The Exploitation of Acorn and Rice in Early Holocene Lower Yangzi River, China

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Abstract: Recent excavations at Shangshan and Xiaohuangshan (11,400-8000 cal BP) in Zhejiang Province have revealed the earliest evidence for the emergence of sedentary villages in the Lower Yangzi River region. Both sites yielded abundant grinding stones but few organic remains. A pilot study of seven stone tools was undertaken to determine the potential of these artefacts for studies of subsistence economy and tool function by analysing starch, phytolith and mineral residues. Starch grains consistent with acorns, tubers, Job's tears and possibly water caltrop were found, but rice was absent. Phytolith densities for rice leaves and stems were high, but low for rice husks. Mineral studies indicate that the residues derived from tool use and the adjacent soil matrix. The results suggest that these grinding stones were used to process starch-rich plants for food and probably fibre additives for making pottery vessels. It is proposed that the intensive exploitation of plants rich in starch and suitable for long term storage, particularly acorns, characterised gathering strategies in the subsistence economy of the early Holocene in the Lower Yangzi River. This study shows the great potential of starch and phytolith analyses in reconstruction of ancient lifeways. More research on the residue materials from these sites will help us to better understand the transition to sedentary Neolithic farming villages in this region.

Key words: Grinding stone; Starch; Phytolith; Acorn; Lower Yangzi River
中图法分类号: K871.13 **文献标识码:** A **文章编号:** 1000-3193 (2010) 03-0317-20

Introduction

China is one of the centres where there is evidence for a shift from mobile hunter-gatherer lifestyles to sedentary Neolithic farming during the early to middle Holocene. The Lower Yangzi

收稿日期: 2009-05-05; **定稿日期:** 2009-08-26
基金项目: 澳大利亚研究基金会发现基金(ARC DP0450025)的资助。
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River region has been a focus of research on the origins of rice domestication. Investigations of several Neolithic sites, such as Kuahuqiao, Hemudu and Tianluoshan in Zhejiang (6000—4000 BC), have revealed important evidence for the development of sedentary farming villages [e.g., 1, 2—7]. However, there has been a lack of information on the period prior to the establishment of these sedentary villages that will help to understand the transitional stage to the Neolithic culture in this region. This situation is about to change, thanks to the recent excavations of the Shangshan and Xiaohuangshan sites in Zhejiang Province (Fig. 1). These sites are the earliest open-air settlements in the Lower Yangzi River region dating to the early Holocene, and provide a rare opportunity to investigate the archaeological record through this important period. In this paper we present the results of our pilot project of residue analyses (starch, phytolith and mineral) on stone tools unearthed in these locations. It is hoped that this investigation will shed light on subsistence economy of the early Holocene people in this region.

The Sites

Shangshan in Pujiang county and Xiaohuangshan in Shengzhou county are located in the south of Hangzhou Bay, an area with many small river basins surrounded by rolling hills (Fig. 1). Both sites were excavated in recent years and the data analyses are still ongoing. One of the most significant discoveries at these sites is the first appearance of a set of material assemblages that characterise the early Neolithic cultures in China. These include house structures, postholes, storage pits, pottery, grinding stones, and polished stone tools [8—10].

The Shangshan site (2 ha) is located on an alluvial plain of the upper Puyang River in a small basin, 10km long, and surrounded by low mountains. The site is situated on two small tablelands about 3-5 m above the surrounding plain. These tablelands are separated by a modern irrigation canal. A total of 1800m^2 has been excavated [8, 10]. Geological profiles from Shangshan indicate that the ancient settlement was situated in close proximity to rivers and lakes. The lower terrace next to the site experienced two incursions recorded as a series of fluvial and lacustrine facies around 1680 and 1580 BP. A drying event occurred no more than 1000 years ago [11]. Such drying and wetting cycles may have compromised the long-term survival of organic remains, as indicated by the absence of pollen in the soil samples from the site. Preservation of organic materials such as macrobotanical remains is low with only one excavation square (5 × 5m) on the lowest and wettest elevation at the site yielding any such remains. These include a rice grain, a few small fragments of carbonized nut shells and several animal bones.

Eight strata were recorded. The earliest horizons (Strata 5—8) span the early Holocene, which is referred to as the Shangshan period and dates to 11400-8600 cal BP. Strata 4, 3 and 2 date to the Hemudu (c. 7000—6000 cal. BP), Late Bronze Age (1st millennium BC), and Late Dynastic (after AD 600) respectively. Archaeological features include a large number of pits, some of which are likely to have been used as storage. At least one house was uncovered, as judged from well-arranged postholes. The lithic assemblage is dominated by flaked stone tools and grinding stones (> 400 slabs and hand-stones). The hand-stones vary in form, including round, square, and rectangular, and appear to have been used for both grinding and pounding. Ceramics are dominated by fibre-tempered large basins, with small proportions of other pottery types, such as plates and jars [10].

The Xiaohuangshan site (5 ha) is located ca. 80km northeast of Shangshan. The deposits here can be divided into three strata: lower, middle and upper. Nearly 2000m^2 has been excavated and storage pits, burials, house foundations and numerous stone and ceramic artefacts have been found. Eight ^{14}C dates from different strata place the site occupation to 9000—7700 cal. BP. Similar to Shangshan, very few organic remains, such as bones, have been recovered, and pollen is absent. The lower stratum belongs to the late Shangshan phase and contains material similar to the Shangshan assemblages. The middle and upper strata are referred to as the Xiaohuangshan culture. More than 900 grinding slabs and hand-stones have been recovered and these are similar in form to those from Shangshan; the largest slabs weighing nearly 30kg [9].

Charred rice (*Oryza* sp.) grains, leaves and stems have been found embedded in pottery as tempers at both sites. Some rice spikelets have been identified as wild (*O. rufipogon*) and cultivated (*O. sativa*) types, as indicated by the form of the rachis [12]. However, it is unclear whether the rice is a domesticated form [5].

Identifying the functions of these grinding stones may provide important insights into the subsistence economy of these communities.

Ecological Setting

The Lower Yangzi River region lies at the northern portion of the subtropical zone. The weather patterns are largely influenced by the summer monsoon and winter monsoon systems with clear seasonal changes [13]. This region experienced a period of relatively dry and cold climate from 13000 to 11670 cal. BP, corresponding to the Younger Dryas [14]. This event was followed by a wet and warm period of the early and middle Holocene interspersed with some cooler and drier episodes, but climatic fluctuations did not change the general subtropical conditions here. The vegetation was dominated by broadleaved evergreen and deciduous trees, such as *Quercus*, *Cyclobalanopsis*, *Lepidobalanus*, *Castanopsis*, *Lithocarpus*, *Corylus*, and *Ostrya*, many of them being nut-bearing trees. A range of non-arboreal and wetland herbs were also present in lower frequencies and were dominated by Poaceae, Cyperaceae and *Typha* sp. [7,14—18].

The increase in nut-bearing trees and a variety of other economic plants in the region coincided with the emergence of the Shangshan and Xiaohuangshan settlements and the subsequent development of the Neolithic villages during the early and middle Holocene. These environmental data are reflected in the plant remains at several waterlogged Neolithic sites in Zhejiang. For example, at Kuahuqiao (c. 8000—7000 cal. BP) [19], Hemudu (c. 7000—6000 cal. BP) [20] and Tianluoshan (c. 7500—6000 cal. BP) [21] (Fig. 1), the remains of economically important starch-rich plants were frequently encountered and include acorns (*Quercus* spp. and *Cyclobalanopsis* spp.), chinquapin (*Castanopsis* spp.), water caltrop (*Trapa* spp.), gorgon fruit (*Euryale ferox*), and Job's tears (*Coix lacryma-jobi*). Acorn and water caltrop in particular were preserved in large quantities in storage pits. Rice also occurred in high frequencies and included both domesticated and wild types [4, 12]. It appears likely that most of the plants unearthed from these Neolithic sites were also exploited by the Shangshan and Xiaohuangshan people, since the general climate and vegetation were similar during the early and middle Holocene in this region.

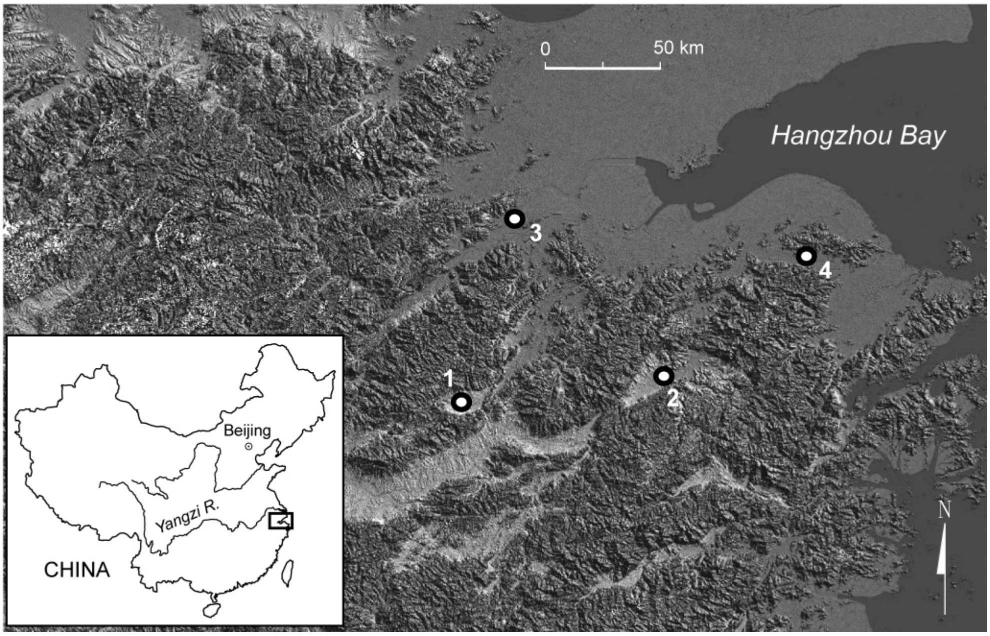

Fig. 1 Location of the sites discussed in this paper

1. Shangshan, 2. Xiaohuangshan, 3. Kuahuqiao, 4. Hemudu, Tianluoshan

Today in Zhejiang rice is the main staple food, and domesticated water caltrop is commonly consumed during the harvesting season in autumn. Modern vegetation is largely characterized by a mixture of deciduous and evergreen trees [16, 22]. Many species of starch-rich nuts from the Fagaceae family grow in the mountainous areas, including *Quercus* (twelve species), *Lithocarpus* (six species), *Cyclobalanopsis* (eight species), *Castanea* (three species) and *Castanopsis* (eight species) [23: 52-66]. The first three genera are commonly referred to as *xiangzi* (acorn), and are still exploited as a starch-rich food in rural areas, but are less common in cities.

Analyses

One avenue to investigating subsistence adaptations is through the functional study of material remains such as grinding stones. Microfossils such as starch and phytoliths preserved as residues on stone tools can provide important information concerning contact materials and tasks related to artefact use. This type of study is particularly important where the preservation of organic remains is poor. The abundance of grinding stones in the lithic assemblage suggests that the materials processed on these tools must have been economically important. The identification of task and function of these tools may hold the key to understanding subsistence strategies during this transitional phase.

Grinding stones are known worldwide and while most were multifunctional tools, they were primarily used for processing plant foodstuffs, particularly nuts, tubers, fruits, and cereals, among others [24—26]. However, the specific function of these tools in China is controversial. For the Neolithic period, the most commonly accepted interpretation of grinding stone use is for processing domesticated cereals [27—29]. This argument is based on ethnological approaches rather than the integrated functional study of the stone tools in question. Several recent studies have employed usewear and starch analyses to investigate the function of grinding stones from several sites in Shandong [30] and Beijing [31, 32]. The results of these analyses suggest that the foodstuffs processed on these tools were predominantly acorns, but also included beans and millet during the early and middle Holocene. However, the grinding stones from the Lower Yangzi River region have not been properly studied.

A pilot study was undertaken to investigate the likelihood that these artefacts could provide direct evidence of plant resource use and to this end a small sample of tools were made available by the site investigators for analysis (Fig. 2). The primary aim of the study was to investigate the function of a range of grinding stones from Shangshan and Xiaohuangshan to determine the associated subsistence strategies. The sample comprised six grinding stones and one flaked tool, dating to the Shangshan and Hemudu periods. The tools were excavated from cultural layers, and subsequently washed and stored (Table 1). Only a limited number of tools still showed visible traces of residues on the used surfaces. The conditions of access to the artefacts permitted only small samples of residues (c. 0.2—0.4g) to be recovered. It is always ideal to collect residue samples from unwashed tools as well as collect soil sediments around the tools for comparison while excavations are still in progress, in order to ensure that the residual remains are directly

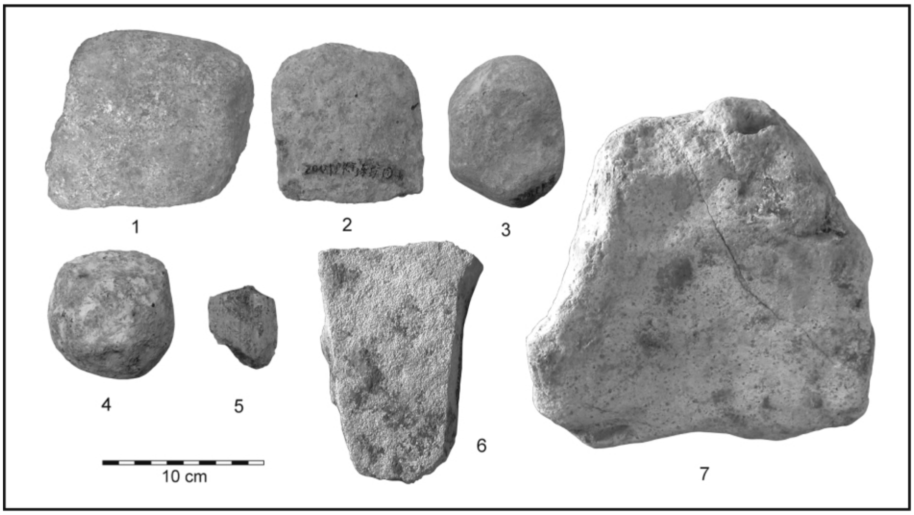

Fig. 2 Stone tools analysed in this study

1. SST5(7):6 ball; 2. SST3(7):10 handstone; 3. SST5(5):2 ball; 4. SST3(7):3 ball; 5. SST0511(4a) flake; 6. XHST0905(8):10 slab/whetstone; 7. XHST11(3):4 slab

related to the tool function [33, 34]. Unfortunately this is not always possible as excavations may have been undertaken before these types of analyses or methodological developments had appeared. In this case, dry sediments were scraped/brushed from used surfaces into clean plastic bags. The samples were subsequently divided into three and submitted for starch (JF), phytolith (AW) and mineral analysis (JW).

Tab. 1 Artefacts examined (SS = Shangshan; XHS = Xiaohuangshan), and yields and measurements from starch and phytolith analyses (S. D. = standard deviation; na = not analysed; mb = membrane bound)

Artefacts				Starch grain analysis							Phytolith analysis		
Sample no.	Chronology	Tool type	Raw material	Residue colour	Wt (g)	n	Grains/100g	Mean length (μm)	S. D.	Range (μm)	Wt (g)	n/gram sediment	Abundance
SST5(5):2	Early Shangshan	ball	vitric fragment tuff	white	0.1	1	1000	—	—	30.49	0.044	1426277	present
SST3(7):10	Early Shangshan	Hand-stone	sed breccia tuff	white	0.2	0	—	—	—	—	0.004	2885909	present
SST3(7):3	Early Shangshan	ball	vitric fragment tuff	dark	0.1	2	2000	15.26	—	11.8—18.72	—	—	sparse
SST5(7):6	Early Shangshan	Hand-stone	tuff-breccia	white	0.1	98 8-single 90-mb	97000	 6.25 11.89	 1.85 5.52	 4.08—9.32 3.13—30.18	na	na	na
SST0511(4a):7	Hemudu	flake	rhyolite	dark	<0.1	5	5000	10.68	8.56	2.5—21.74	0.013	182351	abundant
XHST0905(8):10	Early Xiaohuangshan/Late Shangshan	slab/whet-stone	grey fine-grain sandstone	dark	0.2	5	2500	21.46	2.32	18.27—24.8	0.026	1362237	very sparse
XHST11(3):4	Early Xiaohuangshan/Late Shangshan	slab	river cobble, unidentified	white	0.7	13	1873	19.33	5.05	12.84—29.77	0.047	974470	abundant

Starch Analysis.

The study of ancient starch is a relatively new development in the functional analysis of ground stone tools or other artefact types [34]. That starch does survive through long periods of time has been clearly established in a number of reports from the arid zone to the tropics [35—39]. However, systematic quantification of starch residues and identification that allows classification to family or genus is often not as straightforward as it is for phytoliths and pollen [34]. In recent years this method has also been introduced to China [40, 41], and used in archaeological contexts to understand subsistence economy and tool functions [30, 42, 43].

Modern comparative reference collections are fundamental to the identification of starch [44], with collation and descriptive publication of these collections ongoing [e.g., 36, 45]. Starch can be identified to genera and, in some cases to species when attributes such as size and morphology are distinctive [35, 37]. Based on the presence of certain plants in the pollen record and on macro botanical remains in the archaeological context, we collected modern reference samples from starch-rich plants that may have been economically important in Zhejiang and other regions in China. Our collection includes species of acorns (*Quercus*, *Lithocarpus* and *Cyclobalanopsis*), tubers, cereals, grasses and aquatic plants. Maximum length measurements (through the hilum) were used to quantify the starch populations and provide broad indications of species being processed.

Ancient starch was extracted by heavy liquid separation using sodium polytungstate (Specific Gravity 2.35). The specific gravity used in this study resulted in recovery of both phytoliths and starch; this extraction was undertaken in order to investigate the range of plant microfossils that may have been preserved. Samples were mounted in Permount. The slide-mounted preparations were scanned using a Zeiss Axioskop II brightfield microscope fitted with Nomarksi (Differential Interference Contrast) optics and polarising filters. The Nomarksi method is used because it is designed to give contrast to unstained specimens, as well as providing good visualization of surface features. Images were collected with a Zeiss Axiocam HRc digital camera and archived using Zeiss Axiovision software.

Six of the seven tools sampled yielded starch grains (Table 1) and some of these appeared to have damage to the body of the grain that is consistent with grinding (see Fig. 3H) [cf. 46, 47, 48]. Among the tools from Shangshan, SST5(7):6 (early Shangshan Phase) yielded a set of grains that appear to be membrane bound, plus a number of isolated grains. The membrane-bound grains exhibit features distinctive of starch: extinction crosses that rotate with polarizing filters and distinct lamellae, but more precise details were obscured by the enclosing membrane. All grains appear round to ovoid (Fig. 3A). Some of the isolated grains (e. g. Fig. 3B-E) exhibit distinct morphologies consistent with *Quercus* species (Fig. 3N) including shape, fissures at the hilum and faceting. The maximum length measurements of all the grains, as well as the specific features of the isolated grains in this sample, fit closely with *Quercus* sp. It should be noted, however, that the variability in morphology within a species often precludes absolute identifications on the basis of single grains and is one of the ongoing issues in starch analysis. The starch grains from the SST3(7):3 (early Shangshan Phase) and SST0511(4a):7 (Hemudu period) samples show size and shape characteristics consistent with *Quercus* sp. and *Coix lacryma-jobi* (Job's tears) (Fig. 3B-E compared to N, P; Fig. 4A). *Quercus* sp. and Job's tears starch grains are similar in morphology and because of the small sample size it is therefore difficult to allocate a specific identification.

The SST5(5):2 sample (early Shangshan Phase) contained only one grain that was triangular in shape with an eccentric hilum as commonly seen in yams and tubers (Fig. 3F, lower right). Comparison with tubers from our comparative reference collection indicated that lotus root (*Nelumbo* sp.) and Chinese yam (*Dioscorea opposita* Trunb.), while similar in size, could be excluded on morphological grounds (Fig. 3Q): namely the absence of visible lamaellae and overall shape characteristics of the unknown tuber grain (Fig. 3R). When compared to our Oceania starch database, the grain fell within the size range of 4 species, of which *Dioscorea nummularia*, while not reported from China, was the closest morphological match [36]. Another possible match is *Trapa* sp. (water caltrop), an aquatic plant that has been found in Neolithic deposits in this region (Fig. 3O). Nonetheless, it appears to be most consistent with *Dioscorea*

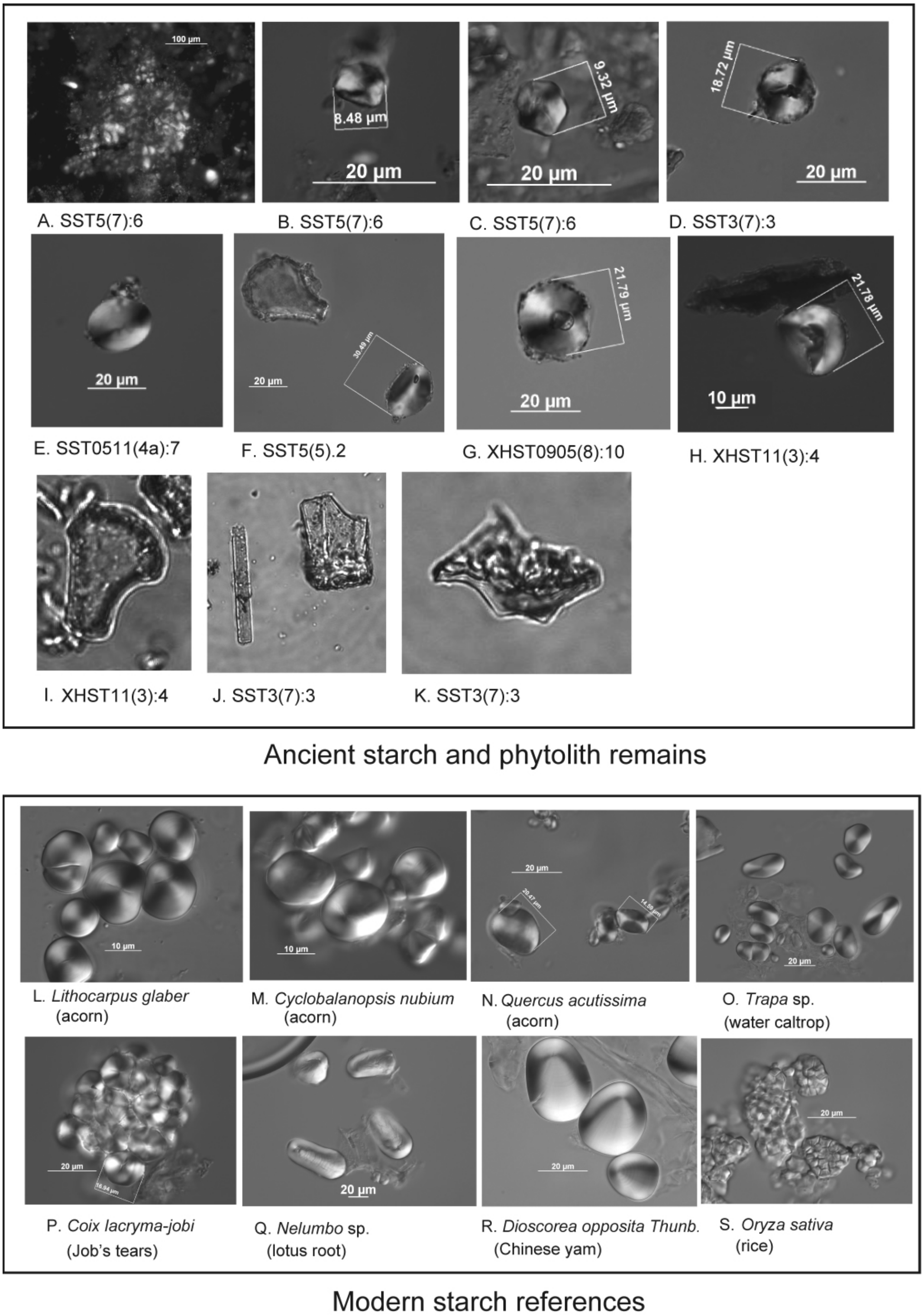

Fig. 3　Starch grains and phytoliths isolated from residues samples collected in Shangshan and Xiaohuangshan, and modern reference samples

A. membrane-bound starch grains, shangshan; B-E: starch grains sirmilar to *Quercus* sp. / *Coix lacryma-jobi*, Shangshan; F: a tuber starch grain (lower right) and a phytolith from rice leaf/stem, Shangshan; G, H: starch grains similar to *Lithocarpus* and *Cyclobalanopsis*, Xiaohuangshan; I. phytolith Keystone from unknown grass leaf, Xiaohuangshan; J. phytolith leaf long cells and bulliform from grasses, Shangshan; K. phytolith from Oryza husk double peaked glume cell, Shangshan; L-S: modern starch reference samples from various plants.

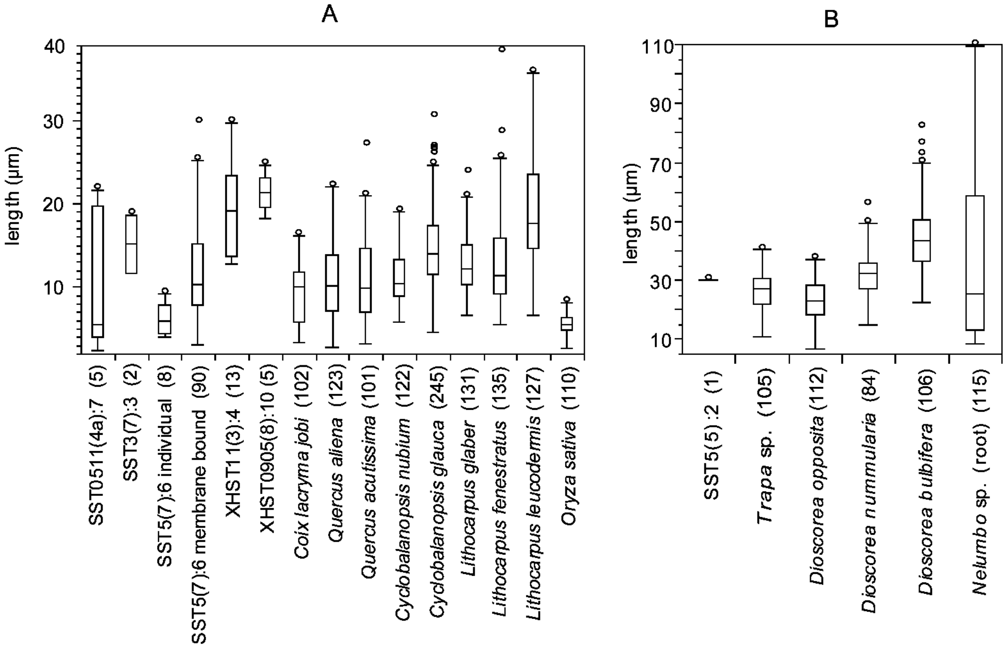

Fig. 4 Comparison of size ranges between ancient starch grains and modern reference samples

A. ancient starch grains comparing with non-tuber reference samples; B. Shangshan T5 (5): 2 grain comparing with water caltrop and tubers; no. in brackets indicating number of grains measured

and more reference samples are required to test this further. No other tuber grains were identified in any of the samples.

Residual starch grains from the Xiaohuangshan samples (Late Shangshan Phase) (Fig. 3G, H), are on average bigger than the Shangshan samples, and they fall within the size range of *Nelumbo* sp. (lotus root), *Cyclobalanopsis* sp. and *Lithocarpus* sp. (acorns) (Fig. 4). In terms of grain morphology, the grains are most similar to *Lithocarpus* sp., as indicated by faceting, fissures at the hilum, and the grain shapes observed for the reference samples. *Cyclobalanopsis* sp. (Fig. 3L, M) also showed broad similarities to a few of the ancient grains recorded.

Rice is excluded as a likely contact material because no rice starch grains were identified in any of the samples (see Fig. 3S). Rather, identification of starch residues to *Quercus* sp. and/or *Coix lacryma-jobi* (Job's tears) at Shangshan, with *Lithocarpus* and/or *Cyclobalanopsis* sp. at Xiaohuangshan suggests alternative uses for these implements. Water caltrop also remains a possibility, though a much larger archaeological sample size would be required to support this identification.

Phytolith Analysis.

In conjunction with technological and use-wear analyses, the study of phytolith assemblages extracted from stone tool surfaces has yielded important information concerning stone tool function [36, 49—52].

The phytoliths were identified by comparison with a reference collection compiled from modern South East Asian plants and the phytolith reference collection at the Institute of Archaeology, University College London. While phytoliths can be used to identify many grasses to genera and sometimes to species, dicotyledons (trees, woody shrubs and herbaceous plants) are more difficult to identify and quantify, partly because they are produced in far lower densities than silica bodies from grasses. The large number of morphotypes within a species or genus, and the presence of the same morphotype across many plant genera can complicate phytolith identification [36: 597]. The real strength in the analysis undertaken here is the possibility of differentiation between the leaves, stems and husks (Fig. 5; Table 2), which affords the opportunity to understand whether cereal seeds, such as rice, may have been processed.

Tab. 2 Comparative % per sample grass leaf/stem, husk and dicot cells recovered from phytolith remains on each tool

Phytolith motphotype	SST3(7):3 ball-shape handstone	SST5(5):2 ball-shape handstone	SST0511(4a): 7 stone flake	SST3(7): 10 handstone	XHST11(3):4 stone slab
Long smooth	12.1	8.8	2.0	11.2	28.3
Long sinuate	0.4	0.0	0.0	0.4	1.9
Long rods	0.4	2.2	0.0	1.7	0.0
Bulliform	2.0	2.9	0.7	0.4	7.6
Keystone	2.8	0.0	2.0	0.0	3.8
cf. *Oryza* keystone	0.0	0.0	0.0	0.0	0.0
Bilobes:	0.8	0.0	0.0	0.0	2.2
Scooped bilobe	0.4	0.0	0.0	0.0	0.0
Rondels:	6.5	5.1	8.2	3.9	10.7
Saddles:	0.8	0.4	1.4	0.9	1.3
Collapsed saddle	0.4	0.4	0.0	0.0	0.0
Smooth Spheroid	0.0	0.0	0.7	0.0	0.0
Total grass leaf /stem single cells	**26.7**	**19.9**	**15.0**	**18.5**	**55.7**
Elongate	0	0.4	1.4	0.4	0.0
Tracheids	2.0	0.0	0.0	0.4	1.3
Blocks	2.4	0.0	0.0	0.0	1.9
Platey	4.9	4.8	2.0	8.6	12.0
Sheet	0.0	1.1	0.0	0.0	0.0
Total dicotyledons	9.31	6.25	3.40	9.48	15.11
Leaf/stem indet	5.3	1.1	2.0	5.6	0.9
Leaf/stem long cells	0.0	0.0	0.0	0.0	0.2
Leaf/stem square-cell	0.0	0.4	0.0	0.0	0.2
Total grass leaf/stem multicells	**5.3**	**1.5**	**2.0**	**5.6**	**1.3**
Long dendritic	0.4	0.0	0.0	0.4	0.0
Indet husk	0.8	0.0	0.0	0.9	0.1
cf. *Oryza* husk	0.4	0.0	0.0	0.4	0.0
Total grass husks	**1.6**	**0.0**	**0.0**	**1.7**	**0.1**

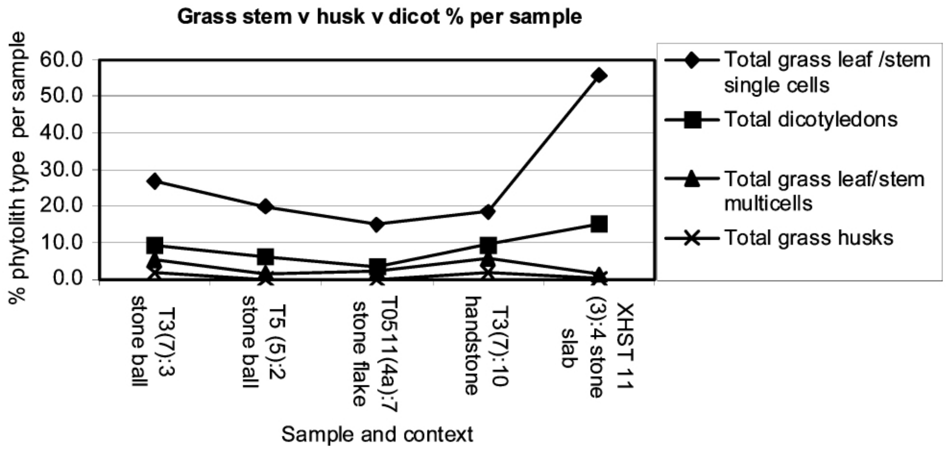

Fig. 5 Comparative % per sample grass leaf/stem, husk and dicot cells from phytolith samples
Sample XHST0905(8):10 was not included as there were too few identifiable phytoliths

Phytoliths were extracted from six residue samples (Table 1) to determine the presence, preservation and abundance of phytolith remains. Following the Phytolith Extraction Protocol established by Arlene Rosen at UCL, where possible, around 0.8g of dried sediment was processed for phytoliths. A minimum of 100 morphologically identifiable silica bodies were counted using a Lexica DM 1000 optical polarising microscope at 400x magnification.

Phytoliths were present at varying densities in five of the samples examined. Smooth and sinuate long-cells, rondel, and bilobe shaped short cells from grass leaf/ stems were ubiquitous, as were bulliform cells from grass leaves (Fig. 3I, J). Husk cells were present in three samples (Fig. 5; Table). The majority of phytoliths observed were indeterminate but a small proportion was identified as rice (*Oryza* sp.). A range of platey forms from dicotyledonous plants were present in all samples (Fig. 3I). Both of the ball-shaped hand-stone samples yielded high proportions of damaged and dissolved silica bodies, which may be related either to ancient use or to post-depositional taphonomic processes.

The highest proportions of phytoliths in all samples were from the leaves and stems of various grasses (Fig. 5), including rice (Fig. 3F). Rice (*Oryza* sp.) husk cells are present in low densities in samples from two hand-stones (T3(7):3 and T3(7):10) (Fig. 3K). Dicotyledonous plants produce far fewer phytoliths than grasses, and they are present in all the samples.

The presence of high residual densities of phytoliths from grass leaves and stems, but low densities from rice husks, suggests that some of the tools were probably used for processing fibre additives for making pottery vessels. In particular, the fibre-tempered pottery pastes at Shangshan show a mixture of mostly leaves and stems with few husks, a pattern similar to ratios seen in the tool phytolith residue samples. The presence of rice phytoliths in the residue samples also suggests that rice was exploited as an economic plant. However, based on phytolith data, it is unclear whether the rice concerned was from wild or cultivated varieties.

The very low proportions of rice husk phytoliths suggests that the grinding stones were not used for dehusking rice. Rice dehusking is traditionally carried out by pounding with wooden mortars and pestles in south China [53] and in other parts of the world. Importantly, experimental studies have shown that grinding slabs and hand-stones are not the most efficient implements for dehusking cereals [54, 55], which perhaps explains the absence of rice starch in our samples.

Mineral Analysis of Residues.

An innovative approach to the examination of the residues was to test the mineral components of the samples from SST0511(4a):7 and SST3(7):10 in order to determine the origins of the residues. The rationale behind this approach was that the mineral residues are expected to be consistent with the stone raw material rather than with the enclosing soil matrix if the plant residues were truly a product of use rather than deposited as a contaminant. This approach, to our knowledge, has not been attempted previously and was undertaken as a 'control' especially considering the excavation and curation history of the artefacts, as described previously.

The surface residues of the two tools were prepared as strew mounts on glass slides and examined under a Nikon petrological microscope, using plane and cross-polarised light to identify the minerals present. The samples were also examined and photographed under a JEOL scanning electron microscope at 15.0 kV and magnifications up to x30000.

In both residue samples, there were abundant fine-sand-sized grains of angular quartz and tabular feldspar, in addition to similar-sized and larger dark angular fragments that sometimes contained phenocrysts of quartz and feldspar. These grains are derived from the artefacts themselves, which are acid volcanic in composition (rhyolite and tuff breccia), comprising quartz and feldspar phenocrysts enclosed in a very fine-grained (typically almost opaque) matrix. The residue samples also contain a considerable component of well-sorted subangular quartz silt and very fine-grained clay, which are derived from the soil matrix surrounding the artifacts. The quartz silt represents loess incorporated into the soil (Fig. 6). Substantial amounts of the residue samples were derived from tool use that involved grinding or pounding, while some of the residues also came from the sediment matrix in direct association with the stone tool surface.

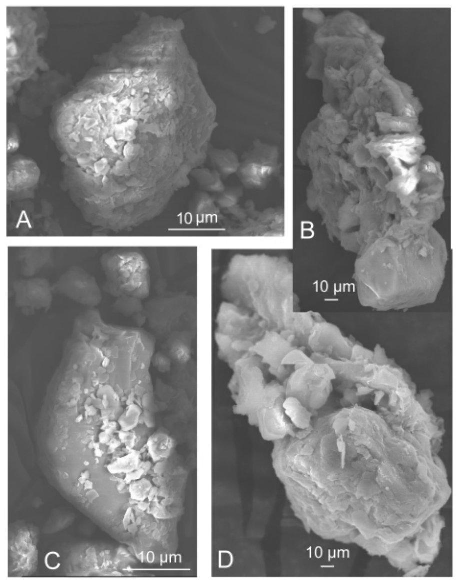

Fig. 6　A, C: subangular clasts of quartz silt with adhering clay grains. B: rhyolite clast, note quartz phenocryst at lower right. D: rhyolite clast-note tabular feldspar phenocryst on lower right. A-residue from breccia tuff tool T3(7):10; B, C and D: residue from rhyolite tool T0511(4a):7

The starch and phytolith residues on the tools examined in this study are more likely to be derived from tool use rather than soils adhering to the tool surface. Field (unpublished results) has observed that starch grains occur in significantly smaller concentrations in soils than on the used surfaces of stone artefacts. Starch survival rates vary considerably in different depositional conditions [56]. It has been argued that starch found on an artefact should represent either authentic contact-residue or sediment transfer within the first months of deposition [57: 1727]. Furthermore, processing of starchy foods on grinding stones will result in starch being spread over most of the tool surface with excess material falling onto the adjacent ground surface. For this reason we cannot rule out the likelihood that starch surviving in the soil near the used tools may have originated from tool use. In this case, identifying the presence of starch and phytoliths provides compelling evidence for starchy plant exploitation at Shangshan and Xiaohuangshan. Some starch grains and phytoliths exhibited damage associated with grinding and pounding (Fig. 3H). Starch grains were consistent with acorn and rice starch was absent, indicating that the samples were not contaminated by modern plants, as acorn is not consumed regularly now but rice is the predominant staple in this region today.

Discussion

Shangshan and Xiaohuangshan were located in resource rich but highly seasonal environments. At the time of site formation, starchy foods were highly seasonal, being abundant during the summer and autumn, but scarce during the winter. The starch analysis suggests that a range of starchy plants were exploited, including acorns and Job's tears, an unidentified tuber and/or possibly water caltrop. This plant microfossil assemblage has parallels with the assemblages recovered from waterlogged Neolithic sites in the region, as mentioned above. The finding of acorn starch is also consistent with pollen records, which document that several genera of oaks were common in the Lower Yangzi River region during the early Holocene.

Acorn is a starch-rich resource that has been exploited as a staple food by people in many parts of the world for millennia [58—60]. Acorn contains a considerable concentration of tannins: as determined from 15 species of *Quercus* (2.21—22.74%) [61]; four species of *Cyclobalanopsis* (2.21—15.75%) [62]; and eight species of *Lithocarpus* (0.63—3.31%) [63]. Acorns have to be rendered edible by an acid removal process. Processing methods vary from region to region, but the essential procedures all include soaking, grinding, shelling, sieving, leaching, and drying; the entire process involving several days of work [e.g., 59—61, 64—66]. In China today, acorns are mainly used for fodder, alcohol, and industrial starch [61, 67], but they are also consumed by people, particularly in times of famine. A common use of acorn starch in Zhejiang and Henan today is to make jelly.

The large number of grinding stones uncovered at Shangshan and Xiaohuangshan and the associated residues indicates that acorns are likely to have been an important staple in people's diet during the early Holocene. Acorn consumption continued through to the middle Holocene period, as shown by acorn starch recovered from a Hemudu period tool at Shangshan (SST0511 (4a):7). This finding is consistent with the large quantities of acorns excavated from Hemudu and Tianluoshan.

Previous studies on subsistence economy of Neolithic settlements in Zhejiang (e. g., Kuahuqiao, Hemudu and Tianluoshan) have noted the importance of wild food resources [19, 21, 68, 69], and some have particularly emphasised the large quantities of acorn remains [3, 19, 70]. There are apparently general spatial correlations between the regions with high percentages of *Quercus* pollen and the presence of grinding stones in the archaeological record during early and middle Holocene in China, possibly indicating intensive acorn processing in those regions [71]. It also has been suggested that the micro-charcoal evidence for burning near the Kuahuqiao site [7] may relate to acorn collection [72]. Our study provides the first hard evidence for the use and processing a wide range of wild plants, predominantly acorns, by people who were likely the ancestors of the rice farmers in the Lower Yangzi River region. The various factors involved in collecting and processing acorns -such as optimally abundant seasonal productivity and long-term storability, followed by high processing costs of time and energy - may have laid the foundations for a stable residential mode, at least among a part of the population. However, further research is needed to investigate regional settlement distribution, population densities, and foraging behaviour involving procurement of acorn and other food resources, in order to better understand changing settlement-subsistence patterns in this region.

Rice, most likely wild at this time, was apparently exploited for multiple purposes (pottery tempers and presumably consumption); but appears unlikely to have been a primary focus of subsistence activities. Wild rice is much less productive than other plants, such as tubers [73] and acorns, and at this time may have been unsuitable as a major staple.

The transition to early stages of Neolithic in the Lower Yangzi River region was possibly accompanied the use of wild rice as an economic plant. However, the optimum climatic conditions, the increased residential stability, and initial exploitation of rice did not automatically stimulate the development of agriculture in this region.

In conclusion, the results of this pilot study provide a compelling argument regarding the function of grinding stones in relation to general subsistence economy in the transition to Neolithic in the Lower Yangzi region. The proposition can be tested in future investigations when more detailed site reports and larger sample sizes are available. Furthermore, given that the preservation of organic remains at the two sites is very poor and artefacts analysed in this study had been washed and curated following excavations, the recovery of residues from these tools demonstrates not only the resilience of use-related residues on stone tools but highlights the enormous potential of these types of studies for the remaining assemblages from these and other important sites in China.

Acknowledgements

This research has been assisted by Zhou Zhekun, Zheng Yunfei, Hu Yaqin, Liu Yonggang, Wei Ming, Gyoung-Ah Lee, Sheahan Bestel, Duncan Jones and Thomas Bartlett. We thank Arlene Rosen for comments on the manuscript. We appreciated the constructive comments from a number of anonymous referees. The authors acknowledge the facilities as well as scientific and technical assistance from the staff in the Australian Centre for Microscopy and Microanalysis

Research Facility (AMMRF) and at the Australian Centre for Microscopy and Microanalysis at the University of Sydney. The mineral images were produced by Alex Fink in the Electron Microscope Unit at La Trobe University. The project was funded by an Australian Research Council Discovery Grant (DP0450025 to Li Liu), La Trobe University and the University of Sydney.

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全新世早期中国长江下游地区橡子和水稻的开发利用

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摘要： 最近发掘的浙江上山和小黄山遗址（11400—8000 cal BP）是长江下游地区迄今发现最早的村落遗址。这两个遗址均出土有大量磨石，而有机物遗存保存很少。本文对 7 件石器进行了淀粉粒、植硅体以及矿物残留物的初步分析，以便检验这些方法在复原古代生计形态和器物功能研究中的可行性。鉴定出的淀粉粒包括橡子、根茎类、薏苡以及疑似菱角等，但是没有发现水稻。在发现的水稻植硅体中，来自茎杆和叶的密度较高，而来自颖壳的密度较低。矿物分析表明残留物来自工具的使用以及周围的土壤基质。结果显示这些磨石曾经用于加工富含淀粉的植物和制陶用的羼和料。我们认为，对富含淀粉并且适于长期贮存的植物特别是橡子的大量开发利用是全新世早期长江下游地区生计形态中采集策略的特征。本研究显示了淀粉粒和植硅体分析在古代生计重建中的巨大潜力。对这些遗址残留物的进一步研究将有助于我们更好地理解这一地区从采集经济到定居农耕经济的转变。

关键词： 磨石；淀粉粒；植硅体；橡子；长江下游

在全新世早期和中期之间，世界上很多人群都经历了从迁徙的狩猎采集经济到定居的农耕经济的转变。考古学证据显示中国是经历这一转变的中心地区之一。近年来，长江下游地区已经成为水稻驯化起源研究的一个焦点。对浙江跨湖桥、河姆渡和田螺山（6000—4000BC）等新石器时代遗址的研究已为该地区定居农耕村落的发生提供了重要证据。但一直缺乏这些定居村落建立之前的信息，以理解这一地区向新石器时代转变的过渡阶段。最近对浙江省上山和小黄山遗址的发掘可以弥补这方面的不足。作为长江下游全新世早期遗址中最早的旷野聚落，这两处遗址提供了研究这一重要时期考古遗存的难得机会。本文对这两处遗址出土的一些石器进行了残留物分析（包括淀粉粒、植硅体和矿物等），以期揭示该地区全新世早期先民的生计形态。

浦江县上山遗址和嵊州市小黄山遗址位于杭州湾南部，这里有众多丘陵环绕的小型盆地。这两处遗址均坐落在盆地中的冲积平原上。其中最重要的发现包括房屋遗存、柱洞、窖穴、陶器、碾磨石器以及磨光石器等，是中国迄今最早的显示新石器早期文化特征的遗迹和遗物组合。

上山遗址共划分出 8 个地层，其中第 5—8 层属于全新世早期阶段，年代测定为距今 11400—8600 BP 之间，被称为上山时期。而第 4、3 和 2 层则归属河姆渡时期（c. 5000—4000BC）。有大量灰坑存在，其中一些可能用于窖藏。石器组合以打制石片石器和碾磨石器为主，磨盘和磨棒超过 400 件。磨棒的形状不一，有球形、方形和长方形；据初步观察，可能用于碾磨和臼捣。

小黄山遗址的文化堆积可以分为上、中、下三层。在近 2000m^2 的发掘面积里已经发现了贮藏坑、墓葬、房屋基址及大量的石、陶器。对来自不同地层的 8 个样品进行的测年结果显示该遗址年代为距今 9000—7700 年。下层出土有类似上山的器物组合，属上山文化晚期阶段。中层和上层为小黄山文化。该

遗址已出土 900 多件石磨盘和磨棒，其形制与上山的同类器物相似。

这两处遗址所出土的夹炭陶中均发现有水稻的谷粒、茎杆及叶片。依据小穗轴的形状，一些水稻的小穗被鉴定为野生型和栽培型。然而，目前的证据尚不能明确这些水稻是否为驯化类型。

长江下游地区位于亚热带北部，气候受冬夏季风的影响强烈，四季分明。受新仙女木事件的影响，该地区在距今约 13000—11670 年间经历了一个相对干燥寒冷的时期。随后经历了全新世早期和中期的温暖潮湿阶段，中间穿插着一些稍微干冷的时期。但是，气候的变迁并没有改变这一地区亚热带的一般特征。植被以常绿阔叶林和落叶林为主，包括栎、青冈、栲、石栎、榛、铁木等。除此之外，此地也生长着一些湿地草本植物，主要有禾本科、莎草科和香蒲科等。

坚果类树木及其它各种经济植物在这一地区的繁盛与上山及小黄山聚落的出现以及随后新石器时代村落的发展在时间上是吻合的。这些环境方面的信息也反映在浙江省其它一些水浸新石器遗址出土的植物遗存中。比如，在跨湖桥（c. 8000—7000 cal. BP）、河姆渡（c. 7000—6000 cal. BP）和田螺山（c. 7500—6000 cal. BP）等遗址中，富含淀粉的重要经济作物遗存很常见，包括橡子（栎属 *Quercus* spp. 和青冈属 *Cyclobalanopsis* spp.）、栲属（*Castanopsis* spp.）、菱属（*Trapa* spp.）、芡实（*Euryale ferox*）、薏苡（*Coix lacryma-jobi*）等。其中尤以窖藏中发现的橡子和菱角为多。稻谷也大量出现，既有野生型也有栽培型。由于全新世早、中期具备相似的气候和植被，上述新石器时代遗址中发现的绝大部分植物很可能也被上山和小黄山的先民开发利用。

研究植物遗存是了解古代社会生计形态的重要途径。鉴于这两个遗址中有机遗存保存不佳，石器中残留的植物微化石可以提供有关其使用功能的信息。这两个遗址均出土有大量磨石，据此推断，用这些磨石所加工的对象应该具有重要的经济意义。因此，分析这些石器上的残留物就可能找到了解这一过渡时期生计策略的关键线索。

本研究的主要目的是调查上述两遗址出土磨石的功能以及与此有关的生计策略。实验样品包括 6 件磨石和一件石片，年代属于上山和河姆渡时期。这些石器均出自文化层，出土后已经清洗。我们对其中少量使用面显示残留物痕迹的石器进行了残留物的刮取，置于洁净塑料袋中。随后进行淀粉粒、植硅体和矿物分析。

在 7 件取样石器中，有 6 件发现了淀粉粒。有些颗粒表面显示碾磨所致的损伤特征。在上山样品中，SST5（7）:6（上山早期）上发现了一群淀粉粒聚集体，因为被一层膜所覆盖而看不清表面的特征，同一样品上还发现了一些单独的淀粉粒。被膜覆盖的颗粒具有明显的淀粉粒特征：随检偏镜旋转而旋转的消光十字以及清晰的轮纹。所有颗粒均呈现圆形或卵形。那些单独的淀粉粒呈现与现代栎属淀粉粒吻合的形貌特征，包括形状、脐点处的裂隙以及小面等。这一样品中所有淀粉粒的最长径分布以及每个独立淀粉粒的特征都与栎属接近，而且看上去它们来源于同一物种。样品 SST3（7）:3（上山早期）和 SST0511（4a）:7（河姆渡时期）的淀粉粒与栎属和薏苡的大小与形状吻合。

样品 SST5（5）:2（上山早期）上仅发现一个淀粉粒，其形貌与薯蓣属或其它根茎类的淀粉粒吻合。我们将其大小及形貌与现代标本库中的根茎类淀粉粒进行了对比。藕的淀粉粒尽管大小与之符合，形貌却不符合，予以排除。山药（*Dioscorea opposita Trunb.*）淀粉粒的大小也与之吻合，但是不同处为未知古代淀粉粒不见轮纹，同时，它们在整体特征上也有差异。将其与大洋洲的淀粉粒数据库比较发现其大小接近薯蓣属植物的 4 个种，而其形貌与 *Dioscorea nummularia* 最接近，但这一物种是中国没有报道过的。另一个可能的匹配是菱角（*Trapa* sp.）。总之，尽管它看起来更像是山药，但仍需测试更多的现代标本才能最终确定。在这批样品中没有发现别的根茎类淀粉粒。

来自小黄山样品（上山晚期）中的淀粉粒总体上比上山的大。它们的尺寸落在莲属（藕）、青冈属和石栎属的范围之内。通过小面、脐点处的裂隙以及形状等形态特征来判断，这些淀粉粒更接近石栎属，并与青冈属具有广泛的相似性。

鉴于所有的样品中均不见水稻淀粉粒，我们认为这些磨石可能不曾用于加工水稻。但是，对上山遗址中栎属、山药以及薏苡的鉴定和小黄山遗址中石栎和青冈的鉴定提示了器物的多种用途。

对石器表面残留物进行植硅体组合的分析，结合工艺和微痕分析，可以提供有关石器功能的重要信息。从 6 个残留物样品中进行了植硅体的提取，以检测植硅体的存在与否、保存状况及丰富程度。6 个检测样品中有 5 个发现了植硅体，其丰富度不一。这些植硅体中的大多数无法确定种属，但是有一小部分被鉴定为水稻（*Oryza* sp.）。在两件球形磨石样品中均发现有高比例的损伤及溶解植硅体，可能与使用或埋藏过程有关。

在所有发现的植硅体中，比例最高的是来自包括水稻在内的各种禾本科茎杆和叶片的植硅体。在两件磨棒上（T3（7）:3，T3（7）:10），发现了低丰度的水稻（*Oryza* sp.）颖壳细胞植硅体。尽管双子叶植物产生的植硅体远少于禾本科植物，前者却在所有样品中都有发现。

来自禾本科茎杆和叶片的植硅体大量出现，而来自水稻颖壳的植硅体却很少，这提示其中一些石器可能是用于加工夹炭陶所需的植物羼和料。根据我们的观察，上山遗址出土夹碳陶坯中的羼和料大部分为茎叶，仅有少量颖壳，这与石器表面植硅体分析的结果是一致的。残留物样品中水稻植硅体的出现也意味着当时水稻已经成为一种经济作物。但是，仅凭植硅体方面的数据，尚不能确定这些水稻是野生型还是栽培型。

为了探明残留物的来源，我们还对样品 SST0511（4a）:7 和 SST3（7）:10 进行了矿物成份测试。其原理是：如果植物残留物确实来自使用过程而非沉积污染，那么残留物的矿物成份应该与石器的成份一致，而非土壤成份。据我们所知，本文是该方法首次应用于出土器物的污染控制。

在两个样品中均发现了大量的角石英和钾长石的细小颗粒，还有一些大小相近或者稍大些的黑色碎片也包括石英和长石的斑晶。这些颗粒来自酸性火山岩（流纹岩和角砾凝灰岩）制成的石器本身，由石英和长石斑晶封闭在一个细小颗粒（通常几乎不透明）的晶格中。残留物样品还包括大量的排列整齐的次棱角形石英粉以及细粒粘土，均来自石器周围的土壤基质。石英粉代表着进入土壤的黄土成份。结果表明，矿物残留中的大部分都与碾磨工具的使用性质有关，但另一些可能来自与石器直接接触的土壤。

因此，本研究中所发现的淀粉粒和植硅体更可能与器物的使用有关而非来自器物表面的泥土。Field 发现淀粉粒在土壤中的密度远小于它在石器使用面上的密度。有学者指出，人工制品上发现的淀粉粒要么源于真实的接触（包括使用和偶然接触），要么来自器物埋藏后最初几个月内周围沉积物的迁移。在用磨石加工淀粉类食物时淀粉粒常遍布整个器物表面，同时过量的材料往往会掉落于附近的地面。如此，我们就不能排除器物附近的泥土在器物使用过程中沾染上淀粉粒的可能性。更重要的是，一些淀粉粒和植硅体呈现由碾磨和臼捣所致的损伤特征。考虑到该地区现在的主食是大米而非橡子，而所发现的淀粉粒中存在较多橡子而不见大米。这些都可以从侧面排除实验过程中的污染。

综上所述，上山和小黄山遗址处在资源丰富但季节性很强的地区。在夏秋两季食物非常充足，冬季则相对匮乏。淀粉粒分析的结果提示当时已经利用多种植物性食物，包括橡子、薏苡、某种根茎植物以及疑似菱角的植物。

上山和小黄山出土的大量磨石及其上发现的残留物说明在全新世早期橡子可能已经成为人类食谱中重要的主食。从上山出土的一个河姆渡时期的石器（SST0511（4a）:7）上发现了橡子的淀粉粒，提示对橡子的消费可能一直持续到全新世中期。这一发现与河姆渡及田螺山出土的大量橡子遗存是吻合的。

这一时期的水稻很可能还是野生的。虽然已经有多种用途（食用为主，附带作为陶器孱和料），但它应该尚未成为经济活动的主要方面。由于野生稻的产量远小于根茎和橡子等其它植物，当时应不适合作为主食。长江下游地区向新石器早期阶段的转变可能伴随着对野生稻的利用。尽管如此，优越的气候条件，更加固定的居住地点以及对稻的最初利用并没有自动地促成农业在这一地区的发展。

本探索性研究提供了长江下游地区在向新石器时代过渡时期与一般生计形态相关的磨石功能的有力论据。最终的结论有待于将来获得遗址详细报告及对更多样品进行验证。同时，这一研究也显示残留物分析在研究石器功能和生计形态方面的巨大潜力；将其应用于中国其它重要遗址中，有望发挥重要作用。（葛威　译）