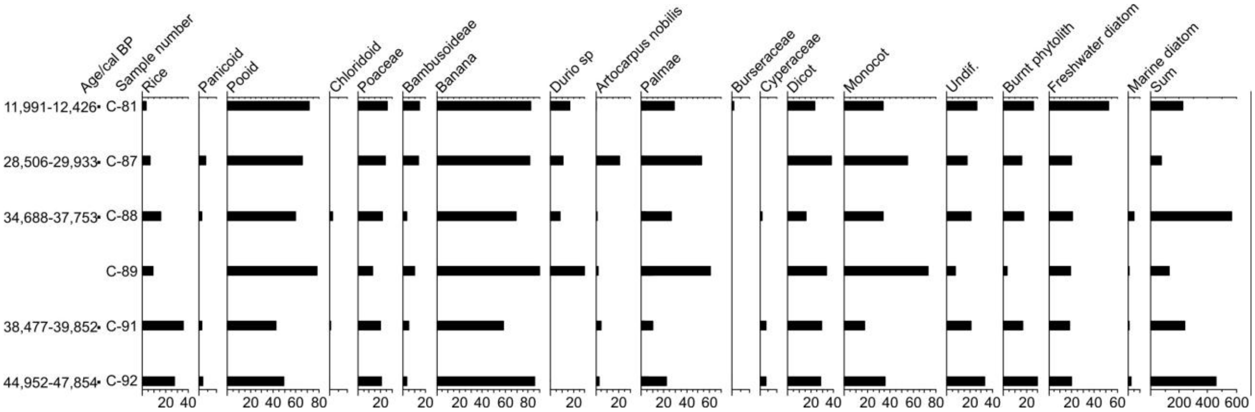
Age/cal BP
Sample number
Rice
Panicoid
Pooid
Chloridoid
Poaceae
Bambusoideae
Banana
Durio sp
Artocarpus nobilis
Palmae
Burseraceae
Cyperaceae
Dicot
Monocot
Undif.
Burnt phytolith
Freshwater diatom
Marine diatom
Sum
11,991-12,426 C-81
28,506-29,933 C-87
34,688-37,753 C-88
C-89
38,477-39,852 C-91
44,952-47,854 C-92
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Fig. 7.

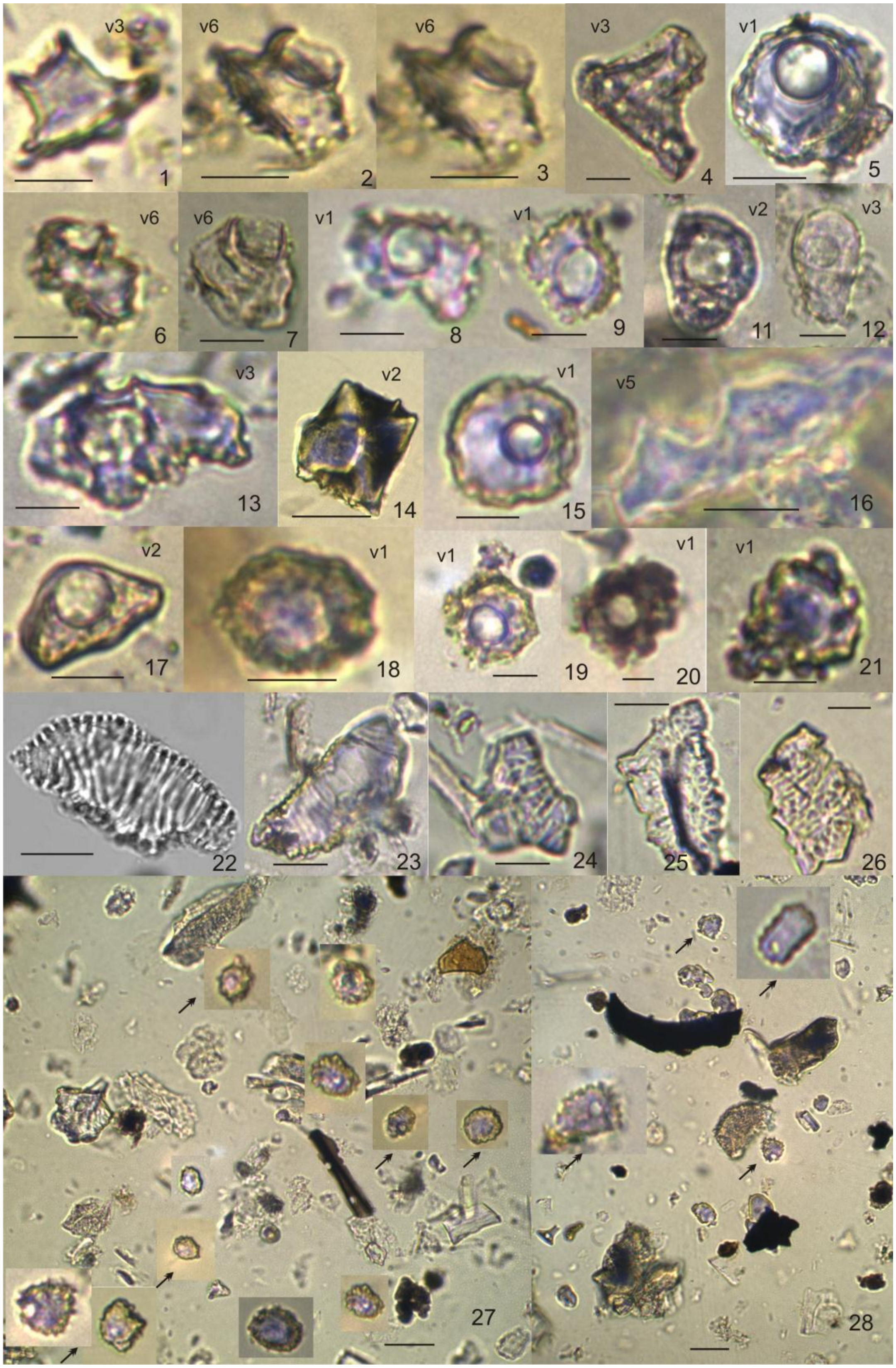
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Fig. 8

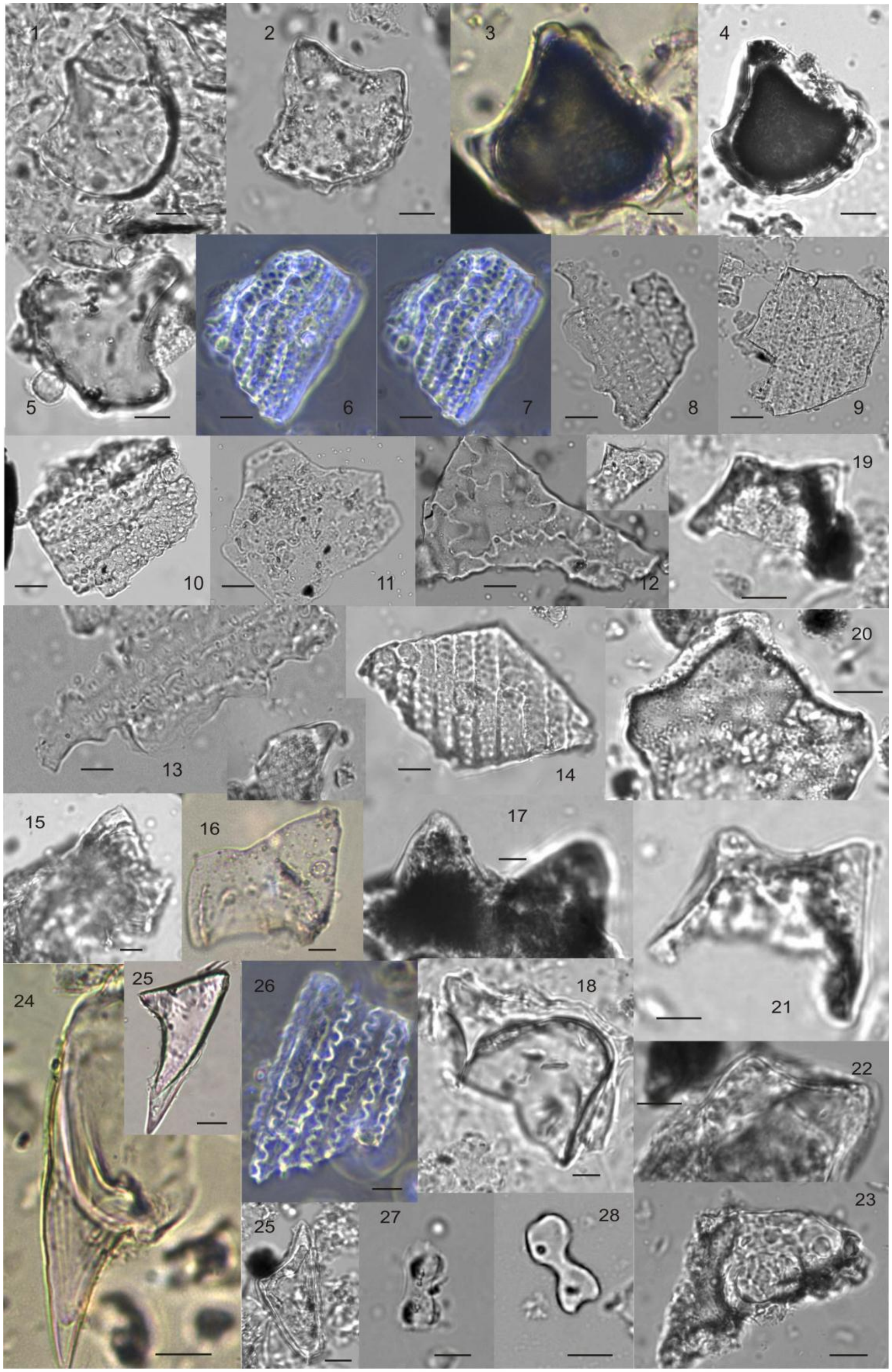

Fig. 9

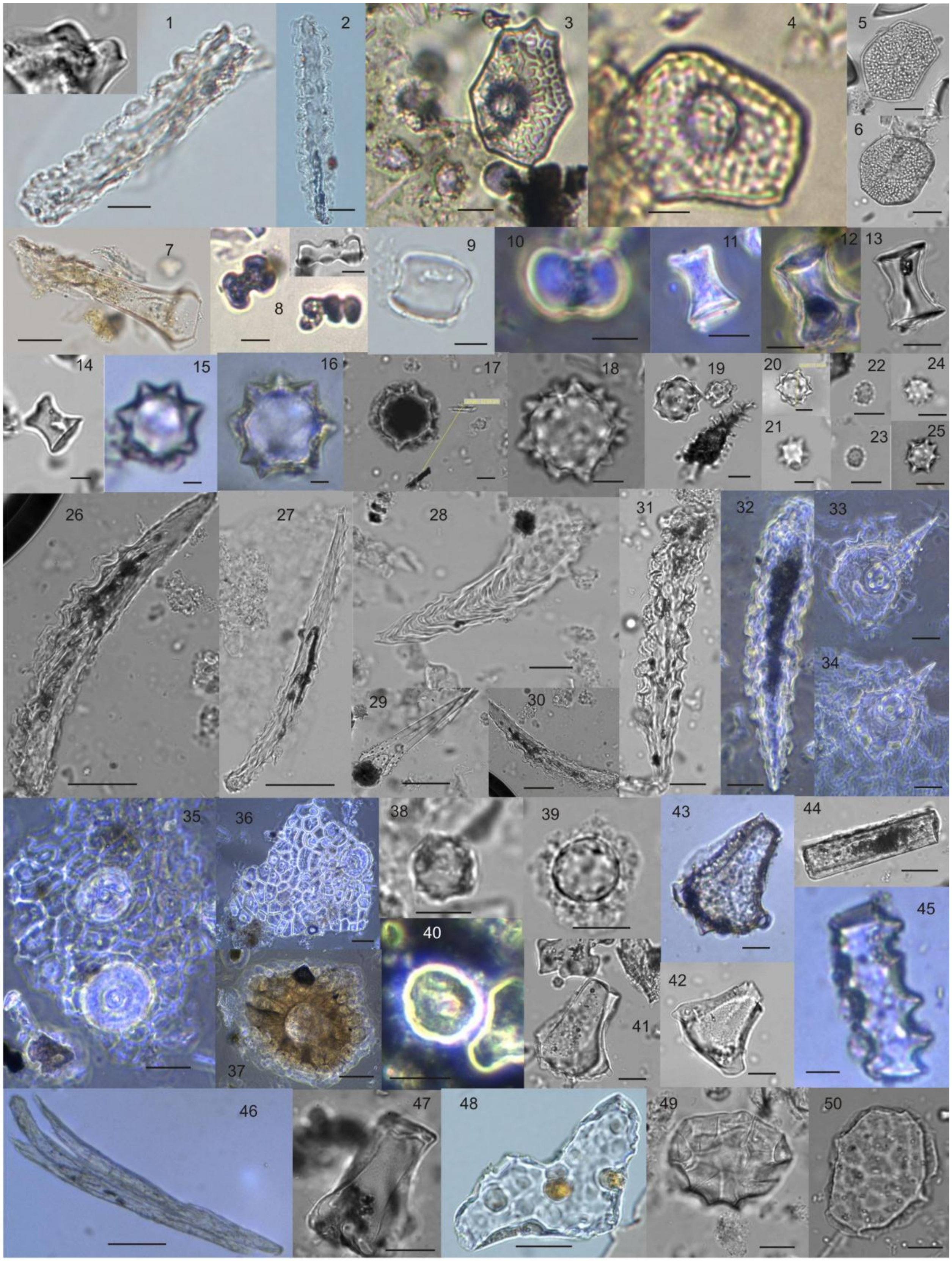
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Fig. 10