

AN ARCHAEOBOTANICAL ANALYSIS OF LATE PALAEOLITHIC, PEILIGANG AND YANGSHAO SITES IN HENAN AND SHANXI PROVINCES, NORTH CHINA

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Dedicated to my family and to my mother

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Abstract

This thesis examines plant based subsistence across the ‘agricultural transition’ in North China. The study was based around the Middle Yellow River region and included the Yiluo Basin in Henan Province, other sites in Henan and the Late Palaeolithic site of Shizitan in Shanxi Province. The study time period covered from c. 20,000 cal BP until the end of the Yangshao period c. 5,000 cal BP, with a focus on the transition period between c. 13,800 cal BP – 5,000 cal BP.

Plant remains examined included charred macrobotanical remains from the Late Palaeolithic, Peiligang and Yangshao periods. Microfossil remains from Peiligang artefacts included both starch and phytolith residues from grinding implements and denticulate stone sickles. The first macrobotanical evidence for the use of millet tribe grasses in North China was presented, with these occurring at the Shizitan site during the Late Palaeolithic period. Millet tribe grasses were subsequently domesticated during the Peiligang period and occur in the study region in the form of small numbers of foxtail and broomcorn millet grains. Domesticated cereal seeds accounted for less than 30 percent of seed taxa in the Peiligang period and less than 12 percent of seed taxa in the Yangshao period. During the Late Palaeolithic and Peiligang periods evidence for experimentation with other grasses was present in the form of panicoid and pooid (cf. Triticeae) starch remains on grinding implements.

Residues recovered from Peiligang grinding implements suggest that acorns were an important aspect of subsistence. Macrobotanical evidence for acorns is recorded in the study region at sites such as Jiahu. Macrobotanical evidence for acorns was not present at Tieshenggou, where many of the analysed grinding implements were recovered. In addition to both *Lithocarpus* sp. and *Quercus* sp. acorns, Peiligang grinding implements preserved underground storage organ starch from the Cucurbitaceae or Dioscoreaceae families. Starch similar to that from the Phaseoloeae tribe of the bean family was also recovered. Denticulate stone sickles preserved evidence of both grass and eudicotyledonous residues from both the Shigu site and the Jiahu site. These residues do not rule out the possibility that these sickles were used to harvest grasses including millets (Shigu) and rice (Jiahu) but further evidence is needed to support this.

The agricultural transition occurred later than expected in the study region, with domesticated cereals only accounting for a small proportion of seed-based subsistence in both the Peiligang and Yangshao periods. This is consistent with ‘middle ground’ subsistence (Smith, B. D., 2001) located between the two extremes of agriculture and hunting-gathering communities on a food production continuum scale.

Declaration

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university, and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Sheahan V. M. Bestel
20 December 2011
San Francisco, California



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Chapter 1: Introduction to Research

Agriculture is thought to have begun in China sometime during the early Holocene. There are debates about when and where the initial occurrence of cereal domestication, an important aspect of agriculture, occurred. Vavilov (1926) proposed eight centres and several sub-centres of agricultural origins worldwide, including China as a region of independent agricultural origins. The regions thought to include agricultural centers have remained relatively constant over time although with frequent revisions of the number of these locations. For instance, Harlan (1971) revised Vavilov's centers to include three generalised origins or locations of agriculture, in the Near East, China and the Americas. Northern China is one of the main world regions where agriculture and complex societies are thought to have developed (Chang, K. C. , 1963; Ho, 1975; Smith, B. D., 1998).

Until quite recently it was traditionally assumed by authorities on the subject that there were only ever two centres of agricultural origins in China (Chang, K. C., 1986; Smith, B. D., 1998). These were thought to include both foxtail and broomcorn millet as a staple in North China and rice agriculture in South China. Recent technological advances have challenged these views. Macrobotanical (IACASS, et al., 2003: 286) and residue (Lu, T. L. D., 2003) research recovered evidence of tubers including taro at the Zengpiyan site in South China. This led Z. Zhao (2005b, 2011) to suggest a third centre of agricultural origins in far South China was based around tuber subsistence and pig domestication. My research investigates the development of plant domestication and agriculture in North China, using a range of macrobotanical and microfossil investigative techniques.

1.1 Background to Research Questions

Subsistence changes are frequently accompanied by social changes (Zeder & B. D. Smith, 2009: 685), although this is not always the case (see Kujit, 2000). Plant subsistence changes in North China before, during and after the Peiligang period were set against a backdrop of social changes including sedentary villages with pit houses and refuse or storage ash pits, animal domestication and pottery production. The plant subsistence changes that accompanied this social change are the focus of my research.

The Jomon in Japan made lacquer-painted pottery by approx. 9,000 cal BP (Minamikayabe, 2002, cited in Crawford 2011: S334). They comprised a complex sedentary society with a dense population of hunter-fisher-gatherers (Crawford, 2008; Matsui & Kanehara, 2006).

Matsui and Kanehara (2006) and also Pearson (2006) suggest that agriculture was lacking in this society. The presence of domesticated crops in numerous Jomon sites has led Crawford (2008: S331) to suggest that the subsistence definitions typically used to conceptualise the Jomon may have been too narrow. In Jomon and other complex societies including Papua New Guinea (Denham, 2007; Denham et al., 2003) the lack of strictly defined 'agriculture' does not preclude complex social development and sedentism. This thesis will investigate the role of grass seed and cereal usage and domestication in the subsistence regime of North China before, during and after the Peiligang period. The Peiligang period is traditionally conceived of as the first agricultural society in North China (Chang, K. C., 1986: 91-93).

1.2 Research Focus and Issues

The major area of research interest relates to broadening the view of plant exploitation during the Late Palaeolithic and early Neolithic Peiligang and Yangshao periods, including the early agricultural periods in North China. This thesis aims to apply new techniques such as starch and phytolith residue research to the study of plant food subsistence in the Chinese Neolithic.

Indigenous development of North Chinese agriculture should include evidence of pre-agricultural or pre-Peiligang use of Paniceae or millet tribe grasses such as foxtail and broomcorn millet. These cereals are thought to have been domesticated during the Peiligang period (Chang, K. C., 1986) and are common in archaeobotanical assemblages throughout much of the North Chinese Neolithic (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007). The precursor to extensive plant domestication has not yet been adequately identified in North China, although Li Liu and colleagues (2002-2004: 82) recognized four *Setaria* sp. seeds at the Peiligang Wuluo Xipo site that were intermediate between wild and domesticated foxtail millet. Plant remains from the Late Palaeolithic Shizitan site (13,800–8,500 cal BP) were examined to recover evidence for pre-agricultural subsistence practices. The macrobotanical remains from Shizitan complement published microfossil evidence from residues collected from Shizitan grinding slabs by Li Liu and colleagues (2011) including myself. Research aimed to provide evidence for the timeline of the transition to agriculture in North China, through attempted recovery of pre-domestication usage of millet cereals.

The Chinese Neolithic plant food spectrum has been poorly understood until recently (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007). Foods that were added to the initial dietary spectrum of broomcorn and foxtail millet subsistence in North China throughout the Neolithic and prior to the early state Erlitou period include rice (Lee, G.-A., et al., 2007; Yang, Z.-Q. & X.-H. Zhang, 2000), wheat (Bestel, 2006; Li, Xiaoqiang, et al., 2007; Zhao, Z., 2009), beefsteak plant (Lee, G.-A., et al., 2007) and soybean (Lee, G.-A., et al., 2007; Lee, G.-A. et al., 2011). The initial domesticate was thought to be foxtail millet (Chang, K. C., 1986: 71-103). However, recent research has suggested that broomcorn millet may have been an earlier and more common domesticate than foxtail millet at several sites in North China (e.g., Barton, L., et al., 2009; Crawford, et al., 2007; Zhao, Z., 2005a). Research investigated whether there was macrobotanical or microfossil evidence for greater use of broomcorn millet rather than foxtail millet in the archaeological record. An extensive plant reference collection was created and utilised to determine whether microfossils could reliably be used to identify the presence of early broomcorn or foxtail millet starch and phytoliths as some of the literature predicts (e.g., Yang, X.Y., et al., 2012). Stone sickles thought to have been used for harvesting these crops were tested for the presence of plant residues, to determine whether some crops were present in greater abundance than others during the Peiligang period. Residues from grinding implements were examined to determine which foods were being processed and ground during the initial agricultural Peiligang period. Evidence from microfossil residues from grinding implements and sickles was compared to macrobotanical plant evidence to determine whether the different sets of archaeobotanical assemblages complemented or contradicted each other.

In China it is typically thought that cereal based agriculture was crucial to the development of early complex society (e.g., Lu, T. L. D. , 2006: 129). This thesis attempts to test this assumption by closely examining the food production systems of early Neolithic North China. What is the role of grass seed and cereal usage in the North China study region? Is there evidence for domesticated cereals being the major subsistence staple during the Peiligang and Yangshao periods? Or were other plants such as acorns and yams, also commonly used? Is there evidence of management or cultivation for wild resources such as acorns or non-domesticated grasses, in the form of a nut or seed size increase, present archaeobotanically? A three-pronged approach to archaeobotanical research was used, with macrobotanical remains being examined as well as microfossil residues techniques such as

starch extraction (Torrence & Barton, 2006) and phytolith research (Piperno, 2006) carried out.

1.3 Dates Presented in Thesis

Dates presented in this thesis are given as reported in the relevant publications. Nearly all of these dates are based on radiocarbon (^{14}C). Where possible, dates are presented using calibrated years before present (years cal BP). Calibrated ^{14}C dates were not provided in older publications, and most published dates were given in uncalibrated format (years BP). Where possible, I have used the recently published calibrated dates for these older sites. In one instance (the Shizitan site), dating methodology was based on thermoluminescence (TL).

It is customary to give historic and dynastic period dates in China in years BC and for ease of recognition I have retained this custom throughout this thesis. For example, the Shang Dynasty is written as *c.* 1,600–1,046 BC, while dates for chronological periods or sites are presented in years cal BP.

1.4 Taxonomic Usage

Linnaean terminology as outlined in the online Flora of China (Z. Y. Wu, et al., 2012) will be used throughout this thesis. More details regarding taxonomic nomenclature are given in Chapter 6. An exception to the Flora of China nomenclature is made in my thesis for foxtail millet and its wild progenitor green foxtail grass (*Setaria italica* ssp. *italica* and *Setaria italica* ssp. *viridis* respectively). The Flora of China (Chen, S. L., D. Z. Li, et al., 2006) and some Chinese researchers (e.g., H. Lu, et al., 2009a; Yang, X. Y., et al., 2012) recognise foxtail millet and green foxtail grass as two separate species. However, the taxa hybridize frequently and naturally (de Wet, et al., 1979) to produce fertile offspring (Prasada Rao, et al., 1987: 109). Thus, international researchers typically refer to them as subspecies of *Setaria italica* and they will be recognised as such here.

1.5 Referencing Terminology and Editorial Style

The style guide used for this thesis follows closely the Society for American Archaeology (SAA) style. Australian spelling and grammatical conventions are used throughout, given the submission of this thesis to an Australian university.

Referencing and in-text citations follow the Harvard style and SAA guide where appropriate. The number of Chinese language sources written by people with similar surnames has necessitated the extensive use of first initials to distinguish between authors. Where two authors both have the same surname and the same first initial, their names are given in full in the in-text citations. For example, Li Liu and Liang Liu are differentiated by the use of their full name. This is in keeping with the referencing style in standard works on Chinese archaeology (e.g., Liu, Li, 2004). However, other primary authors with the surname Liu but a different initial are cited in-text by their surname followed by their initials. An example is the citation of Chengjiang Liu, who is referred to in in-text citations as (Liu, C. J., et al., 2008).

Standard or recognisable Chinese references such as IACASS (Institute of Archaeology, Chinese Academy of Social Sciences) are used throughout the text and in references.

1.6 Thesis Outline

My research investigates the origins of agriculture and social complexity in the Yiluo and nearby regions of North China. Artefacts that had been used as agricultural proxies since excavations in the 1970s and 1980s were tested for residues, and the multifunctionality of grinding implements and stone knives or sickles was established (2010b; 2010c; 2011). New archaeobotanical residue techniques have recently recovered evidence for the extensive use of non-cereal foods such as acorns and yams (Liu, Li, et al., 2010c) during the formative agricultural Peiligang period. This raises doubts about cereals being the food basis of initial social complexity in North China.

Chapter 2 defines the theoretical scope of the project and defines key terms. Theoretical models relating to the origins of agriculture are summarized, and models of the Neolithic and broad spectrum ‘revolution’ packages are examined. B. D. Smith’s (2001) middle ground between hunter-gatherers and agriculturalists is examined. Precise definitions of terms such as ‘agriculture’ are discussed in the literature (e.g., Bellwood, 2005; Denham, 2007). The evolving nature of plant domestication has also led to debates about the exact definition of the term (Fuller, et al., 2007; Liu, Li, G.-A. Lee, et al., 2007), especially with regard to the domestication of rice in South China. These and other key terms are discussed in Chapter 2.

The chronological and archaeological backgrounds for my research are outlined in Chapter 3. The time period under study dates from Late Palaeolithic times (*c.* 20,000 cal BP) through the Peiligang period (*c.* 9,000 – 7,000 cal BP) when agriculture is traditionally thought to have developed. Flotation and seed remains from the post-agricultural Yangshao period (*c.* 7,000–5,000 cal BP) were also briefly examined as an adjunct to understanding cereal agriculture development in the North China region.

My study region is described in Chapter 4. The study area covers parts of Henan and neighbouring Shanxi Provinces, located in the North China loess plains and plateau. This is within the middle reaches of the Yellow River. Social complexity in ancient China frequently developed along major rivers as these provided food and transport.

Chapter 5 outlines the samples collected during fieldwork and the method used to collect them. Bulk sediment flotation samples were collected and processed in China, while residue samples containing starch grains and phytoliths were processed in La Trobe, Monash and Stanford University laboratories.

Modern reference samples were collected in China, Australia, and the USA. The method of collection is outlined in Chapter 6 and details of plants contained in the collection are given in Chapter 7. This modern reference collection was used to identify ancient plant remains extracted from the flotation and residue samples. Details of the ancient plants identified are given in Chapters 8 to 10. Chapter 8 identifies seed remains from flotation samples collected from Late Palaeolithic, Peiligang and Yangshao periods. The implications of the small numbers of seeds recovered are addressed. Starch and other residues extracted from *mopan* and *mobang* (Chinese grinding implement bases and top stones respectively) are detailed in Chapter 9. Starch residues from these Peiligang artefacts were identified with reference to the starch reference materials detailed in Chapter 7 section 7.3. Residues from modern experimental sickles used to harvest reeds, acorns and grasses are presented in Chapter 10 and compared to ancient residues from Peiligang stone sickles. These were identified using the phytolith references outlined in Chapter 7 section 7.2. A summary of the project findings is given in the concluding Chapter 11 where implications of project data for understanding the origins of agriculture and social complexity in North China are examined.

Chapter 2: Theoretical Models and Definitions

Theoretical models relevant to this thesis include chronological models that attempt to explain human dietary choices and shifts in subsistence patterns. Bettinger's (1979, 1991) models of hunter-gatherer foraging behaviours include optimal foraging and central place theory. Other theories which attempt to explain major changes in human subsistence behaviour include the broad spectrum revolution (Flannery, 1969) and the Neolithic Revolution (Childe, 1936). The location of agricultural centres as either on river valleys or on Braidwood's (1960) 'hilly flanks' was recently examined by X. Liu and colleagues (2009), although some dates used to support Braidwood's model have now been reevaluated. Jones' (2004) models for the initial domestication and spread of domesticated millets across Eurasia may suggest early contacts between disparate nomadic societies. B. D. Smith's (2001) middle ground between agriculturalists and hunter-gatherers attempts to more accurately describe human subsistence before, during, and after agriculture. These models will be summarized briefly below. After presenting my research throughout this thesis, I will re-evaluate which models are relevant and applicable to the origins of agriculture in North China in Chapter 11.

2.1 Hunter-Gatherer Subsistence and Foraging Theory

The fields of behavioural ecology and evolutionary biology have contributed much to anthropological theory regarding human subsistence (Bettinger, 1979; 1991; Kennett and Winterhalder, 2006; Winterhalder & E. A. Smith, 1981; Winterhalder, 1981a, 2001). The reader is referred to these and other volumes for more discussion and examples of optimal foraging and other human behavioural ecology theories.

In short, optimal foraging theory requires foragers to maximise the net rate of energy gain (Bettinger, 1991: 84) as they acquire subsistence foods. The departure and return of foragers to a central place (Orians & Pearson, 1979) was exemplified through ethnographic models of acorn and mussel processing in California (Bettinger, et al., 1997). In this study, acorns were typically carried in baskets back to a central place for processing or storage in above ground granaries (Bettinger, et al., 1997: 895).

Bettinger (1991: 84-104) outlined optimal foraging theory in relation to diet breadth, food patch choice and foraging time. The diet breadth model requires foragers to maximise the net energy intake per unit of foraging time (Bettinger, 1991: 84). Meat is typically

considered a high ranked resource, giving a high caloric return for the time invested in obtaining it (Winterhalder, 1981b: 86-87). Many plant foods are included as typically low-ranked resources and seeds are included in this category (O'Connell & Hawkes, 1981: 99). Low ranked resources typically give a poor caloric return for the amount of time invested in preparing them for consumption.

One of several drawbacks to optimal foraging theory is that the forager must be 'economy-minded' (Bettinger, 1991: 84) in terms of minimising time taken to capture and process resources. In cases where time or resources appear plentiful, this may not always be the case. For instance, despite the 'extensive pounding, leaching and cooking' time taken to process acorns (Bettinger, 1991: 100), acorns are still staples among certain Californian groups (Ortiz, 1991). According to Hupa Indian woman Melodie George-Moore (Pers. Comm., November 17, 2010), once acorns are collected and stored they require only a short amount of time to de-shell, grind, and leach before cooking them on hot rocks for twenty minutes. It is possible that the description of acorns as a low-ranked resource (Bettinger, 1991: 100) is inaccurate. Low ranked resources are typically abundant, localized, and a predictable food source, but are often time-consuming to process (Winterhalder & E. A. Smith, 1981: 50-51). Given the application of optimal foraging theory to acorn processing in the literature (Bettinger, et al., 1997) this thesis will investigate whether optimal foraging theory may reasonably be applied to understand early Neolithic North Chinese subsistence including a change in diet from acorns processing to domesticated cereals.

2.2 Broad Spectrum Revolution

Flannery (1969b) proposed that humans, due to population pressure, began to exploit low-ranked foods such as small mammals, birds, fish and grasses. He suggested that this broadening of the food resource base led eventually to cereal domestication and the beginnings of agriculture. He termed this the 'broad spectrum revolution' (Flannery, 1969: 77). Initially, Flannery's theory was proposed to explain the origins of agriculture, which is typically thought to be a phenomenon related to the last 10,000 years (Bettinger, et al., 2010: 10). However, the model has recently been applied to Middle Palaeolithic sites such as Kebara Cave and Amud Cave in Israel.

Over 4,000 charred seed and fruit remains were recovered from the Middle Palaeolithic (c. 60,000–48,000 cal BP) site of Kebara Cave, Israel (Lev, et al., 2005). These comprised 48

different taxa including numerous legumes. Nuts such as acorns and pistachios were present, as well as seeds from plants with underground storage organs. Only ten grass seeds were present at the site but the early presence of grasses led Lev and colleagues (2005) to suggest that the broad spectrum revolution was underway.

Phytolith evidence for the broad spectrum revolution was provided by Madella and colleagues (2002) in their study of the Middle Palaeolithic (*c.* 55,000–70,000 BP) Amud Cave in Israel. The use of grasses at this site was suggested from the numerous phytolith remains of cereal panicles. Other phytolith remains included herbaceous and ligneous remains of plants and trees that were less diagnostic.

Weiss and colleagues (2004b) found support for the broad spectrum revolution in the 90,000 seeds recovered from the *c.* 23,000 year old Ohalo II site. Staples included Triticeae tribe grasses (including wheat, barley and wild wheats) as well as small grained grasses. The small grained grasses disappeared from the Levantine diet of the next 15,000 years (Weiss, Ehud, et al., 2004a). More recently Li Liu and colleagues (2011) identified the collection of a range of wild plants visible as starch residues on grinding implements at Shizitan in North China. In the subsequent Peiligang period only a small number of plants were domesticated which Li Liu and colleagues (2011) suggest parallels the transition from the broad spectrum revolution to agriculture in the Near East. In this thesis I will examine whether there is enough evidence from plant remains to determine whether the broad spectrum revolution may also be recognized in the North China study area.

2.3 The Neolithic Revolution

Childe (1936) described a number of social changes that he termed the ‘Neolithic Revolution’ based on Near Eastern models of the origins of farming. When applied to China this Neolithic ‘package’ was thought to include the domestication of dogs, pigs and chickens, as well as the domestication of rice in the south and millet in the north. However, the concept of a ‘package’ of social changes has been criticized. Thomas (1996) has critiqued models that link numerous changes and introductions occurring at precisely the same time and place. As Barker (2006: 24) describes it, the Neolithic neither took place during the Neolithic period, nor was it a revolution. He suggested that the concept described by Childe actually began in the Late Palaeolithic, long before changes that are typically considered ‘neolithic’ were visible in the archaeological record. In addition, his critique was that the process of ‘neolithization’ was probably not quick and short like a

‘revolution,’ but prolonged (Barker, 2006: 26) and protracted (e.g., Allaby et al., 2008). For example, it may have taken several thousands of years for plants such as rice to become domesticated (e.g., Liu, Li, G.-A., Lee, et al., 2007) although the exact timing of this process is debated (Fuller, et al., 2007). Modern researchers continue to study social changes in North China, where evidence such as the recent discovery of broomcorn millet several hundred years earlier than foxtail millet at multiple sites (Barton, L., et al., 2009; Crawford, et al., 2007), allows the deconstruction of the Neolithic ‘package.’

2.3.1 River Valleys and Foothills

A focus on the Yellow River basin region as being the centre of northern Chinese agricultural origins is partly because this is the first known region where complex societies developed into a four-tiered, state-level civilization (Liu, Li, & X. Chen, 2003; Liu, Li, et al., 2002-2004). Complex societies emerged in many other areas of China during the mid-late Holocene. A lack of research on these areas may also be partly to blame for the Yellow River Basin regional focus. However, a valley based model of agricultural origins has been prominent since the first English language publications on the subject (An, 1989; Chang, K. C., 1963).

More recently X. Liu and colleagues (2009) have suggested that the earliest millet farms in North China occurred in the foothills of mountain chains, rather than in the fertile valleys of the Yellow River system. This is consistent with Braidwood’s ‘hilly flanks’ hypothesis which suggested that it was not the fertile river valleys but the drier hillsides above them, that were the focus for early plant domestication (1960).

Research on North Chinese agriculture has focused mainly on foxtail millet as the first and major millet crop (Chang, K. C., 1986; Ho, 1975). However, recent research has suggested that broomcorn millet was the initial North Chinese domesticate (Barton, L., et al., 2009; Crawford, et al., 2007; Zhao, Z., 2005a).

2.3.2 The Spread of Millet Agriculture

In their recent review of millets across Eurasia, Hunt and colleagues (2008) collated and reviewed published records of the occurrence of broomcorn and foxtail millet prior to about 7,000 cal BP. They attempted to use non-English language sources where available, but note significant issues with identification criteria and reporting in the literature (Hunt, et al., 2008). Taxonomic issues, including those relating to the designation of a seed as

being either wild or domesticated, and issues arising from poor or dubious identifications, also presented difficulties in understanding the occurrence of early domesticated millet (Hunt, et al., 2008: S13).

The published records suggest that both broomcorn and foxtail millet occur in a number of 8th and 9th millennium BP sites in the Yellow River valley region of North China.

Broomcorn millet occurs at approximately the same time in sites in eastern Europe and the Caucasus region, although foxtail millet does not occur in this region until the 7th–6th millennium BP (Jones, 2004). Several hypotheses are provided by Jones (2004) to explain the distributions of millets, including: a single domestication event at either the Chinese (e.g., Bellwood, 2006) or the European end of Eurasia, and a subsequent spread across the intervening central Asian steppe; multiple domestication events at one or both ends of Eurasia; or a diffuse domestication event across Eurasia as a whole. More research is needed to understand the domestication origins of broomcorn millet.

Another plant that may provide clarity on early contacts between nomadic people is the bottle gourd (*Lagenaria siceraria*), although they were not recovered in the study region. Bottle gourds occur in China at an early time between c. 9,000–8,000 cal BP at sites including Hemudu in Zhejiang Province, South China (Crawford, 1992). They are considered to be of African origin (Erickson et al., 2005) so this issue and its possible relation to the spread of humans across Eurasia requires further research. It has been suggested that bottle gourds may have spread via ocean currents to the Americas directly from Africa (Carter, 1953; Whitaker & Carter, 1954). More recent hypotheses suggest they were carried from Asia to the Americas by humans (Erickson, et al., 2005). This would make it one of the world's oldest domesticated plant taxa.

2.4 The Middle Ground Between Hunter-Gatherers and Agriculturalists

Hunter-gatherers and agriculturalists were formerly dichotomized as having two separate types of subsistence (Crawford, 2008). B. D. Smith (2001) suggested that there was a 'middle ground' between these subsistence behaviours that is both long-term and stable. Ancient people who foraged for wild resources and produced foods or manage crops, including cereal or nut crops, may inhabit a conceptual middle ground between formerly dichotomized hunter-gatherers and agriculturalists. Crawford (2011) suggested that the Jomon of Japan exemplify such behaviours, given that the Jomon utilized domesticated

crops and wild resources for millennia. This thesis will investigate whether this ‘in-between’ description is relevant to the ‘origins of agriculture’ subsistence spectrum during the study time period in North China.

2.5 Theories of Early Agriculture

This thesis is not a discussion on the worldwide emergence of agriculture. Rather, it takes the form of a case study of the emergence of a number of changes that occurred in the Middle Yellow River region of North China. These changes are typically grouped under the heading of ‘agriculture.’ Such changes include the appearance of heavy material culture items such as large grinding implements and the introduction of pits for storage or other purposes. These changes suggest an increase in sedentism in formerly mobile communities. Plant and animal domestication was apparent at this time. New technologies included widespread pottery and standardised stone tools, including *mopan* and *mobang* grinders and denticulate stone sickles. These and other social changes are typically termed the ‘origins of agriculture’ in North China (Chang, K. C., 1986: 91-93). This thesis aims to investigate and document in a precise manner, exactly which plant food or subsistence changes took place and when these changes occurred. Thus, speculation about ‘why’ is not the point of this research and will not be discussed in detail.

Literature concerning the origins of agriculture may be separated into the where, when, and how of agricultural origins (e.g., Lu, T. L. D., 1999: 7). Theories about ‘why’ agriculture arose tend to be more speculative and researchers do not necessarily agree on the reasons (Bar-Yosef, 2002:39). Zeder and B. D. Smith (2009) suggested that single cause, universal model factors frequently invoked in the search for an understanding of agricultural origins were of limited explanatory value. They suggested that likely reasons for the adaptation of agricultural origins involved multicausal factors operating at both macro and micro scales (Zeder & B. D. Smith, 2009: 687). The response of people and regions to various factors provides an important component to understanding regional variations in subsistence patterns (Zeder & B. D. Smith, 2009: 687).

When attempting to explain why something occurred, whether in current or past time periods, one is continually utilising one’s own frame of reference (Denham & Haberle, 2008: 484-485). For this reason, and to avoid misrepresentations, it may be best to simply state *when*, *where* and *how* something has occurred in the past. Speculating as to why a situation arose or occurred is less precise (Denham & Haberle, 2008: 484-485). This thesis

will examine North China as a case study of agricultural origins and will present data relevant to the study region.

2.5.1 What is Agriculture?—Definitions of Relevant Terms

The study of agricultural origins is a multidisciplinary field. Botanists, archaeologists, anthropologists and geneticists all debate definitions of key concepts and ideas (Ladizinsky, 1998: 4; Zohary & Hopf, 2000:1-2). Zeder and B. D. Smith (2009) have described this ‘conversation’ as ‘talking past each other in a crowded room,’ while Harris (1989:11) wrote of being ‘bedeviled by confusion’ over the exact definitions of terms such as agriculture, horticulture, cultivation and domestication.

The identification of ‘agriculture’ in relation to archaeology frequently refers to a complex or package of social changes. These include animal and plant domestication and the onset of sedentism. These changes were previously referred to as the ‘Neolithic Revolution’ after Childe’s (1936) Eurasian-based concept. When applied to non-European areas such as China or Papua New Guinea, this package is not always evident in the way that Childe predicted. This has led some researchers (e.g., Terrell, et al., 2003) to call for the abandonment of the term ‘agriculture’ entirely. Deconstructing this ‘package’ is the work of current researchers focusing on the origins of agriculture and related debates (cf Vrydaghs & Denham, 2007: 7).

Debates on the exact definitions of agriculture and related concepts include discussions over terms such as cultivation, domestication, plant management, sedentism and social complexity. Current debates regarding the use and definition of cultivation, domestication, social complexity and agriculture, but with a focus on plants rather than animals, will be examined below.

2.5.1.1 CULTIVATION

In a general sense the term ‘cultivation’ is used as Helbaek (1970: 194) described, to further the growth or ‘output’ of plants. When a crop is cultivated it may be watered, weeded, hoed and nurtured with the desired endpoint of obtaining a good seed harvest. To Bronson (1977: 28), cultivation was defined as ‘deliberately growing’ or a purposeful manipulation of nature’s resources, with the concept of intention clearly recognised.

Cultivation is ‘associated with agriculture’ to Ladinsky (1998: 6), although this definition does not allow for cultivation of plants in a hunter-gatherer context if agriculture has not been identified. Under this botanical definition it becomes difficult to discuss cultivation in societies that fall into B. D. Smith’s (2001) ‘middle ground’ between hunter-gatherers and agriculturalists. An example are the Jomon of Japan who grew domesticated cereal crops yet subsisted mainly on wild or gathered nuts and taxa (Crawford, 2008, 2011). The Jomon are typically not considered agriculturalists (Matsui & Kanehara, 2006; Pearson, 2006), (although see Crawford, 2008 who suggests they defy classification as either hunter-gatherers or agriculturalists). Therefore under Ladinsky’s definition they may not be considered to have ‘cultivated’ their crops as they lack the necessary association with agriculture. However, Jomon cultivation of rice and millets, as well as management of tree crops such as chestnuts, is typically not disputed by many or most researchers (Crawford, 2008: 262; 2011; Matsui & Kanehara, 2006).

Cultivation of a plant population may not lead to any detectable changes across that population, in contrast to the definition of domestication (see below). Some definitions of cultivation incorporate an aspect of human intention or management of a plant or plant population (e.g., Bellwood, 2005: 13; Price & Bar-Yosef, 2011: S165). Such human actions are typically geared towards subsequent human use of the plant for food, fodder, or other activities such as the management of tree crops to provide nuts or wood for shelter or fuel. In this definition of cultivation there is a purposeful or considered intent to manage or use resources, meaning that past human intentions are inferred. An example of cultivated resources comes from the Late Archaic and Early Woodland economies of eastern North America. Indigenous crops that were intensively cultivated but never underwent visible morphological changes include maygrass (*Phalaris caroliniana*) and little barley (*Hordium pusillum*) (Smith, B. D. & Cowan, 2003: 111). These taxa were never domesticated but there is substantial evidence for their use and cultivation as crops in archaeological sites in eastern North America (Smith, B. D. & Cowan, 2003). The definition of cultivation decided upon by participants at the recent symposium entitled ‘The Origins of Agriculture’ also emphasized the potential for cultivated plants to be either wild or domesticated (Price & Bar-Yosef, 2011: S165).

The concept of crop cultivation may incorporate pre and post ‘domestication’ changes in society and food production regimes. Pre-domestication cultivation refers to the initial exploitation of a plant population prior to the population becoming phenotypically distinct

or domesticated. Crop cultivation as defined by Harris (2007), Jones and Brown (2007: 47) and B. D. Smith (2001) may or may not lead to eventual crop domestication or agriculture. It may also be a stable and sustainable method of subsistence that is ‘more than ... transitional’ (Jones & Brown, 2007).

The concept of pre-domestication usage of cereals is slightly different to Hillman and Davies’ (1990) concept of pre-domestication cultivation. It refers to evidence for use of certain plants, but a lack of evidence for deliberately planting or cultivating plants. Logically, usage of a certain plant probably preceeded cultivation of the same plants, although this is not definitely the case. It is theoretically possible that both usage and cultivation of plants occurred together, although an initial step of usage being separate to a second stage of plant cultivation may in some societies seem more likely. The concept of pre-domestication usage of plants is invoked in this thesis due to evidence for the use of, but a lack of evidence for cultivation of, millet tribe grasses in the Late Palaeolithic period.

In the Near East, pre-domestication cultivation lasted for 1–2 millennia (Tanno & Wilcox, 2006; Weiss, et al., 2006). It has been suggested that the process of rice domestication in South China took millennia to occur (Fuller, et al., 2007) although this is still debated (e.g., Liu, Li, G.-A. Lee, et al., 2007). Therefore issues concerning seeds grown under conditions of ‘non-domestication cultivation’ (see Hillman & Davies, 1990, 1992) may also occur in China. This is especially likely when archaeobotany is used to investigate the period before, during and after the origins of agriculture. In some cases cultivation of plants does lead to domestication and eventually agriculture. However, finding evidence for the process of plant or seed modification in the archaeobotanical record can be challenging (Brown, 1999).

Weeds in a crop field fall into a grey area between wild and cultivated resources. They may be harvested and eaten along with a crop or they may be winnowed and separated out from the domesticated crop prior to or during harvest. In either case they were still managed or modified by human users, quite possibly without the element of human intent. Under most definitions of cultivation such unintentional modification or management of resources would fall under the category of wild plants. However, if the seeds occur in great numbers in archaeological sites, or if they occur over a prolonged period of time, the argument can be made that such taxa were deliberately cultivated.

Some plants are more likely than others to exhibit visible seed changes under domestication. Self-pollinating cereals and/or legumes may be more likely to show changes under extensive cultivation than plants such as yams or tubers (Zohary & Hopf, 2000). Genetic changes, including those linked to increased seed and/or starch grain size, typically occur via genetic means through sexual reproduction. Plants such as yams, which are typically re-planted or propagated by vegetative means including cuttings or replanting tubers, are an exact clone of the parent plant. This means that they are unlikely to exhibit generational changes, although there may be a small possibility of genetic or somatic mutations occurring during growth. Evidence of plant domestication is traditionally given more importance or focus in the archaeological record than plant cultivation. However, pre-domestication cultivation or cultivation without visible morphological changes may also be culturally significant. However, this is typically more difficult to identify in archaeology sites. Plants including yams and tree crops are less likely to be identified as domesticates, despite having potentially been cultivated and used for millennia. This is partly because tree crops do not easily exhibit seed size increases, and thus are less likely to be identified as 'cultivated' or managed, despite the exact domesticated status of the plant being unknown. However, tree crops from the Jomon period in Japan include chestnuts that have been identified as managed, through DNA analyses showing evidence of reduced variation in the genetic population (Sato, et al., 2003). Yams also appear to have been used and may have been grown or cultivated since Late Palaeolithic times in North China (Liu, Li, et al., 2011). However, the domestication status of yams in North China is unclear and requires further research.

In this thesis, cultivation is defined as the human management of plants. This includes growing resources such as millet crops and/or management of tree crops such as oaks, walnuts or chestnuts (see also Bellwood, 2005: 13). Evidence for collection of seeds or nuts, such as the evidence of nut storage pits at Jiahu site (Zhao, Z. & Zhang, J. 2009) is evidence of use only and not of management, although management of tree crop resources may also have occurred. Cultivation may thus be practiced on plants that are either domesticated or wild (Bellwood, 2005: 13; Lu, T. L. D., 1999: 9). However, cultivation of plants may be independent of domestication. Cultivation is an important and sustainable subsistence activity in its own right and does not necessarily lead to domestication or agriculture. For the purposes of this research, with its focus on the emergence of millet agriculture in North China, cultivated plants will be recognised as equally important to domesticated taxa. However, without residue studies to suggest the presence of certain

types of plant remains on artefacts, the existence of cultivated plants may be difficult to prove.

2.5.1.2 DOMESTICATION

There have been numerous attempts at definitions of domestication, in spite of the difficulties inherent in defining ‘domestication’ in the archaeological record (see Vrydaghs & Denham, 2007: 2-5). Harlan’s (1992) broad ecological definition of domestication refers to domesticates as those plants having been brought into the *domus* or other managed contexts such as a back yard or a golf course. However, this may not allow identification of more intensively used plant remains from archaeological sites, where samples sizes are small or quantification is problematic. Other definitions of domestication refer to plant use by humans, including a ‘symbiosis’ between humans and domesticated plants (Reed, 1984). At the recent ‘Origins of Agriculture’ symposium plant domesticates were defined as having ‘morphological or genetic changes’ (Price & Bar-Yosef, 2011: 165), although this definition does not state explicitly that these changes were due to human intervention.

Denham (2007: 99) notes that the traditional method of defining domestication based on phenotypic changes is too inflexible to include a diverse range of plant management practices. He refers in part to gardening type practices that occur in Papua New Guinea, where the traditional cereal-based agriculture and associated distinctive phenotypic changes are absent. It is possible that in Late Palaeolithic and early Neolithic China staple foods may also have included non-seed usage. Yams and especially acorns are now thought to have been important in North China prior to intensive millet agriculture (Liu, Li, et al., 2010b; 2010c; 2011), although this is a relatively recent discovery.

Since ‘domestication is an evolutionary process’ (Ladizinsky, 1998: 7) it is not surprising that there may be difficulties with identifying domesticates in the archaeological record, especially those in the early stages of domestication (see also Fuller, et al., 2007).

Definitions of domestication that may usefully be applied to archaeological plant remains generally refer to a method of distinguishing the altered or domesticated plant from the wild ancestor (Zohary & Hopf, 2000: 16-19; 241). Defining exactly at what point along this continuum a plant may be called ‘domesticated’ poses many problems for archaeologists (e.g., see debate between L. Jiang and Li Liu (2006) and the response by Fuller and colleagues (2007)).

2.5.1.2.1 Identifying Domestication—Phenotype

Definitions of plant domestication frequently refer to phenotypic or morphological changes in plants. There are a range of ‘domestication syndrome’ traits that occur after a plant is domesticated (Smartt & Hymowitz, 1985: 45; Zohary & Hopf, 2000: 18-19; 93-94). These may include an increase in seed size as well as a range of other traits that form part of the domestication syndrome (Zohary & Hopf, 2000: 93-94). An example of phenotypic changes include the increased seed width and breadth of domesticated foxtail millet (*Setaria italica* ssp. *italica*) when compared with its wild progenitor green foxtail grass (*Setaria italica* ssp. *viridis*) (cf. Lee, G.-A., et al., 2007: S1). However, a definition of domestication based on increased seed size is controversial (Fuller, et al., 2007; Lee, G.-A., et al., 2007). Factors such as growing conditions or maturity of the seed, as well as seed changes during charring or carbonisation, may influence the size of the seed in the archaeological record. Other changes that accompany plant domestication may include indehiscent or non-splitting bean pods or a non-shattering cereal rachis (Zohary & Hopf, 2000: 16-19; 93-94). These and other domestication traits such as increased seed production, awn reduction and synchronous tillering (Zohary & Hopf, 2000: 19) are less easy to identify in the archaeological record.

In the *Handbook for the Convention on Biological Diversity* (2005: 5) a domesticated plant is defined as a "species in which the evolutionary process has been influenced by humans to meet their needs." The traits that form under domestication are thought to have been caused at least in part by human selective pressure although this pressure may not have been intentional (Zohary, 1989). When used in an archaeological sense, domestication of a plant usually implies the effect of human usage or impact on a plant. This selective pressure may have led to domestication in a few short generations (Hillman & Davies, 1990) or over a longer, millennia-like timescale (e.g., Allaby, et al., 2008; Fuller, et al., 2007).

Due in part to the alleged poor preservation and/or recovery of rachis and pod fragments in the archaeological record, investigations into other means of identifying domestication are underway. These include research into phenotypic changes in microbotanical plant morphology. This research has been utilised to differentiate domesticated and wild plants in the Americas including maize (Piperno, et al., 2009). In China domesticated broomcorn millet has been identified (Lu, H. et al., 2009a) although not without controversy (Zhao, Z., 2011: S301).

Piperno and colleagues (2009: 5019-5021) suggest that the increased size and less regular morphology of starch granules from the Xihuatoxtla site in the Central Balsas River Valley in Mexico, is evidence of maize domestication in this region by 8,700 BP. They suggest that size and morphological changes in the scalloped surface features of domesticated squash phytoliths (*Cucurbita* sp.) are present in the archaeological record in the 9th millennium BP suggesting early cucurbit domestication (Piperno, et al., 2009: 5022-5023).

Other issues mentioned in the literature in relation to identifying plant domestication in its early stages include environmental change rather than human selection factors being a possible cause for altered phenotype in taxa (Hillman & Davies, 1990). This is especially relevant in areas where climate change is involved or invoked as a driving force in understanding agricultural origins. Relict populations, also quite possible in areas where climate change is thought to have occurred, may allow the alteration of phenotypes in plant populations by a process of genetic drift. The question of phenotypic plasticity, or a range of variation in plant morphology has also been raised as a possible confounding factor in the identification of plant or animal domestication (Gremillion & Piperno, 2009). Further research may be required before such phenotypic changes can be easily detected in the archaeological record.

Phenotypic plasticity is a potentially confounding factor when attempting to understand the impact that ancient humans may have had on the phenotype or morphology of ancient plant fragments. This has the potential to play an important initial role in evolutionary change (Gremillion & Piperno, 2009: 617). Phenotypic plasticity may make it difficult to identify human induced domestication changes or agriculture based on morphometric changes alone. However, it may be possible to study the phenotypic responses of plants to determine the probable cause for an altered morphotype (Allaby, et al., 2008). The linked issues of gene expression may also confound or obfuscate the suggested evidence of domestication based on plant or seed morphology.

Other methods of identifying domestication in the archaeological record may be based on genotypic changes relating to the reduced ability of a plant to reproduce in the wild (Zohary & Hopf, 2000: 16-19). Such genetic changes may be detected through ancient DNA analysis. The role of aDNA in determining domestication has yet to be fully explored, but is likely to produce useful data with regards to this research question if ancient plant DNA can be successfully extracted.

Allaby and colleagues (2008) have noted that until recently domestication was conceived of as being a rather rapid process. This was partly based on experimental harvesting leading to domestication in wheat (Hillman & Davies, 1990), where results suggested that seed changes similar to those exhibited under domestication could take place in approximately 100 years. Instead of this rapid transition model of plant domestication and subsequent agricultural adoption, new research suggests that pre-domestication cultivation may have been a prolonged occurrence lasting millennia (e.g., Tanno and Wilcox, 2006; Zhao, Z., 2011). Computer simulations suggest that a prolonged model of plant domestication is likely (Allaby, et al., 2008). Data presented in this thesis on the occurrence of *Setaria* type seeds at the Late Palaeolithic Shizitan site may also attest to a more prolonged period of panicoid grass use prior to domestication in North China (see Chapter 8 and discussion in Chapter 11).

2.5.1.2.2 Identifying Domestication—Genetics and Genotype

With an increase in the available techniques known to archaeologists and archaeobotanists, as well as phenotypic changes, definitions of domestication can now rely on genetic evidence to determine whether a plant is wild or has been irrevocably altered by alleged human intervention in its life cycle. Genetic or genotypic changes may or may not be visible morphologically, unlike phenotypic changes which by definition are outwardly visible. Genotypic changes occurring with domestication frequently cause controversy over their identification. Methods of identifying genotypic changes are outlined below.

Definitions of domestication frequently invoke human ‘manipulation’ or use of a plant, to the extent that genetic changes occur which result in new species or varieties of that plant (Bender, 1975: 1). Alterations to the plant genome may stem from long term usage of the taxon (Bronson 1977: 25), although this is not always the case (see Hillman & Davies, 1990). Such selection may be from either conscious or unconscious genetic selective pressure (MacNeish, 1991: 10). Selective pressure refers to the ‘survival of the fittest’ syndrome suggested initially by Darwin (1859) where environmentally favored taxa are more likely to survive and reproduce.

One of these ‘genetic changes’ or ‘genetic effects’ referred to is the inability of certain domesticated plants to reproduce or disperse without human aid (Hillman & Davies, 1990; Redman, 1978: 93) although this is not true of all domesticates. Harlan (1992) suggests that such genetic changes are typically visible in cereals and/or legumes. Zohary and Hopf

(2000: 16-19; 93-94) argue that domesticates tend to occur in human made or anthropogenic habitats. However, this may be a chicken and egg scenario, with humans making the most use of those anthropogenic plants that commonly occur as weeds near their chosen habitation places (Crawford, 2005). Reproductive isolation of cultivated or cropped plants from wild plants may also enhance the process of domestication (Jones & Brown, 2007). Paddy field rice isolated or separated from neighbouring rice stands by irrigation channels or ditches could have enhanced this process in antiquity: Fuller and Qin (2009: 95-97) suggest that this may have aided the domestication process of rice growing at sites with early paddy fields such as Xiaoxieshan and Chuodun in southern China. To produce genotypic changes in a plant, reproductive isolation may be more important than preferential human selection for desirable traits (Jones & Brown, 2007). Reproductive isolation of crops is typically difficult to prove in archaeological sites but future research may find evidence of this through genetically visible molecular markers (Jones & Brown, 2007). These may be linked to specific populations of taxa and indicate genetic inbreeding or other population based changes.

Substitution of a single transcription may allow the transfer of rice from a free-shattering to a non-shattering stalk reliant on human intervention to reproduce (Konishi, et al., 2006; Li, C., et al., 2006). Purugganan and Fuller (2009: 846) note that molecular genetic studies have identified nine 'domestication genes' in plants. An additional 26 other genetic loci, which are involved in crop seed diversity that may be linked to human cultural preference or different agricultural environments, have been identified by researchers (Purugganan and Fuller, 2009: 846).

Such reproductive or dispersal changes in plants are often used as an indication of 'domestication.' These include changes in the rachis shattering ability of some grasses such as rice, meaning that the plant is more reliant on human intervention in its lifecycle to reproduce (Fuller, et al., 2007; Zohary & Hopf, 2000: 318-320). However, certain wild type grasses may exhibit small proportions of non-shattering rachis in a wild population. Other changes linked to domestication include reduced pod dehiscence in some legumes such as lentils and peas (Zohary & Hopf, 2000: 93-94). Such evidence for reduced seed independence tends to be rare in the early Chinese archaeological record, although Fuller and colleagues (2009) have recovered non-shattering rice rachis from Tianluoshan in South China.

Phenotypic changes described above stem from genetic factors and so are inherited through to the next generation of plants or animals being cultivated or utilised. Recent debates have focused on describing in more detail the mechanisms responsible for such genetic changes in plants (Gremillion & Piperno, 2009; Jones & Brown, 2007; Zohary & Hopf, 2000). It is possible that the exact role that humans play in such morphological plant changes has been overestimated. For example, Jones and Brown (2007) suggest that reproductive isolation or movement with human migration of a species is likely to cause morphological change in the seeds of the grain being tilled. Such a scenario is more likely to cause domestication changes than selective picking of larger grains by humans tending the crop (Jones & Brown, 2007).

Molecular evidence is increasingly being utilised in an attempt to understand changes in food production systems during the early Holocene (Allaby, et al., 2008). However, molecular data is frequently controversial and is usually more accepted when supported by palaeoenvironmental or archaeological evidence (Harris, 2007: 16-17).

In an effort to investigate the mechanisms of domestication in detail, Jones and Brown (2007) examine the genetic basis of morphological changes generally attributed to the domestication process. They described such genetic changes as either discrete polymorphisms or continuous variables (Jones & Brown, 2007: 38-39). A discrete polymorphism is a morphological trait usually controlled by one or a small number of gene loci. An example of a discrete polymorphism is the rapid dehiscence of lentil and pea pods (Zohary & Hopf, 2000: 93). The gene responsible is controlled by a single locus and this trait disappears under domestication (Jones & Brown, 2007: 38). In general however, discrete polymorphic traits are rare in archaeologically important species (Jones & Brown, 2007: 39).

Visible morphological traits may also be caused by continuous variables such as the linkage of a trait to multiple genetic loci. The size changes visible in the seed or grain of some domesticated species are caused by continuous variables. It is difficult to define causative factors for these types of morphological changes, meaning that actual causation factors for certain domestication spectrum traits may remain obscured (Jones & Brown, 2007: 38-39). In addition to this, a complex interplay of a range of factors may affect plant taxa, with nutritional and environmental factors also playing a part in morphological plant change.

Despite the possibility of confounding environmental variables on the identification of domesticates, this thesis defines domestication as the phenotypic or genotypic alteration of a plant or plant population. This may be phenotypically or genotypically visible. For instance, the enlarged seed size of domesticated millet and rice crops and a non-shattering rice rachis are both examples of domestication that may be visible in the archaeological record. An example of genotypic changes not outwardly visible includes the reduced genetic variability of Japanese chestnut populations (Sato, et al., 2003). This is evidence of an ancient domestication process, although it requires a comparison with modern chestnut populations for it to be evident. Domestication may be independent of cultivation, as in domesticated but weedy or wild growing forms of foxtail millet (*Setaria italica* ssp *italica*) that have become naturalized on the streets of Beijing. That is, a plant from a domesticated population may naturalise or grow wild without human tending or intervention.

2.5.1.3 SOCIAL COMPLEXITY

A range of factors are considered relevant to the identification of social complexity in the archaeological record. These include issues of settlement size (small versus large) (Price, 2003: 59) and settlement hierarchy (Liu, Li, 1996b; Liu, Li, et al., 2002-2004). Residential mobility, which is typically high in hunter-gatherer communities but lower or non-existent in agricultural societies, may be used to measure social complexity (Price, 2003: 59). Archaeologically this may be determined by site size and evidence of large items such as pottery or stone grinding implements that mobile foragers would find difficult to take with them. Evidence for social and political organization is considered an important measure of complexity (Kelly, 1995: 294), as more complex societies typically exhibit a more complex and stratified social hierarchy than egalitarian societies such as the Peiligang (Liu, Li, et al., 2002-2004; Underhill, 1994). Population density and food storage are considered factors relevant to the description and identification of a range of complex behaviours (Price & Bar-Yosef, 2011: 59). They are typically thought to increase in more complex societies (Liu, Li, 1996a, 1996b, 2004). Archaeobotanical evidence of increased population density may include increased seed numbers (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007), which occur in the Yangshao and subsequent cultural periods. Pits thought to have been used for storage and/or rubbish disposal first appear in the study region in the Peiligang period. They are typically thought to have been used for storage of millet grains (Lu, H., et al., 2009a: 7367) although this is not necessarily always the case (see discussion in Chapter 8). Definitions of social complexity evident in the archaeological record may be used in discussions of hunter-gatherer groups in relation to origins of agriculture type

debates. This is because a high level of social complexity is usually associated with agricultural societies (e.g., Lu, T. L. D., 1999: 5).

Social complexity may be viewed as a continuum along which various levels of social population grouping are defined. These may include nomadic or hunter-gatherer societies with few material possessions, which is usual in a nomadic lifestyle. Agricultural societies with some degree of sedentism are typically defined as being at the other end of this continuum. Social complexity as it is typically defined in the literature is by necessity based on materialistic or artefactual changes in society. These may include evidence of a less egalitarian society, such as socially stratified grave goods (e.g., Underhill, 1994).

Prime movers postulated as responsible for transitions toward a greater degree of social complexity include population growth (Cohen, M. N., 1977), which may have contributed to environmental or resource constraints (cf. Shelach, 2002: 11). Climate and environmental changes may also contribute to social changes (Liu, Li, 2004: 19). Political or economic controls including religious systems have been invoked as factors in the later development of chiefdoms and states (see Shelach, 2002: 11).

2.5.1.4 AGRICULTURE

Given the range of multidisciplinary specialists frequently involved in a project, it is not surprising that there are numerous definitions for ‘agriculture.’ The topic has been researched for well over a century (Harris, 1996: 1; Zohary & Hopf, 2000: 1) and consequently there is a large body of literature on the topic, not all of which will be reviewed here. I will examine the most relevant current debates regarding the origins of agriculture which pertain to North China. The review focus will be on the archaeological identification of agriculture based on material remains, rather than on ethnographically based or abstract definitions of the term.

Evidence from the archaeological record used in the ‘origins of agriculture’ debate in North China includes research on size and morphological characteristics of macro and microfossils such as plant seeds, starch and phytoliths. Less direct lines of evidence including modern day botany, genetics and phylogeography may also be utilised. Definitions of agriculture that relate to ‘Neolithic Revolution’ style packages frequently refer to large scale changes in social organisation, generally thought to have been based around changes to food procurement or production strategies (Chang, K. C., 1986; Ho,

1975). Formerly, societies were conceptualised as either agricultural or hunter-gatherer (e.g., Chang, K. C., 1986; Ho, 1975) although this dichotomous concept has fallen out of favour in recent times (e.g., Crawford, 2008; Denham, 2007). Researchers now seek to classify and identify the range of in-between subsistence practices that B. D. Smith (2001) has called the 'middle-ground.'

Abstract definitions of agriculture (e.g., Redman, 1978: 93) refer to the series of 'new relationships' that form between 'people, land, plants and animals' under agricultural conditions. These alternate definitions of agriculture note the interaction with, or manipulation of, the environment by people in an evolutionary manner (Rindos, 1984: 100). In many cases, agriculture is distinguished from horticulture, and this again may be differentiated from arboriculture (see Bellwood, 2005: 13). For example, MacNeish (1991: 11) describes the planting of seeds in large fields or areas as agricultural, but a smaller, more individual scale of plant management and planting is labelled horticulture or gardening (see also Bogaard, 2005: 179). However, this distinction is not always upheld and Bellwood (2005: 13) uses a general definition of agriculture which may incorporate horticulture, arboriculture and the raising of cereal and other plant resources.

Social changes that may accompany agriculture are also considered important in defining the term, to the extent that Ladinsky (1998: 6-9) suggested that initially agriculture was most likely a cultural or social, rather than a genetic, event. Recent researchers (Denham, 2007: 99; Hather, 1996; Ingold, 1996) also define agriculture as a social concept that can be inferred based around involvement with and dependence on plants and plant management. Locations such as Papua New Guinea, with its lack of clearly evidenced seed domesticates are thereby included in this definition. However, the social changes accompanying initial agriculture may be difficult to see or identify in archaeology sites that may be thousands of years old.

Non-archaeologists such as Ladinsky (1998: 6-9) note that agriculture may include the raising of both wild and domesticated plants. Bellwood (2005: 13) concurs with this general definition. However, in relation to the archaeological record, agriculture has frequently been defined by the presence of plant or animal domesticates rather than by the existence of, or evidence for, intensive or long term cultivation of plant or animal resources (e.g., Fuller, et al., 2007). Bronson (1977: 25) suggested that agriculture was a 'substantial' dependence on plants grown or produced by humans. Rindos (1984: 236) concurs that,

with regard to agriculture, the ‘commonsense’ definition requires that a ‘substantial’ part of subsistence should be from domesticated plants (e.g., Harris, 1996: 4). Later researchers put a numerical figure on this definition of agriculture. For example, Zvelebil (1996: 325) defined agriculture as a reliance on 50 percent or more of the diet coming from domesticates. Despite the difficulties in identifying the presence of domesticated plants or animals, B. D. Smith (2001: 14) has suggested that domestication is still a useful marker to divide foraging from farming. However, B. D. Smith (2001) recognizes a long and sometimes stable ‘middle ground’ in-between these two extremes of a subsistence continuum.

Domestication of plants or animals has in numerous cases been used as evidence for the presence of agriculture (Chang, K. C., 1986: 91-93; Handan Wenwu, 1977; Hebeisheng, 1981; IACASS, 1984; Kaifeng Diqu, 1979). Other aspects that attempt to delineate between hunter-gatherers and farmers from the remains visible in the archaeological record have included sedentism (see Jiang, L. & Li, Liu, 2006). A correlation between pottery and agriculture has also been suggested (e.g., Lu, T. L. D., 1999: 11), with some researchers suggesting that the presence of pottery at a site is indicative of cooking millets or rice and therefore of agriculture (Feng, M. Q., 1992; Xu, W. S., 1994). However, this is now not widely accepted as pottery has been found in Japan and China that predates domesticated crops by several thousand years (Yan, 2002: 152; Yasuda, 2002b).

Recent discussions regarding the precise definitions of agriculture and other terms have been stimulated by researchers working in different environmental regions of the world. This is especially the case where macrobotanical remains are poorly preserved (see Denham, 2007). In tropical areas such as Papua New Guinea, plant remains such as yams and tubers may be more accurately identified by recently developed techniques such as starch and phytolith research (e.g., Denham & Haberle, 2008; Denham, et al., 2003; Fullagar et al., 2006).

Problems with the definition or recognition of agriculture in the archaeological record include the fact that the area of the earliest cultivation or intensive use of the plant is likely to only yield a poor signal for domestication of that plant (Vrydaghs & Denham, 2007: 3). In some situations the identification of cultivation has relied on proxy indicators of agriculture such as the presence of large numbers of supposedly agricultural tools such as

hoes or spades, or on artefacts such as grinding implements thought to have been used for domesticated cereal processing (cf. Chang, K. C., 1986: 87-95).

Another problem with identifying the initial or first occurrence of genotypic domesticates relates to a founder effect. It is likely that early domesticates should first be evident only when transported outside of their natural geographic range (cf. Jones & Brown, 2007). If a plant is cultivated for millennia but still allowed to interbreed with local wild populations then genetic mixing with wild populations may not allow the plant population to maintain phenotypic changes caused by selective pressures. Thus evidence for cultivation may be indirect and include artefactual or cultural evidence for use of the plant. This may take the form of residues. Perhaps even the consistent presence of a plant in archaeology sites could be indicative of its constant use.

If a plant is taken out of its natural habitat to be managed elsewhere, then the likely founder effect of a small population being translocated and the possible subsequent genetic drift in the new population, may produce effects similar to those caused by plant domestication (Vrydaghs & Denham, 2007: 3-4). Vegetative plant remains commonly propagated by cutting and which are technically clones of the original parent plant, would also exemplify such domestication. However, this may not necessarily be morphologically or phenotypically evident. For instance, where plants such as taro or yams were transported by Austronesian speaking peoples (Kirch, 2000: 109-110), genetic evidence of this should be present in the subsequent crops. However, vegetatively propagated plants are less commonly identified as agricultural despite obvious evidence for their management and domestication. Such cases are more likely to be considered horticultural rather than agricultural but may be considered a different type of agriculture (Denham, 2007; Denham & Haberle, 2008; Denham, et al., 2003).

The presence of domesticates does not necessarily indicate agriculture (Crawford, 2008; Vrydaghs & Denham, 2007: 4) especially in the case of 'domesticated' plants that have been naturalised or grow unmanaged in the wild. This is exemplified by the Jomon of Japan where domesticates such as rice and millet were present in low numbers (Crawford, 1983, 2008, 2011). Despite the presence of domesticates, a high degree of sedentism and a high population density, the Jomon are traditionally conceptualised as hunter-gatherers (e.g., Matsui & Kanehara, 2006; Pearson, 2006; although Crawford, 2008 finds they defy classification as either hunter-gatherers or agriculturalists).

Denham (2007: 97) notes that the characteristics of agriculture may differ in various environmental regions. Agriculture in humid or tropical regions appears to differ from agriculture in semi arid regions (Cohen, D. J., 2011; Denham, 2007: 97). That is, there is a range of subsistence and food production practices across various cultural and environmental regions. The characteristics of intensive plant management and use leading to morphological changes in the plant may differ according to the staple foods being used and the plants that occur in a particular region. However, to assign greater importance to one type of intensified subsistence (agriculture) than another (horticulture or arboriculture) is at best inaccurate. Such distinctions probably relate at least partly to the type of environment where the ancient culture existed. Another consideration may be the type and availability of staple plant foods fit for human consumption.

The definition of agriculture in my thesis will not attempt to include all types of social groupings, and will utilise a working definition relevant to my research in China. For the purpose of this research I will define ‘agriculture’ as evidence for intensive cultivation or substantial management of plant foods. This is typically indicated by the presence of domesticates but may include evidence of both domesticated and cultivated plant foods. The social changes that certain researchers describe as being linked to agriculture may also be taken into consideration under this definition. Some degree of social inequality and a settlement hierarchy as evidenced by grave goods and other material culture is therefore a requirement of agriculture. Understanding intensified plant food production and subsistence changes may allow a greater understanding of the other social changes occurring at a similar time to plant domestication in the study region.

2.5.2 Summary of Definitions

The definitions given above of cultivation, domestication and social complexity may in some cases be grouped into a definition of an agricultural society. The mobile hunter-gatherers of the Late Palaeolithic study region do not appear to exhibit plant cultivation, domestication, sedentism or a high degree of social complexity (Liu, Li, et al., 2011; Guojia, 2004; Shizitan Kaogudui, 2010). However, the increased sedentism and material goods of the Peiligang and later cultures, with a range of items difficult to transport such as pottery and pit dwellings, exhibit a changed culture and possibly an altered resource base as well. Evidence for Peiligang plant cultivation, domestication and agricultural complexity are examined throughout this thesis.

In this thesis the term ‘agriculture’ will be used in a very general sense to indicate significant social complexity as well as the presence of domesticated seed plants such as cereals. In North China the occurrence of plant cultivation preceeded agriculture and may be evident in the study region in the Peiligang period where small numbers of plant domesticates and small egalitarian sites are evident (Liu, Li, 2004: 74). This thesis will investigate the subsistence base for Late Palaeolithic, Peiligang and Yangshao periods in the study region and changes in subsistence over time.

Chapter 3: Archaeological Background

This thesis is concerned with understanding the origins of agriculture in North China. An overview of the cultural and chronological background in the study region will be given here. This chapter will present the current state of knowledge regarding plant subsistence from North China during the Late Palaeolithic and early Neolithic periods. Firstly the Late Palaeolithic Xiachuan and Shizitan site complexes will be discussed. This will be followed by a discussion of the origins and transition to agriculture in North China during the Peiligang and Yangshao periods. Agriculture is thought to have developed in more than one center or region in China (Cohen, D. J., 2011; Smith, B. D., 1998; Zhao, Z., 2011) and current ideas regarding the proposed centres of plant domestication in China will be examined. Both broomcorn and foxtail millet are thought to have been domesticated in North China while rice was thought to have been domesticated in South China along the Yangzi River. Taro and yams may have been domesticated in southwestern China (Zhao, Z., 2005b, 2011). Further research is needed to fully understand these issues and interactions among peoples from the various environmental regions.

3.1 Palaeolithic Subsistence and Early Agriculture in North China

This thesis examines plant subsistence from the period after the last glacial maximum (LGM) in North China until the emergence of plant domestication and agriculture in the Peiligang and Yangshao periods. The Shizitan site S14 locality dates to *c.* 20,700–20,000 cal BP while the S9 locality is nearby but dates to a later time, from 13,800 – 8,500 cal BP. The Peiligang period dates from *c.* 9,000 – 7,000 cal BP while the Yangshao period dates from *c.* 7,000 – 5,000 cal BP. These and subsequent cultural periods until the beginning of written records during the Shang Dynasty (1,600 – 1,046 BC) in North China are examined below. Sites examined for this thesis include Late Palaeolithic, Peiligang and Yangshao period sites, however, the subsequent Longshan and Erlitou periods and the Shang Dynasty will be summarized. This summarized for the information of the reader when these periods are mentioned throughout the text.

3.1.1 Late Palaeolithic Subsistence in North China

Evidence for late Palaeolithic subsistence is frequently sparse or ill defined. Over 1,000 Palaeolithic sites have been found in China and more than 100 excavated (Lu, Z., 2003). However, many sites were excavated prior to the advent of flotation and so plant remains and/or data are rarely available. Thus to understand palaeolithic subsistence it is common

to base assumptions mainly on animal bones or on stone artefacts assumed to be used for plant food processing (Chang, K. C., 1986: 83-93). The research presented in this thesis represents some of the first systematically collected macrobotanical evidence for Late Palaeolithic subsistence in North China (Chapter 8).

3.1.1.1 XIACHUAN SITE COMPLEX

The late Palaeolithic Xiachuan site complex consists of sixteen sites located in the Fuyi River basin, Shanxi province, North China (Wang, J. et al., 1978). The sites date from around 24,000–16,000 cal BP and provide some evidence for subsistence changes in the late Palaeolithic period (Lu, T. L. D., 1999: 28-31). In the absence of botanical archaeological material, stone artefacts are typically used to provide evidence about ancient subsistence.

The recovery of microlithic blades from Xiachuan is thought to indicate the hunting of fast-footed ungulates that became more common after the LGM (IACASS and Shanxisheng, 1978; Wang, J., et al., 1978; for English summary see Lu, T. L. D., 1999: 30). Thin and flat denticulate flakes are another new type of tool to emerge in the Xiachuan complex (IACASS and Shanxisheng, 1978). Based on similarities with later denticulate sickle implements including Peiligang stone sickles, it was suggested that these implements were used for cereal grinding (Shi, X. B., 1989). This assumption was not tested until T. L. D. Lu (2001) examined use-wear traces and suggested the tools were used for reaping grass panicles. T. L. D. Lu (1999: 30) also tested the fragments of grinding artefacts that occur in upper layers of the Xiachuan site complex (IACASS, et al., 1978). These are among the earliest grinding implements in China (Wang, J., et al., 1978). Preliminary use-wear studies suggest that some of the stones were used for grass or cereal grinding (Lu, T. L. D., 1999: 30).

In the Holocene in particular, the presence of grinding artefacts in China is usually taken to indicate the processing of cereals or grasses (Liu, Li, et al., 2002-2004: 81). This assumption has until recently remained untested by use-wear or residue analyses (although see IACASS, et al., 2003: 286-289; Liu, Li, et al., 2010b; 2010c).

3.1.1.2 SHIZITAN SITE COMPLEX

The late Palaeolithic, multi-locality site of Shizitan (approx. 20,000 to 8,500 cal BP) yielded several grinding implements (Linfen Culture Bureau, 1989). Starch and microfossil

research by Professor Li Liu at this site is ongoing. The flotation samples from the Late Palaeolithic at Shizitan have so far yielded evidence of a range of wild panicoid grass seeds including *Echinochloa* sp., *Panicum* sp. and *Setaria* type seeds, as well as the remains of fruit or gourd rind (Bestel, et al., 2009; see also this thesis, Chapter 8). Panicoid grasses are from the Paniceae tribe of the grass family and include seeds which were cultivated in Holocene China and Japan. Modern domesticates common in North China today such as *Echinochloa crus-galli* (barnyard millet), *Panicum miliaceum* (broomcorn millet) and *Setaria italica* ssp. *italica* (foxtail millet) are all panicoid grasses in the Paniceae or millet tribe.

Plant remains have not been systematically collected from any other Palaeolithic site in North China although an unfulfilled expectation of rice remains has fuelled flotation research at sites such as Zengpiyan (IACASS, et al., 2003: 286-289) and Yuchanyan (Yuan, Jiarong, 2002) in South China.

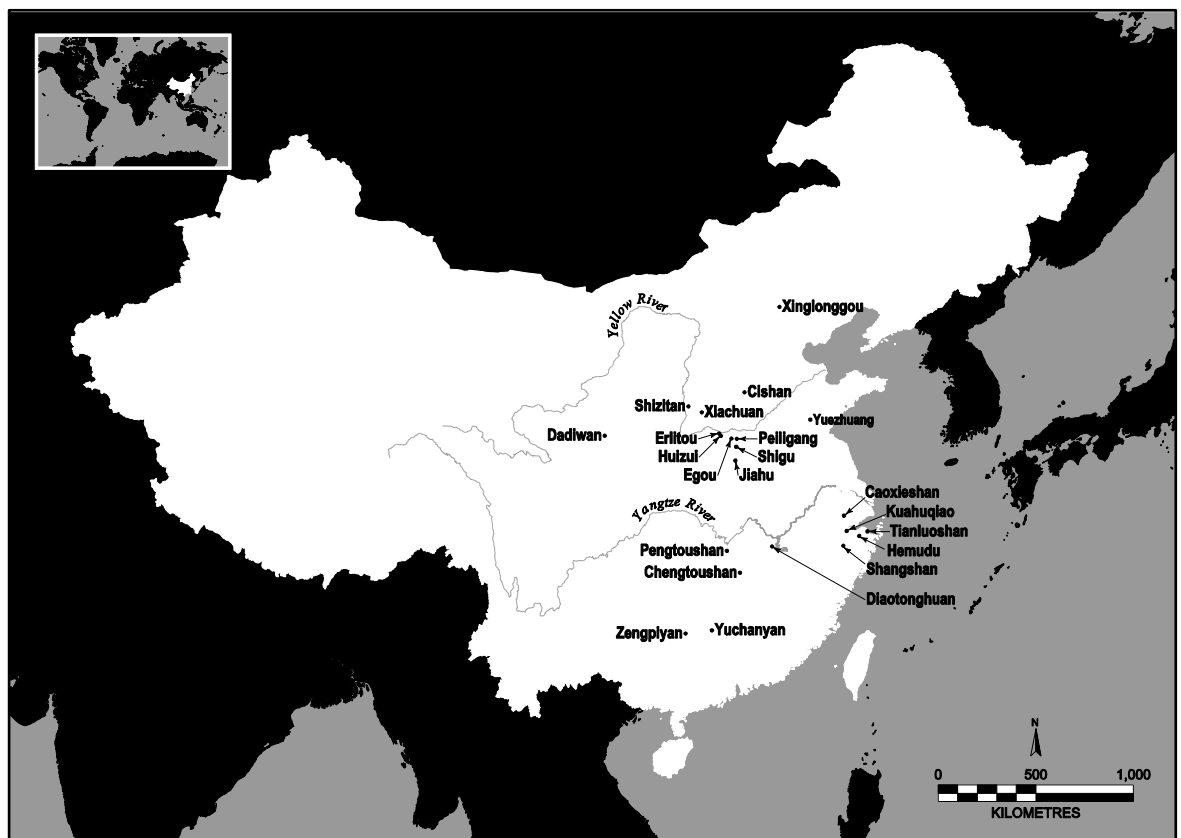


Figure 3-1 Map of main sites mentioned in text

3.1.2 Neolithic China and the First Domesticated Crops

China is considered one of the worldwide hotspots of plant domestication (Ho, 1977) and a number of important modern crops were domesticated there. These include some early

Neolithic domesticates such as foxtail and broomcorn millet (Chang, K. C., 1986: 91-93), rice (Jiang, L. & Li Liu, 2006) and perhaps taro (Zhao, Z., 2011). These important original plant domesticates will be examined in more detail below.

3.1.2.1 NORTH CHINA—FOXTAIL MILLET

The earliest domesticated foxtail millet identified by archaeobotanists in China was until recently thought to be from the Xinglonggou site in the Liao River region of northeast China and was dated to c. 8,300 cal BP (Zhao, Z., 2005a). Revised dates now place broomcorn and foxtail millet from this site between 7,670–7,610 cal BP (Zhao, Z., 2011: S301). Early millet also occurs at Dadiwan in Qin'an, Gansu province, dated to 7,800 – 7,350 cal BP (Barton, L., et al., 2009; Liu, C., 2006), in the Yiluo Basin in the Peiligang period (Liu, Li, et al., 2002-2004) and at Yuezhuang in Shandong Province by c.8000 cal BP (Crawford, et al., 2007) (see Table 3-1). In fact, many early millet dates in North China, including those in the Middle, Upper and Lower regions of the Yellow River, now date between c.7,800–7,000 cal BP (Table 3-1). This seems to suggest a relatively rapid spread of broomcorn millet across North China once domestication occurred.

Analysis of genetic data including polymorphisms at both ribosomal and mitochondrial genetic loci indicate that East Asia is the centre of origin of foxtail millet (Fukunaga et al., 2006; Fukunaga & Kato, 2003; Fukunaga et al., 2002). An independent domestication event or series of events of foxtail millet races in Afghanistan and northwestern Pakistan is also suggested by genetic data of an international collection of foxtail millet (Fukunaga, et al., 2006). Other proposed centres of origin for foxtail millet include Taiwan and the Philippines in tropical East Asia. However, Fukunaga and colleagues (Fukunaga, et al., 2006) note that the ribosomal markers have a complex evolution, meaning that this proposed centre of origin is only tentative.

Table 3-1 Early Domesticated Millet in North China

Site	Type of Millet	Date	Notes
Cishan	Initial discovery suggested 88 pits full of foxtail millet (Handan Wenwu , 1977; Hebeisheng, 1981) but no single grains evident. Recent re-examination of site (Lu, H., et al., 2009a) recovered no grains but phytolith evidence suggested early section of site only broomcorn millet. Small amounts of foxtail millet present after 8,700 cal BP (Lu, H., et al., 2009a: 7367).	10,300–8,700 cal BP (Lu, H., et al., 2009a). Earlier dates for site correspond to 7,355±100 and 7235±105 uncal BP (1977; 1981). Z. Zhao (2011: S301) suggests these fit with the new date of 7,671–7,596 cal BP given by Lu and colleagues (2009a: figure 3) for the CS-BWG sample stored in Cishan museum since the 1970s.	Dates not on millet seeds itself. Recent (Lu, H., et al., 2009a) dating of site critiqued by Z. Zhao (2011: 301).
Dadiwan	8 grains of broomcorn millet in early Phase of site (Gansu Provincial, 2006: 914)	7,800–7,350 cal BP (Gansu Provincial, 2006: 914)	
Fudian Dong	3 broomcorn millet and 2 foxtail millet grains (see Chapter 8)	7,504–7,412 cal BP	
Xinglonggou	1,400 grains of broomcorn millet and 60 grains of foxtail millet (Zhao, Z., 2011: S301)	Early date put broomcorn millet at 8,300 cal BP (Zhao, Z., 2005a). Revised date of charred millet seeds places site at 7,670–7,610 cal BP (Zhao, Z., 2011: S301).	Site appears to have been recently redated
Yuezhuang	40 grains of broomcorn millet and one grain of foxtail millet (Crawford, et al., 2007)	7050±80 cal BP	

3.1.2.2 NORTH CHINA—BROOMCORN MILLET

Evidence from at least four sites with early millet remains in North China has suggested that broomcorn millet (*Panicum miliaceum*) may have preceeded foxtail millet as a crop. Broomcorn millet predates foxtail millet at Cishan (Lu, H., et al., 2009a), Dadiwan (Barton, L., et al., 2009), Xinglonggou (Zhao, Z., 2005a) and Yuezhuang (Crawford, et al., 2007). Broomcorn millet remains were significantly more abundant at the Xinglonggou site (Zhao, Z., 2005a). L. Barton and colleagues (2009: 5523) have suggested that broomcorn millet appeared in North China from an unidentified source and wild progenitor and was gradually replaced by foxtail millet in the archaeological record. G-A. Lee and colleagues were able to write in 2007 (Lee, G.-A., et al., 2007: 1091-1092) that it was unclear whether the early appearance of broomcorn millet was a regional or local phenomenon. The subsequent evidence published from Dadiwan in the Upper Yellow River Valley (Barton, L., et al., 2009) and Cishan in Wuan, southern Hebei Province (Lu, H., et al., 2009a) support this being a regional occurrence.

Based on research from the site of Daidwan in western China it appears that there are two distinct phases of subsistence separated by around 700 years in the archaeological record (Barton, L., et al., 2009). The earlier phase 1, which is pre-Yangshao or Middle Neolithic in type, dates from 7,900–7,200 cal BP and carbonised broomcorn millet remains are rare for this period (Barton, L., et al., 2009: 5523). However, phase 2 at the Dadiwan site, which dates from 6,500 – 4,900 cal BP, has a greater number of carbonised broomcorn millet remains (Gansusheng, 2006: 614-616; Barton, L., et al., 2009: 5523). The research of L. Barton and colleagues is based partly on artefacts related to sedentism and farming recovered from the site and partly on an analysis of diet based on dog, pig and human carbon isotope studies.

Previously D. J. Cohen (1998) suggested that broomcorn millet was domesticated in central Asia and then appeared in China. Molecular research by Hunt et al. (2011) is consistent with either a single domestication even in North China or with multiple domestication events including in China and in Eastern Europe. Research has not yet identified the wild progenitor of broomcorn millet although *Panicum miliaceum* ssp. *ruderales* (Zohary & Hopf, 2000: 83-86) and *Panicum bisulcatum* (Zhao, Z., 2005a) have both been suggested. However, this latter is a C3 plant while *Panicum miliaceum* is a C4 plant, meaning that it cannot be ancestral to broomcorn millet.

The site of Cishan is located in Wuan, Hebei Province. It is one of the Peiligang and related cultures and is the type site for the Cishan culture (Chang, K. C., 1986: 88-95). Cishan was first excavated in 1976–77 (Handan Wenwu, 1977) and has recently been re-examined. During the site's re-evaluation sediments were dated to between ca. 10,300–8,700 cal BP (Lu, H., et al., 2009a) although the dating of this site is not well accepted (see Zhao, Z., 2011: S301). It appears likely that the material used to re-date this site came from the bulk sediment sample rather than actual millet grains (Zhao, Z., 2011: S301), making it less accurate. In addition, Z. Zhao (2011: S301) noted that re-dated sample CS-BWG had been stored in a vial in the Cishan Museum since the original 1970s excavation. When H. Lu and colleagues re-dated this original sample, the results returned a date between 7,671–7,596 cal BP (Lu, H., et al., 2009a: figure 3). This is a more acceptable date for Peiligang remains, and Z. Zhao (2011: S301) notes that it fits well with the original dates.

No macrobotanical remains were recovered from the Cishan site in the 1970s, although researchers at the time noted 88 storage pits full of grain (Hebeisheng, 1981). H. Lu and

colleagues (2009a: 7367) also could not recover any charred seeds from the site, despite this alleged abundance of ancient grains. Questions are also raised concerning the form of preservation of the grain. Q. Huang (1982: 418-420) notes that the storage pits were full of 'grain-shaped voids' (see Hunt, et al., 2008: S11 for English translation). The photograph of the 'husks' of these seeds (Lu, H., et al., 2009a; figure 1; figure S2) does not clarify matters as identifiable husks are not clearly visible. In a more recent explanation H. Lu and colleagues (Lu, H., et al., 2009a) note that the grains in the storage pits at Cishan had 'oxidised into ash' meaning that macrobotanical analysis was not possible for the site. It would appear that either only voids or ash (sometimes translated as 'dust') were present at the site, and one wonders about the exact state of existence of the storage pits full of grain at Cishan. Several of the Cishan pits that were identified during research as grain storage pits have canine skeletons at the base of the pit (Pu, 1987), raising questions about the probability that it is a grain storage pit.

Recent research on the earliest ashy layer of pits at the Cishan site identified the phytoliths from the site as broomcorn millet rather than foxtail millet (Lu, H., et al., 2009a). In the upper layer of the sediment, only broomcorn millet remains were preserved and in the lower layer mainly broomcorn millet phytoliths along with small numbers of foxtail millet phytoliths were preserved (Lu, H., et al., 2009a).

Given that later ash pits in Neolithic China typically contain numerous and varied seed remains, questions remain about the existence of other plant material at the site. While reed phytoliths in the pits were identified as mats of *Phragmites australis* (Lu, H., et al., 2009a) no mention is made of other phytoliths from the sediment examined. Later seed crop remains in Neolithic China typically contain numerous weedy forms of Paniceae tribe grasses (cf Lee, G.-A., et al., 2007). In H. Lu and colleagues' (2009a) article the absence of a discussion of wild phytoliths appears indicative of a focus on domesticated plants to the detriment of wild taxa (aside from a brief mention of *Phragmites australis* reed phytoliths). In addition, having an extremely high percentage of diagnostic phytoliths in a sample is unusual. Further research is required to identify the plant remains, and the date of those remains, from the Cishan site..

3.1.2.3 NORTH CHINA—RESIDUES

It was assumed that the Neolithic Revolution occurred in North China as an indigenous package (Chang, K. C., 1986: 87; Ho, 1975). Domesticated dogs and pigs, cultivated rice

or millet cereals, pottery and sedentism were thought to occur at broadly the same time in the middle Holocene. In North China evidence for millet farming was thought to be based on three main pieces of evidence. These included pits full of millet such as those at the Cishan site (mentioned above), stone sickles supposedly used for harvesting cereals, and stone grinding *mopan* with *mobang* assumed to have been used for grinding cereal grains into flour (Chang, K. C., 1986: 91-92). These latter two artefacts only occur in the Peiligang and related cultures (Chang, K. C., 1986: 92-93) and disappear from the archaeological record during the Yangshao and subsequent periods.

Recent research on residues in North China has examined the function of grinding *mopan* and *mobang* initially assumed to be used for cereal processing (Liu, Li, et al., 2010b; 2010c). As millet grains do not need to be ground prior to consumption it was not expected that millet starch would be present in large quantities on the grinding artefacts. Microfossil studies of starch grains and phytoliths on grinding *mopan* from Peiligang sites at Egou and in other areas of North China exhibited a variety of starch grains on the artefacts (Liu, Li, et al., 2010b; 2010c; Tao, et al., 2011; Zhang, Y., et al., 2011). Some of these starch grains probably represent acorn grinding prior to leaching and eventual consumption (Liu, Li, et al., 2010c). Other starch grains may indicate the processing of foods such as millet, beans, and yams (Liu, Li, et al., 2010c). This suggests that these grinding implements were multifunctional. Thus they are not reliable indicators of cereal processing and grinding or of agriculture.

3.1.2.4 SOUTH CHINA—RICE

Rice cultivation and agriculture in the Yangtze River region of South China is thought to date to the start of the Holocene or the late Palaeolithic period (Cohen, D. J., 1998; Higham, 2005; Yasuda, 2002b).

Based on rice phytolith morphology, W. Zhang (2002) suggested that rice cultivation occurred from at least the late Pleistocene or early Holocene in South China. Rice phytoliths are present at the Diaotonghuan Cave (Figure 3-1) at around 12,000–11,000 cal BP, with a mix of wild and domesticated rice from 10,000 – 8,000 cal BP, and mainly domesticated rice from approximately 7,000 cal BP onwards (Zhao, Z., 1998). At the site of Shangshan, in Zhejiang province early rice grains have been found in the Shangshan layer of the site, which dates from around 11,000 – 9,000 cal BP (Jiang, L. & Li Liu, 2006). L. Jiang and Li Liu (2006) raised the possibility that the rice at this site was in an

early stage of cultivation. This suggestion was based partly on the presence of large building structures, pits and post holes, which suggests some degree of sedentism. Y. Zheng and L. Jiang (2009) suggest the rice is cultivated and transitional between wild and domesticated rice, although this is debated. Fuller and colleagues (Fuller, et al., 2007; 2008; 2009) argue that fully domesticated rice occurs later at 6,900–6,600 cal BP at Tianluoshan in South China (Fuller, et al., 2009).

The site of Bashidang from the Pengtoushan culture (c. 8,500–7,500 cal BP) has large quantities of rice present (Crawford & Shen, 1998). However, on the basis of the small grain sizes Fuller and colleagues (2007: 326) suggest that these are wild rice grains. Tianluoshan has evidence of an increase in non-shattering rachis bases and a corresponding increase in the percentage of rice remains as a part of total subsistence over the 6,900 – 6,600 cal BP period (Fuller, et al., 2009). This is taken by Fuller and colleagues (2009) to be evidence of the unfolding process of rice domestication.

In South China debates around agriculture have invoked the question of sedentism and the size range of wild versus domesticated rice (Fuller, et al., 2007; Jiang, L. & Li Liu, 2006). The debate also hinges in part on the definitions of domestication and what markers visible in the archaeological record may be reliably used to indicate domestication.

Fuller and colleagues (2009) argue that rice domestication was a slow process that began around 8,000 BP at sites such as Kuahuqiao and later continued at sites such as Hemudu and Tianluoshan in Zhejiang province in southern China. Based on both grain and phytolith size changes over time in the archaeological record (Fuller, et al., 2007) albeit from two disparate sites, Fuller and colleagues (2007) suggested that rice cultivation was completed nearly two millennia later by 6,000 cal BP. In a later article this date changed, with Fuller and colleagues (2009: 1608) instead suggesting that the process of rice domestication ‘culminated’ after 6,500 cal BP.

The occurrence of rapid domestication in rice was noted by Oka and Morishima (1971) after experiments involving a knife to harvest rice, with an increase in seed weight and seed spikelet number and reduced seed shedding after only five generations. B. D. Smith (1998: 73) also experimented with the use of knives or sickles for harvesting cereals.

Initially modern forms of *Oryza* sp. rice were thought to have come from a single ancestor, and differentiated into the japonica and indica types post domestication (Chang, T. T., 1989; Oka, 1988). More recent genetic studies have suggested that these two types of rice have different progenitors, being *Oryza nivara* for *Oryza indica* and *Oryza rufipogon* giving rise to *Oryza japonica* (Sato, et al., 1990). In fact, genetic research has suggested two separate rice domestication events for japonica rice in South China and two domestication events for indica rice in south Asia or western Southeast Asia (Londo, et al., 2006). Theories favouring multiple centres of domestication are now in favour (e.g., Londo, et al., 2006) and a non-linear process of domestication appears likely (Liu, Li, et al., G.-A. Lee, et al., 2007).

Whilst the domesticated or cultivated status of rice remains in early Holocene South China are questioned (Fuller, et al., 2007; 2009), unequivocal evidence for rice cultivation occurs in the form of the earliest rice paddy in South China. A rice paddy occurs at the Chengtoushan site in the middle Yangzi River region, dated to 6,300 cal BP (Liu, Li, G.-A. Lee, et al., 2007). Irrigation ditches and levels of rice phytoliths in soil that one would expect from a rice paddy have been found at Caoxieshan and at Chuodun in the Lower Yangtze River region, dating to the late Majiabang culture (6,300 – 6,000 cal BP) (Cao, Z. H., et al., 2006; Li, C. H., et al., 2007).

Rice use or at least the occurrence of rice in archaeological sites may have been present in the middle Yangtze region between 10,000–8,000 cal BP at sites such as Pengtoushan (Pei, 1998) and Bashidang (Higham & Lu, 1998) in Hunan Province. Plant fibre tempers in pottery occur at Pengtoushan 1,000 years after the technology appears at the Shangshan site in Zhejiang Province, South China (Pei, 1998; see also Jiang, L. and Li Liu 2006: 359). Rice stalks and husks were initially used as a pottery fibre temper at Shangshan around 10,000 cal BP (Jiang, L. & Li Liu, 2006). A number of non-shattering (domesticated type) rice base spikelets subsequently appeared at Tianluoshan by 6,600 cal BP (Fuller, et al., 2009). The increasing number of rice spikelet bases from archaeobotanical samples at the site there may correlate to the increasing dietary importance of rice in South China (Fuller, et al., 2009: 1608-1609) although numerous other plant remains are also evident.

Fuller and colleagues (2007) suggest that wild rice consumption was initially supplementary to a foraging strategy based mainly on nuts. They discuss a shift from heavy acorn and nut use to heavy rice consumption during the Neolithic of South China

(Fuller and Qin, 2010). They suggest that cultivation of rice had begun by 8,000–7,700 cal BP based on domesticated type spikelet bases at Kuahuqiao (Fuller, et al., 2009: 1609).

Based on the presence of wild rice at sites such as Diaotonghuan, Li Liu, G.-A. Lee and colleagues (2007: 1064) suggest that rice was in use for over 5,000 years prior to a more intensive phase of rice use at Hemudu c. 7,000 BP. They also note the extensive use of wild rice outside the current rice growing range at Jiahu in Henan province by c. 9,000 cal BP (Liu, Li, G.-A. Lee, et al., 2007: 1064). The transition of rice from pottery fibre temper to staple food source is not yet fully understood; it is possible that rice was utilised as food and the stalks as pottery temper, but that charred rice grains have not been well preserved.

3.1.2.5 SOUTH CHINA—TARO

Recent archaeobotanical research has led Z. Zhao (2005b, 2011) to suggest that a third centre of agricultural origin developed in far South China. This is partly based on archaeobotanical residue research at the Zengpiyan site in southern China's Guangxi province (see IACASS, et al., 2003: 341-343). Macrobotanical root remains, as well as taro residues on grinding slabs, were found at Zengpiyan (IACASS, et al., 2003: 341-343) suggesting the occurrence of a complex society with a high population density and domesticated dogs and pigs. Z. Zhao (2005b) examined macro-and microbotanical data from three sites in central-south China, Zengpiyan, Xiaojin and Dingsishan. Contrary to expectations none of these sites preserved evidence for the use of rice in early occupation layers, although rice did occur at the latter two sites as a result of northern diffusion after 6,000 cal BP onwards. Based on the lack of rice and other evidence Z. Zhao (2005b, 2011) suggested that a third centre of agricultural origins concentrating on tubers and with pig domestication may have arisen in the far south of China during the early-mid Holocene. D. Cohen (2011) has suggested that this represents multiple or 'wet' and 'dry' facets of the same development of agriculture. Further and more detailed research, which is beyond the scope of this thesis, is needed to understand the co-existence of several types of agriculture (dry millet farming, wet rice agriculture and yam or taro cropping) within the broader China region.

3.2 Cultural Periods in the North China Study Region

This research focuses on archaeobotanical remains and subsistence in the Yiluo Basin region of North China, from the late Palaeolithic Shizitan site (13,800–8,500 cal BP) through the Peiligang (9,000–7,000 cal BP) to the Yangshao (7,000–5,000 cal BP) periods.

The chronological background of the study region, covering parts of Shanxi and Henan Provinces, is outlined below. Much of this region is located within the reaches of the Middle Yellow River Region. However, the extent of the influence of some of these cultural periods stretches beyond the Middle Yellow River region and sites including Jiahu are technically not part of the middle Yellow River. As artefacts from Jiahu were made available for study they are nevertheless included in this research.

3.2.1 Late Palaeolithic Site Complexes

Late Palaeolithic cultures in the study region include the Xiachuan culture (23,900–16,400 uncal BP) (Lu, T. L. D., 1999: 29) and the Shizitan culture (13,800–8,500 cal BP) (Liu, Li, et al., 2011). Both these cultures are located in Shanxi Province. The Xiachuan culture complex occurs at 16 locations in the Fuyi River Basin (Wang, J., et al., 1978) while the Shizitan site cluster is located at over 25 sites along the Qingshui River (Liu, Li, et al., 2011). The chronological gap of over 2,000 years between these cultures may reflect a lack of research and dating at the sites, rather than an absence of human occupation. Both cultures include microlithic flaked implements as well as grinding implements.

Palaeolithic sites have not been found in the Yiluo Basin region of Henan Province, North China, despite an extensive systematic survey project (Liu, Li, & X. Chen, 2007).

Traditional surveys have covered 8,000 km² in southern Shanxi (Dingcun Wendui, 1986; Gao, et al., 1984; Shanxidui, 1989) and over 167,000 km² in Henan Province (Guojia, 1991) and have also not recovered Palaeolithic deposits, despite a tendency towards finding suitable sites for excavation (Liu, Li, 2004: 161-162). It is possible that the region had minimal or no human settlement during late Palaeolithic times. It is also likely that flooding may have covered ephemeral Palaeolithic sites through erosion and loess deposition. Since the late Pleistocene the Yellow River has flooded and changed course repeatedly (Liu, Li, 2004: 20).

Sites such as Nanzhuangtou and Hutouliang, which date to the period between 11,000-9,000 cal BP, were excavated prior to the widespread use of flotation and so did not preserve plant remains (Gao, et al., 1984). The sites have now been completely excavated so no plant remains from this period are evident in flotation samples as of January 2012.

3.2.2 Neolithic Cultural Periods

There are three main cultural periods spanning the Neolithic of the Yiluo Basin region of northern China (Table 3-2). These occur prior to the advent of the first state level civilization in China, the Erlitou period (Liu, Li, & X. Chen, 2003). Subsequent dynastic or historic periods for which written records occur after the Erlitou period. Neolithic sites in North China are mainly recognized from pottery typologies although radiocarbon (^{14}C) dates are available for the later Erlitou period (Xia Shang Zhou, 2000). The chief features of these Neolithic, early state (Erlitou) and early dynastic (Shang) periods will be discussed below. Although only artefacts or residues from the Peiligang and Yangshao periods were examined, other time periods in the study region will be discussed briefly to provide a chronological background or overview of the study area.

Table 3-2. Chronology of the Study Region, Henan and Shanxi Provinces, North China †

Period	Date	Plant Subsistence	Animals Husbanded/ Domesticated	Characteristic Material Culture
Xiachuan complex	23,900–16,400 BP	Unknown	Bones rare; a few wild ox and wild sheep remains	Microlithic flake tools; denticulate flakes; grinding implements
Shizitan complex	13,800–8,500 cal BP	Wild millet tribe grasses	Wild animals including deer	Microlithic tools; ochre grinding slabs and handstones
Peiligang	9,000–7,000 cal BP	Broomcorn and foxtail millet domestication; soybeans and rice present at Jiahu	Probably pigs and dogs	Grinding slabs with small feet; denticulate stone sickles; polished stone tools; red-orange pottery
Yangshao	7,000–5,000 cal BP	Millet, soybean and rice	Pigs and dogs	Egalitarian society, few elite or status objects
Longshan	5,000–4,000 cal BP	Millet, soybean, rice and wheat	Pigs, dogs, cattle, chicken and sheep/goat	White pottery; egg-shell pottery; increased population; indicators of increasing warfare
Erlitou	3,900–3,500 cal BP	Millet, soybean, rice, wheat, barley		Emergence of the first state

† References for details given in this table are provided in the accompanying text.

3.2.2.1 PEILIGANG PERIOD 9,000–7,000 CAL. BP

The Peiligang period coincided with warm and moist climatic conditions in north China, including the 9,800–4,500 cal BP mid-Holocene hypsithermal (An, et al., 2000: 747-758).

Pollen analysis of the Yellow River Basin region during this time suggests the presence of monsoonal evergreen forests associated with broad-leaved taxa and a decrease in herbaceous taxa and conifers such as pines (Yi, et al., 2003: 624).

The Peiligang culture is the earliest Neolithic culture in the middle Yellow River valley region and settlements in the Yiluo Region are small and possibly seasonal (Liu, Li, et al., 2002-2004: 81). Some degree of craft specialisation relating to lithic production and thin black pottery ware (Liao & Yang, 2000; Zhengzhoushi and Gongyishi, 1999) may have taken place in this region (Liu, Li, et al., 2002-2004: 81-93), but societies were relatively egalitarian.

In general the Peiligang is characterized by orange-red pottery (although the earliest pottery in China occurred well before this) and highly polished stone tools. Domesticated animals during this time include pigs and probably dogs, and plant domesticates include broomcorn and foxtail millets (Chang, K. C., 1986: 87-95; Lee, G.-A., et al., 2007; Liu, Li, et al., 2002-2004: 81).

Specific artefacts characteristic of the Peiligang period include grinding slabs with four little legs and associated muller/pestles, as well as denticulate stone sickles. Given discussions regarding the exact terminology of ground-stone implements and the range of different descriptive names used in different parts of the world (Rowan & Ebeling, 2008) these will be termed *mopan* (basal grinding stone) and *mobang* (upper handstone or *mobang*) throughout this thesis (see also Liu, Li, et al., 2011). In the absence of residue studies these latter were thought to have been used mainly for grinding cereals such as the recently domesticated millets (Chang, K. C., 1986: 87-95; Liu, Li, et al., 2002-2004: 81) although recent research has challenged this (Liu, Li, et al., 2010b; 2010c; Zhang, Y., et al., 2011). Residue and use-wear studies have determined that these artefacts were multifunctional, and were used to grind a variety of plants including acorns, beans, tubers and panicoid and pooid grasses (Liu, Li, et al., 2010c; Zhang, Y., et al., 2011). It is possible that these stone grinding implements disappear from the archaeological record during the following Yangshao period due to a greater, rather than decreasing, focus on millet cropping and cultivation. However, future research on grinding items from different Peiligang sites is needed to provide a broader picture of the use of these tools.

The significance of the actual use of these artefacts relates to long held, yet untested, assumptions regarding human subsistence during the Peiligang, initially regarded as the earliest agricultural period in north China. Research on Peiligang-aged flotation samples (this thesis, Chapter 8) has suggested that the newly domesticated millet cereals previously thought to have been a major focus of subsistence, are uncommon or absent in the archaeological record at a range of Peiligang sites. Based on this, I propose that wild or gathered plant foods, possibly including nuts, were more likely an staple of the early Holocene subsistence regime.

Another Peiligang artefact that disappeared from the archaeological record by the Yangshao period is denticulate stone sickles. These sickles were assumed to have been used for harvesting cereals (see Liu, Li, et al., 2002-2004: 81-82). Residues from these sickles were examined and results are presented in Chapter 10.

Animals, specifically dogs and pigs (Yuan, Jing, 2001; Yuan, Jing & Flad, 2002) were also domesticated during the Peiligang period. However, no animal teeth were available for residue analysis. While the Jiahu site in southeastern Henan province is considered to be Peiligang in age, the Peiligang period here dates from c.9,000–7,000 cal BP (Henan Provincial 1999) and has different characteristics to the Peiligang of the Yiluo Region. For example, the Jiahu site has early rice cultivation (Zhang, J. & Wang, 1998), early writing (Li, Xueqin et al., 2003) and is also known for the world's earliest occurrence of musical instruments (Zhang, J. et al., 1999). The Jiahu site has preserved evidence of numerous other unique artefacts including plant and nut remains (Zhao, Z. & J. Zhang, 2009). Further details regarding the Jiahu site are discussed in Chapter 4.

3.2.2.2 YANGSHAO PERIOD 7,000–5,000 CAL BP

The Yangshao period (7,000–5,000 cal BP) coincides with the climatic maximum in North China (An, et al., 2000; Shi, Y., et al., 1993). Lakes on the North China Plains enlarged in area during this period while the Gobi desert in western China decreased in overall size (Shi, Y., et al., 1993). The Yiluo region at this time was warmer and moister than during the preceding Peiligang period. Population growth and a two-tiered settlement hierarchy developed in what was otherwise a relatively egalitarian society (Liu, Li, et al., 2002-2004: 84-85) as the lack of elite goods or socially stratified burials suggests. Domesticates included pigs and dogs (Yuan, Jing & Flad, 2002). It is widely held that millet agriculture

provided a staple food in the region (Chang, K. C., 1986: 107-155; Lee, G.-A., et al., 2007; Liu, Li, et al., 2002-2004: 85).

There is some evidence for environmental deterioration during the Yangshao period. Climate change and environmental degradation occur at an early stage in Neolithic China (Li, Y. Y., et al., 2006), although evidence from geomorphological research cited by Rosen (Rosen, 2008) occurs early in the agricultural sequence. Through her Yiluo Project research, Rosen (2007b) has identified previously stable landscapes that subsequently exhibit episodes of hillside erosion and increased alluviation or sediment build-up in valleys. She suggests this may be a result of changing agricultural practices including rice paddy farming (Rosen, 2007b; Rosen, 2008).

In recent years, a greater research focus on rice found in north China has shown that millet and rice agriculture were not mutually exclusive (Lee, G.-A., et al., 2007). In fact, rice may have been raised as a minor crop with millet as a staple food (Yang, Z.-Q. & Zhang, 2000) although further research is needed to clarify this. The site of Yulinzhuang in the Yiluo region has rice phytoliths dating to the late Yangshao period (Liu, Li, et al., 2002-2004: 85) while the earliest rice paddy in North China, identified from geomorphological analysis and phytoliths, occurs at Huizui, also in the Yiluo region (Rosen, 2007b). Despite this, macrobotanical analysis of Yangshao flotation samples collected during the China 2007 field season did not provide any macrobotanical rice remains. This attests to the sporadic uptake of rice agriculture in the region.

3.2.2.3 LONGSHAN PERIOD 5,000–4,000 CAL. BP

The Longshan period (5,000–4,000 cal. BP) was characterized by increasing social complexity, and increased inter-group conflicts (Liu, Li, 1996a, 1996b; Underhill, 1994). Social complexity is indicated by the social hierarchy suggested by the presence of a three-tiered site size settlement hierarchy (Liu, Li, 2004: 169-170). Increased social stratification also occurred during this time (Liu, Li, 1996a; Underhill, 1994) as evidenced in part by the presence of elite goods including white pottery (found only in ritual contexts), eggshell pottery, jade items and increasingly elaborate burials. Environmental fluctuations and changes as well as a general cooling are also evident (Liu, Li, et al., 2002-2004: 85-88). This may have contributed to the increased conflict and warfare evident in the archaeological record (Liu, Li, 1996b) as food or resources became scarce. Evergreen and

broadleaved trees decreased and coniferous (pine) and herbaceous pollen grains increased in sediment samples at the time (Yi, et al., 2003).

Animals kept or domesticated at this time include sheep/goats (difficult to separate morphologically so usually classed together as caprines), dogs, pigs, and probably cattle and chickens (Yuan, Jing, 2001; Yuan, Jing & Flad, 2002). The staple crop of the time was foxtail millet and rice was becoming more common. New cultigens of the time period include wheat (*Triticum aestivum*), which is not native to the eastern China region (Crawford et al., 2005: 319; Lee, G.-A., et al., 2007; Li, Xiaoqiang, et al., 2007; Zhao, Z., 2009). As with the introduction of wheat, the introduction of caprines probably reflects some degree of contact with western China (Zhao, Z., 2009) and tentatively with southwest Asia.

Wheat (*Triticum* sp.) first appears in China during the mid-fifth millennium BP. This type of early wheat is typically identified as wheat (*Triticum aestivum*) (Zhao, Z., 2011:S296) or bread wheat (*Triticum aestivum*) (Crawford 2006: 78-79). A few wheat grains have been uncovered at the Longshan culture site of Liangchengzhen in Shandong province, east China (Crawford, et al., 2005: 311; Lee, G.-A., et al., 2007) while the oldest known wheat in northwestern China (c.4,650 cal BP) comes from the Majiayao culture which is dated to 5,250–4,300 cal BP (Li et al. 2007). In the Yiluo River valley region wheat occurs in the Erlitou period (3,900 – 3,500 cal BP) at both Zaojiaoshu (Luoyang, 2002) and Huizui West sites (Bestel, 2006) although only in small quantities.

Recent research by Z. Zhao (2009; 2010) has suggested that the earliest introduction of wheat to China occurred via the northern route across the Russian steppes and then down into the central plains region, rather than via the eastern route across central Asia which Li Xiaoqiang and colleagues (2007) had previously proposed. The introduction of wheat to China is a focus of research for the current project, as it suggests contacts with distant tribes or traders. Reasons for the introduction of wheat to north China are unclear. Given the initial scarcity of wheat in the macrobotanical record it may have first been introduced to the area as a luxury or trade item. Such items may become so coveted that they eventually become more common until they become a staple (Van der Veen, 2003). In support of this hypothesis, oracle bone inscriptions record that during the late Shang period (1600 – 1046 BC) wheat had become a staple crop (Keightley, 2000). The occurrence of wheat tribe (Triticeae) wild grasses as starch grains in the Late Palaeolithic Shizitan site

(Liu, Li, et al., 2011) is related to the introduction of wheat, as it appears similar grasses had been in use prior to the occurrence of wheat for millennia.

3.2.3 Erlitou Period 3,900–3,500 cal BP

The Erlitou culture coincides in time and place with the mythical Chinese Xia Dynasty (Liu, Li, X. Chen, & B. Li, 2007). The Erlitou period is the first state level civilization in China, comprised of a four tiered settlement hierarchy of towns and villages (Liu, Li, & X. Chen, 2003, 2007). Second tier centres of the Erlitou state include the site of Huizui, located about 15km east of Erlitou (Liu, Li, et al., 2002-2004). Over the past ten years this site has been the focus of detailed excavations and research by the international, interdisciplinary Yiluo River Basin research team (Liu, Li, & X. Chen, 2007). Much archaeological data collected from Huizui through this project was available including macrobotanical research on seed crop and weed subsistence (Bestel, 2006; Lee, G.-A. & Bestel, 2007).

Huizui was a ground-stone tool-making, secondary centre of the Erlitou state (Ford, 2001, 2004, 2007) and was located about 15km from the state capital Erlitou. Archaeobotanical research at Huizui during the Erlitou period suggests that a broad spectrum of food plants supplemented the staple millet crops, including domesticates like broomcorn millet (*Panicum miliaceum*), rice (*Oryza sativa*) and the newly introduced wheat (*Triticum aestivum*). Other possible cultigens at the site may include soybean (*Glycine* sp.) and chenopods (*Chenopodium/ Amaranthus* sp.) (Bestel, 2006; Lee, G.-A. & Bestel, 2007).

The exact date of the domestication of soybeans in Asia is contentious although the earliest, clearly domesticated soybean in Asia is from the Mumun period in Korea (Crawford & Lee, 2003; Lee, G.-A., et al., 2011). Numerous wild soybeans occur at Jiahu in the Peiligang period (Lee, G.-A., et al., 2011; Zhao, Z. & J. Zhang, 2009). Soybeans intermediate in size between wild and domesticated varieties occur in the Erlitou period at Zaojiaoshu (Luoyang, 2002) and at Huizui in the Yiluo region (Bestel, 2006). In view of these findings, historical records which date the introduction of domesticated soybeans to the central Yellow River region of China 664 BC, with the return of a general to his home after fighting in foreign regions (e.g., see Ho, 1977: 452), are probably not referring to the earliest occurrence of domesticated soybean in the region.

3.2.4 Shang (c. 1,600–1,046 BC) and Later Dynastic Society

The Neolithic and early state or Erlitou period in China are typically examined separately from those periods where written records are available. Such periods include the Shang and later dynasties. They are summarized here briefly for the convenience of the reader and also to allow the reader less familiar with Chinese history to orient themselves with regard to more famous Chinese archaeological discoveries. Early dynastic Shang society is considered synonymous with the Erligang period (c. 1,600–1,300 BC). Late Shang society is when the first written records, the oracle bone inscriptions, appear in the ancient city of Anyang, in Henan province, China.

The Shang Dynasty was replaced by the Zhou Dynasty in 1,046 BC. The Zhou is divided into western (1,046–771 BC) and eastern (770–221 BC) periods and immediately precedes the Qin Dynasty (221–207 BC), famous for its tomb of the emperor Qin with his underground army of terracotta soldiers. Neither Eastern Zhou nor Qin Dynasty material culture remains occur in the Yiluo region, but the periods are given here to allow orientation of Chinese prehistory to those unfamiliar with the regional chronology.

Chapter 4: Research Area and Site Location

4.1 Introduction to Palaeoenvironment

Research for this project took place in Henan and Shanxi Provinces, in the middle Yellow River area of North China (Figure 3-1). The main fieldwork was undertaken in the Yiluo River Basin region of Henan Province which is located in the loess plains (see Figure 3-1; Figure 4-1 and Table 4-1). The modern climate in this general region is considered to be temperate and seasonally monsoonal (Ren 1985:151-185). However, during the past 100,000 years major changes have occurred in climate, vegetation and the way humans impact on the landscape. Greater human populations were evident in the study region after the last glacial maximum (Liu, Li, et al., 2011; 2002-2004: 78; see also Rosen, 2008).

Recent research suggests that all ice sheets were at their LGM positions between 26,500–19,000 or 20,000 cal BP (Clark, et al., 2009). This thesis will take the LGM to be the period between *c.* 26,500–19,000 cal BP. There was considerable global asynchronicity between this event and the associated climatic minimum (Gamble & Soffer, 1990: 4-5). However, deglaciation began to occur in the study region after *c.* 17,000 cal BP (Xia, Z., et al., 2002: 74).

This chapter will provide an overview of what is known about the palaeoenvironment of North China in the late Palaeolithic and early Neolithic (Peiligang and Yangshao) periods. This thesis will focus on the study region of Henan and neighbouring Shanxi provinces.

4.2 Palaeoenvironmental Information from the Research Area

Archaeobotanical analysis of prehistory frequently uses palaeoenvironmental data as a baseline to understand changes in environment and subsistence. The developmental changes in the Neolithic in China are best examined within an environmental context (Liu, Li, 2004: 19) where humans may be seen as part of the ecological landscape. The dramatic environmental changes that occurred during the Holocene within the middle Yellow River region may be partly attributed to human impact (e.g., Rosen 2008).

Pollen records are frequently used for palaeoenvironmental understanding as they may contain high resolution data relating to floristic changes in the past. Sediment samples for pollen analysis were collected during fieldwork in the Yiluo Region but unfortunately they contained insufficient pollen for analysis (Kale Sniderman, 2010, Pers. Comm.). Published

pollen data analyses of the study region will be used to describe the palaeoenvironmental and climatic background of the study region.

4.2.1 Late Palaeolithic

An extensive pollen study of the Shizitan site in southern Shanxi identified four broad pollen zones over the period from 35,100–9,400 cal BP (Xia, Z., et al., 2002) and suggested that the site had been a relatively arid steppe for much of this time. Detailed pollen analyses are rarely available and to exemplify the pollen flora in the region¹ an outline of the Shizitan pollen records will be provided. The pollen and geological dates for the site predate the archaeological dates (oldest archaeology is at 20,700–20,000 cal BP). The period from 35,100–17,000 cal BP corresponds to the last glacial period in this region and the landscape was similar to a modern desert steppe. Herbaceous pollen accounts for 59.8–96.5 percent of the sample, with *Artemisia* sp. and Chenopodiaceae followed by Poaceae (grass) pollen being most common (Xia, Z., et al., 2002: 74). Trees account for 3.5–25.2 percent of taxa with pine trees (*Pinus* sp.) dominant and no deciduous or broadleaved taxa. Some ferns were present (Xia, Z., et al., 2002: 74).

The period from 17,000–11,900 cal BP was characterised by mild and semi-arid steppe conditions. Archaeological remains were present during this time period. Across this steppe, herbs were most prominent (75.7–100 percent of taxa)² and taxa such as *Artemisia* sp. were included. Chenopods (Chenopodiaceae) and grasses (Poaceae) were included in the herbaceous pollen category. Common temperate steppe species included buttercups (Ranunculaceae), daisies (Asteraceae formerly Compositae), beans and legumes (Fabaceae formerly Leguminosae) and fleshy fruits and berries from the rose family (Rosaceae) (Xia, Z., et al., 2002: 72). Trees include a majority of pine trees (*Pinus* sp.) with some deciduous and broadleaved species including tamarisks (Tamaricaceae). Other broadleaved taxa include oaks (*Quercus* sp.), elms (*Ulmus* sp.), birch (*Betula* sp.) and hornbeam (*Carpinus* sp.). Trees accounted for 1–24.3 percent of pollen taxa. In addition to the above, the Tree

¹ Shizitan site in Shanxi Province is located approximately 300 km from the main Yiluo study region in Henan Province. It is located on the loess plateau rather than the loess plain of North China but is still in the Middle Yellow River region.

² Figures in the original article by Xia and colleagues (2002: 72) do not add up to 100 percent so some percentages of pollen have been estimated from the pollen diagram.

of Heaven (*Ailanthus* sp.), sumac (*Rhus* sp.) and willows (*Salix* sp.) as well as some ferns, were present (Xia, Z., et al., 2002: 72).

The period from 11,900–10,500 cal BP was similar to a cold and dry desert steppe covered with herbs (86.8–100 percent of pollen taxa). The variety of herbaceous taxa decreased during this period, with *Artemisia* and chenopods most common. The only other herbaceous taxa present at this time were grasses (Poaceae), buttercups (Ranunculaceae) and hops (*Humulus* sp.). Trees (0–13.2 percent of pollen) included predominantly pines (*Pinus* sp.) with minimal broadleaved taxa including birch (*Betula* sp.), linden (*Tilia* sp.), sumac (*Rhus* sp.) and tamarisks (Tamaricaceae). Some ferns were present (Xia, Z., et al., 2002: 72).

The period from 10,500–9,400 cal BP ranged from mild and semi-arid to warm and semi-humid. A greater diversity of taxa were present in the pollen assemblage (Xia, Z., et al., 2002: 72). Herbaceous pollen taxa (76.4–90.4 percent) were dominated by *Artemisia*, Chenopodiaceae and grasses (Poaceae). They also included temperate steppe species such as meadow-rue (*Thalictrum* sp.), buttercups (Ranunculaceae), buckwheats (Polygonaceae), daisies (Asteraceae formerly Compositae), mustards (Brassicaceae formerly Cruciferae), beans and legumes (Fabaceae formerly Leguminosae), olives (Oleaceae) and mints (Lamiaceae formerly Labiateae). Pines (*Pinus* sp.) were common components of the tree flora (trees account for 3.8–13.9 percent of pollen taxa), with other broadleaved trees including birch (*Betula* sp.), oaks (*Quercus* sp.), maples (*Acer* sp.), willows (*Salix* sp.), hornbeams (*Carpinus* sp.), tree of heaven (*Ailanthus* sp.), sumac (*Rhus* sp.) and mulberries (Moraceae). Ferns increased to account for more than 10 percent of pollen and spore taxa during this semi-humid phase (Xia, Z., et al., 2002).

In summary, through the period from 35,100–9,400 cal BP the Shizitan site was a steppe environment alternating between dry and cold climates with reduced pollen taxa and warmer and more temperate conditions with a greater variety of plants. Herbaceous taxa account for between approximately 60–100 percent of taxa in pollen samples and commonly include *Artemisia*, chenopods and grasses. Trees and ferns account for the remainder of the pollen taxa with pine trees dominating. It is only after deglaciation began around 17,000 cal BP that broadleaved taxa such as oaks (*Quercus* sp.), willows (*Salix* sp.) and birch (*Betula* sp.) began to occur.

Pollen taxa recovered from the Jiahu site in southern Henan province prior to the Peiligang period is similar to the taxa described from Shizitan. At Jiahu herbs and shrubs comprised 76 percent of the total pre-cultural pollen profile, including 64 percent *Artemisia* pollen (Zhang, J., 1991). Fern and algae spores were common and made up approximately 18 percent of the pre-cultural pollen taxa. Approximately 6 percent of the pollen taxa at Jiahu at this time were trees. Pine trees were most abundant and *Salix*, *Alnus* and *Quercus* ssp. pollen was also present in small amounts (Zhang, J., 1991). During the early Peiligang (cultural) period at Jiahu arboreal pollen increased to 18.3 percent, dominated by deciduous trees such as oaks, walnuts and elms (Henansheng, 1999; Zhang, J., 1991: 803). Tree cover subsequently declined (Zhang, J., 1991) possibly due to human agricultural activity (Lu, T. L. D., 1999: 14).

4.2.2 Holocene

Despite the date for the Holocene epoch having been set by an international geological body at *c.* 11,650 cal BP, dates for the Holocene and the Holocene climatic optimum or hypsithermal vary around the globe. In the Near East, Rosen (2007a: 97) identifies the start of the Holocene at around 9,500 BC. In China T. L. D. Lu (1999: 9) sets the date for the Holocene at around 10,000 cal BP. Writing several years later L. Liu (2004: 24-25) puts the initial Holocene at around 11,000 cal BP and notes that this is also the initial Neolithic period in North China. Writing about western China, Bettinger and colleagues (2007: 85) place the Holocene at approximately 11,600 cal BP. The United States Geological Survey (USGS) website places the Holocene epoch at $11,477 \pm 85$ cal BP (USGS, 2012). Due to archaeological differences regarding the exact date, the term Holocene will be used in a general sense to mean the approximate date of 11,500 cal BP.

The east Asian monsoon front appears to have been one of the more important factors affecting climate and the environment in the middle Yellow River region of North China during the early Holocene (Li, Xiaoqiang, et al., 2003; Liu, Li, 2004: Chapter 2). It would have affected human occupation of the area by influencing vegetation, water levels in lakes and rivers, and river flooding events.

While the pollen record may provide an outline of vegetation communities in the past it is typically unable to link taxa to cultural use. This is the strength of palaeoethnobotany.

4.2.2.1 INITIAL HOLOCENE

The initial Holocene in North China gradually transformed from a cool and dry climate to a warmer, wetter climate due to the shifting East Asian monsoonal belt (An, et al., 2000; Li, Xiaoqiang, et al., 2003). Pollen profiles from the Yellow River basin suggest that grasses decreased while broad-leaved forest taxa increase between 12,000–9,800 cal BP (Yi, et al., 2003). This is consistent with a temperature increase. Peak rainfall occurred with the front of the East Asian summer monsoon at approximately 9,000 cal BP (An, et al., 2000) and this probably made the climate wet and almost sub-tropical in the study region. The monsoon front gradually moved towards southeastern China during the later Holocene (see fig 2.3 in Liu, Li, 2004: 24) and this climatic change may have been partly responsible for a decline in some subtropical taxa (Li, H., 1983: 24, 29). The establishment of this monsoon front was asynchronous across China. It was earliest in north-east China between c.10,000–8,000 cal BP and latest in the southern sub-tropical zone (An, et al., 2000).

4.2.2.2 HOLOCENE HYPsITHERMAL

The worldwide climatic event frequently known as the climatic optimum or hypsithermal, is generally placed at around 9,000 – 6,000 BP (Gamble & Soffer, 1990: 4). There is debate about the exact time of the Holocene hypsithermal in China (An, et al., 2000: 744). It has been variously placed at 10,000–7,500 cal BP and its end at 5,000–2,000 cal BP (An, et al., 2000: 744). This is partly because there is also debate about the exact definition of the hypsithermal. For instance, Winkler and Wang (1993) define it by post-glacial maximum temperatures. To other researchers, rainfall is the key characteristic with Bates and Jackson (1987) defining the Holocene hypsithermal as the most equable post-glacial climate including warm temperatures and abundant rainfall. An and colleagues (2000) define it on peak East Asian summer monsoon precipitation detected by geological data and numeric modelling.

A recent study using geological data and climatic modelling designates the period between 9,800–4,500 cal. BP as the Holocene hypsithermal in China (An, et al., 2000). In this study pollen was used as an indicator of rainfall (An, et al., 2000: 747) as floristic types are closely aligned to climatic and precipitation levels. During this time records show that precipitation in the central plains region increased significantly with subsequent high water levels in lakes and rivers in most parts of eastern and central China around 10,000–7,000 cal BP (An, et al., 2000: 747, 758).

In the central Yellow River region of Henan Province the Central Plains lowland areas were probably relatively moist during the Holocene hypsithermal (Liu, Li, 2004: 26). Much of the Yellow River valley was covered by sub-tropical forest type vegetation (Winkler & Wang, 1993: 247). Yangshao sites in Henan are typically small and scattered (Liu, Li, et al., 2002-2004: 83) and may also be located on relatively high ground (Cao, B., 1994: 64). This may be due to high rainfall and expanded freshwater in lowland regions (Liu, Li, 2004: 26). However, in southern Shanxi and western Henan, a dense distribution of Yangshao sites suggests a flourishing population which Li Liu (2004: 26-27) has linked to the southward retreat of the East Asian monsoonal front.

The Holocene hypsithermal at Midiwan in the upper Yellow River valley was detected between 10,000–7,500 cal BP (Li, Xiaoqiang, et al., 2003: 783). In the lower Yellow River region the hypsithermal at a similar time is visible in palynological studies which suggest the presence of monsoonal evergreen forest associated with diverse broad-leaved deciduous taxa and a decrease in herbs and conifers (Yi, et al., 2003: 624). The changing climates of the Holocene hypsithermal would have directly affected flora and fauna in the study region, and a decrease in precipitation or temperature may have led to local species extinctions. The impact this may have had on Neolithic populations in the study area requires further research before it is comprehensively understood.

4.2.2.3 HUMAN IMPACT ON ENVIRONMENT

Forest cover decreased in most regions of North China except for the northeast, during the Yangshao period after c.6,000 cal BP (Ren, G., 2007). Environmental changes have been documented in various regions of China during the Holocene period (e.g., Feng, Z. D., et al., 2006). The decline of certain taxa and some other environmental changes occurring during the mid-late Holocene have been attributed to human activity (Li, C. H., et al., 2007; Li, Y. Y., et al., 2006; Ren, G., 2007; Rosen, 2008). A major aspect of human activity is thought to include the intensification and expansion of crop cultivation during this period.

Ren (2007) notes a decline in forest cover in China from around 5,000 cal BP in all regions of China except for northeast China, based on his and colleagues' pollen data covering almost 150 sites across China (Ren, Guoyu 2007: 120). This decline in forest cover after 5,000 cal BP coincides spatially and temporally with expanding crop cultivation and agriculture (Ren, Guoyu 2007; Ren, Guoyu & Beug, 2002). Some researchers see the

decrease in arboreal or forest cover pollen over the past 5,000 years of the Holocene as being linked partly to climatic drying (see Ren, G., 2007: 120) as well as human activity (Ren, G. & Beug, 2002; Ren, G. & L. Zhang, 1998).

Having studied soil samples from the Yiluo Basin, using phytolith and other microfossil analysis methods, Rosen (2008) noted that vegetation changes began in the Yangshao (7,000–5,000 cal BP) period and continued until modern times. She suggests that the advent of these initial Yangshao-period changes coincides with farming in the region. An example is the early occurrence of a rice paddy located near modern Huizui village (Rosen, 2007b), interpreted from ancient waterlogged sediments and rice phytoliths.

The introduction of certain crops to the region undoubtedly affected local vegetation. Crops introduced during the early Neolithic period to North China include rice during the Yangshao and wheat and barley during the Longshan. The intensive use of certain cultivated plants including broomcorn and foxtail millet which also became domesticated in the early Neolithic in North China would also have upset the ecological balance. Being on the Yellow River floodplain would also have affected ancient people and their material culture. The Yellow River is noted in modern times for extreme flooding and for numerous course changes over the past 5,000 years (Yi, et al., 2003: 609; Zou, 1997). Along with flooding from the Yellow River, the introduction of intense cropping may have caused local or regional vegetation changes such as a loss of tree cover. Further research is required to fully understand the palaeoenvironmental change in the study region.

4.2.2.4 PALAEOENVIRONMENTAL SUMMARY

Pollen data typically looks at both the local and regional composition of a pollen assemblage. Taxa represented may be located within several kilometres of a sampled site depending on whether the pollen is wind or insect pollinated. As such, pollen profiles do not always agree when applied to a regional perspective. Ren (2007) mapped published pollen data from 2,000 year intervals from North China. In most regions forest cover increased from 10,000–6,000 cal BP although in the eastern monsoon regions forest cover declined slightly around 8,000 cal BP. This general model of a decline in forest taxa in the later Holocene is consistent with increased human occupation and crop cultivation in the region at this time.

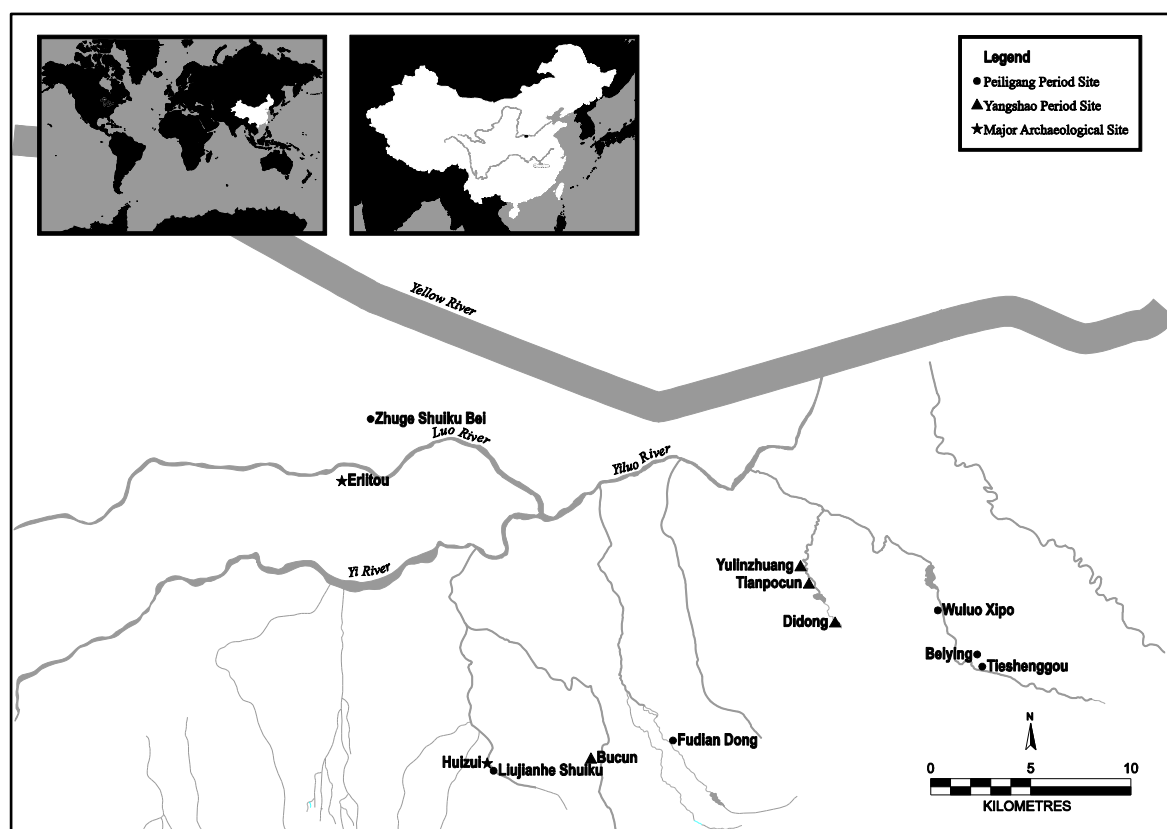


Figure 4-1 Sites sampled 2007–2008, in the Yiluo Basin region of Henan Province, China. After Li, Liu and colleagues, 2002–2004: Figure 4.

Table 4-1. Key to Figure 4-2 Showing Site Numbers and Names in English and Chinese

Site Number	Site Name (English)	Site Name (Chinese)	Age of Site
10	Xishiqiao	西石桥	Late Peiligang
29	Tieshenggou	铁生沟	Late Peiligang
42	Wuluo Xipo	坞罗西坡	Late Peiligang
44	Beiyong	北营	Late Peiligang
49	Tianpocun	天坡村	Yangshao
50	Yulinzhuang	羽林庄	Yangshao
52	Didong	堤东	Yangshao
124	Fudian Dong	府店东	Late Peiligang
152	Zhuge Shuiku Bei	逐各 水库北	Late Peiligang
187	Liujianhe Shuiku	浏涧河水库	Late Peiligang
204	Bucun	布村	Yangshao

Increased human population in the study region is suggested by an increase in Yangshao and later period sites (Liu, Li, et al., 2002-2004) and increased numbers of seeds in ash pits (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007). This includes an increased number of

settlements from five known sites during the Peiligang period to over thirty seven sites in the Yangshao period in the Yiluo survey region (Liu, Li, et al., 2002-2004: 83). More sites were found during later surveys (see chapter 5) taking the total number of Peiligang sites in the entire Yiluo Basin to 13 (Liu, Li, 2011). A corresponding increase in site numbers during the Yangshao is found in Henan province; over eight hundred Yangshao sites were found before the 1990s (Guojia, 1991). This is ten times more than the number of Peiligang sites found during the same period (Guojia, 1991). An increase in crop seed remains from the Yangshao period onwards has been taken as proxy evidence for increased populations in the region (Lee, G.-A. & Bestel, 2007).

4.3 Major Sites Sampled

A total of 13 sites were sampled for this research (see Table 4-1, Table 4-2 and Figure 4-1), with most sites being small sites located during the Yiluo Basin survey (see Liu, Li & X. Chen, 2007; Liu, Li, et al., 2002-2004 for more details of this survey). In addition, several sites were excavated prior to this research. Artefacts stored in museums or cultural institutions in China were sampled. A brief overview and description of these previously excavated sites will be presented here. The smaller sites that were discovered during the Yiluo Region survey and the Erlitou Survey (Liu, Li, et al., 2002-2004) will not be discussed in detail. These are typically small scatters of pot sherds that occasionally have ash pits. Many of the sites located during the Yiluo survey did not even have ash pits present and in such cases flotation samples were collected from cultural layers.

Table 4-2. Sites with Artefacts Examined as Part of this Thesis.

Site Name	Details of Site	County/Province	Age	References
Egou		Mixian County, Henan Province	Peiligang	Henansheng, 1981
Huizui		Yanshi, Henan Province	Yangshao and later periods	Li, Liu, et al., 2002–2004
Jiahu		Wuyang County, Henan Province	Peiligang	Henansheng, 1999
Shigu		Changge County, Henan Province	Peiligang	Henansheng, 1987
Shizitan	Locality S14	Jixian County, Shanxi Province	Late Palaeolithic	Xia, Z., et al., 2002; Li, Liu et al. 2011
Shizitan	Locality S9	Jixian County, Shanxi Province	Late Palaeolithic	Xia, Z., et al., 2002; Li, Liu et al. 2011
Tieshenggou		Gongyi County, Henan Province	Peiligang	Fu 1980; Kaifeng Diqu, 1980; IACASS 1986; Gongyishi, 1992

Site Name	Details of Site	County/Province	Age	References
Yiluo Basin Region		Henan Province	various	Li, Liu, et al., 2002–2004
	Beiyang		Late Peiligang	
	Bucun		Yangshao	
	Didong		Yangshao	
	Fudian Dong		Late Peiligang	Li, Liu, et al., 2002–2004
	Liujianhe Shuiku		Late Peiligang	
	Tianpocun		Yangshao	
	Tieshenggou		Late Peiligang	Li, Liu, et al., 2002–2004
	Wuluo Xipo		Late Peiligang	Li, Liu, et al., 2002–2004
	Xishiqiao		Late Peiligang	
	Yulinzhuang		Yangshao	
	Zhuge Shuiku Bei		Late Peiligang	

4.3.1 Egou

The Egou site is located in Mixian County, Henan Province (Henansheng, 1981). It is situated on a tableland surrounded by low hills, with the Wei and Sui rivers nearby. The site covers an area greater than 8,000 m² and over 200 m² of this was excavated in the 1970s. The cultural deposits tend to be thin and are generally less than 0.5 m beneath the surface. Six house foundations, 44 ash pits and approximately 370 artefacts were recovered from the excavated area. Of the 133 stone tools recovered, 20 were grinding stones and 18 of these were recovered from burials (Henansheng, 1981; see also Li Liu, et al., 2010c for an English translation). Three grinding stones from the Egou site were examined for residue and use-wear analyses by Li Liu and colleagues (2010c) and I assisted with this research. The grinding implements were found to be multi-functional tools that had been used extensively for acorn grinding, as well as for grinding yams, beans and grasses. Further details of the Egou grinding implements I examined for this research will be given in Chapter 9.

4.3.2 Huizui

Huizui site is located in the Yiluo region of Henan Province approximately 15 km from the well known site of Erlitou, capital of the first state level civilisation in China (Liu, Li, & X. Chen, 2003). Huizui was excavated in the 1950s (Henan Cultural 1961; Henan Institute 1990) and again in 2002–2006 by Professors Li Liu and Xingcan Chen (Chen, X., et al., 2010a, 2010b, 2010c). The site was occupied from the Yangshao period (7,000–5,000 cal BP) until modern times. Huizui was a stone tool manufacturing centre during the Erlitou period (Ford, 2001, 2004, 2007; Liu, Li, et al., 2002–2004: 90–91) when it probably supplied stone spades for use in agriculture to the nearby capital at Erlitou (Ford, 2007; Liu, Li, et al., 2002–2004: 91). It seems likely that oolitic dolomite used to produce the spades came from the Songshan mountains which are located a few kilometers south of Huizui (Liu, Li, et al., 2002–2004: 91; Webb, et al., 2007). The grinding slabs used to produce the spades were made of sandstone; two sandstone quarries with yellow and purple sandstones similar to those occurring at Huizui are located about 1km away from Huizui, to the south east and east respectively (Liu, Li, et al., 2002–2004: 90).

Archaeobotanical research on flotation samples from Huizui show an increase in seeds in general, and crop seeds in particular, from the Yangshao to the Erlitou periods (Lee, G.-A. & Bestel, 2007). This corresponds with an increase in site size and site number, across the Yangshao to Erlitou periods (Liu, Li, et al., 2002–2004). During the Erlitou period Huizui was a secondary or regional centre. Wild grass seeds as well as domesticated crops including wheat (*Triticum aestivum*) were present at this time (Bestel, 2006) and the presence of introduced early wheat may provide evidence for trade. More research is needed to fully understand the dispersal of wheat during the Longshan and Erlitou period in North China.

4.3.3 Jiahu

The Jiahu site is located in the Huai River valley of Henan Province. It lies east of Mount Funiu and in ancient times the Sha River ran to the north of the site while the Ni River currently runs south of the site (Li, X., et al., 2003: 32). The site was excavated in 1962 and has been excavated several times since the 1980s (Li, X., et al., 2003). It is 5.5ha in size and includes several multi-roomed houses (Henansheng, 1999; see Li Liu 2004: 75 for an English summary). The site denotes the earliest development of the Peiligang culture and is dated with conventional ^{14}C to 9,000–7,800 cal BP (Zhang, J., et al., 1999). Three phases have been identified at the site, phase one 9,000–8,600 cal BP; phase two 8,600–

8,200 cal BP and phase three 8,200–7,700 cal BP (Zhang, J. & Wang, 1998; Henan Institute, 1999: 515; Zhang, J., et al., 1999; Cucchi et al., 2011). These phases signify the early, early/middle and middle Peiligang culture respectively.

The significance of the Jiahu site is derived in part from the evidence of early writing (Li, X., et al., 2003) and the early development of music including a crane-bone flute (Zhang, J., et al., 1999). Stone tools and pottery appear to have been locally produced (Liu, Li, 2004: 78) and a number of stone sickles from the Jiahu site were analysed for plant residues (see Chapter 10). Residues from pot sherds at the Jiahu site were found to contain an early type of alcohol made from rice and honey as well as other ingredients (McGovern, et al., 2004). Jiahu also has evidence for early pig domestication by 8,600 cal BP (Cucchi, et al., 2011).

Perhaps the most hotly debated issue stemming from the Jiahu site is the evidence for early rice cultivation (Liu, Li, et al., 2007a). In the past debate has focused on whether this rice is domesticated or morphologically wild. Claims for domestication remain controversial (Chen, B. & Q. Jiang, 1997; Fuller, et al., 2007; Jiang, L. & Li Liu, 2006; Liu, Li, G.-A. Lee, et al., 2007; Zhang, J. & X. Wang, 1998). The rice at Jiahu is outside the modern geographical range for wild rice (Chen, B. & Q. Jiang, 1997) although it is unclear whether it was outside the range for early Neolithic wild rice as well. This is especially difficult to determine given the climatic and environmental changes across the region over the past 9,000 years. Despite this, numerous grains of rice at Jiahu suggest that rice was cultivated at the site. Dr. Zhijun Zhao, the paleoethnobotanist who examined the grains, has suggested the rice exhibited a large range of sizes and was probably in the early stages of domestication (Zhao, Z., & J. Zhang, 2009: 88, 93). Z. Zhao and J. Zhang (2009: 93) also suggested that the numerous grains of soybean (*Glycine max* ssp. *soja*) at the site were cultivated although they are morphologically wild. The subsistence spectrum from Jiahu is similar to sites such as Hemudu and Kuahuqiao from Zhejiang Province in South China, where rice was cultivated and a range of tubers and water plants were present in the waterlogged deposits (Zhejiangsheng, 2003; 2004; see also Liu, Li, G.-A. Lee, et al., 2007 for English translation). Other plant remains at Jiahu included acorns (*Quercus* sp.), water caltrop (*Trapa* sp.), lotus root (*Nelumbo nucifera*), walnut (*Juglans* sp.) and wild grapes (*Vitis* sp.) (Zhao, Z., & J. Zhang, 2009).

4.3.4 Shigu

The Shigu site in Changge county of Henan province is located at the confluence of the Shiliang and Xiaohong Rivers. A total of over 200 square metres was excavated in the 1970s (Henansheng, 1987). This revealed three house foundations, 189 ash pits, 69 burials and 440 artefacts. The artefacts recovered included eleven grinding stones, most of which were recovered from burials (Henansheng, 1987; Liu, Li, et al., 2010c). Several of these were subsequently stored in the Institute of Archaeology in Zhengzhou, Henan Province. The residues from these grinding implements were extracted and analysed for plant remains during fieldwork in 2008. Three grinding stones from this site were examined for residues and use-wear by Li, Liu and colleagues (2010c) and I assisted with this research. While residue preservation from the Shigu artefacts was poor, starch recovered included mainly acorn starch as well as bean and yam starch. Use-wear was consistent with acorn grinding (Liu, Li, et al., 2010c). Other Shigu artefacts were sampled for this thesis and the results are presented in Chapter 9.

Flotation was not routinely applied to sites excavated in China prior to the 21st century. However, macrobotanical remains visible to the naked eye were collected from the Shigu site. These carbonized plant remains were identified in the old excavation report as hazlenuts (*Corylus* sp.), walnuts (*Juglans* sp.), elm fruit (*Ulmus* sp.) and jujube dates (*Zizyphus jujuba*) (Henansheng, 1987).

4.3.5 Shizitan

The Shizitan site cluster is located in Jixian county, Shanxi Province (Xia, Z., et al., 2002). It is located in the middle reaches of the Yellow River region on the banks of the Qingshui River, a tributary of the Yellow River (Xia, Z., et al., 2002:71). A number of archaeological sites were recovered around the Shizitan area with different scatters of artefacts being recorded at separate localities. The Shizitan deposits stretch intermittently for about 15 km along the Qingshui River.

The S14 locality preserved the oldest archeological remains at Shizitan, dated to c. 20,700–20,000 cal BP (BA01158 on burnt bone dates to 20,700–20,000 cal BP as detailed in Appendix 4). The younger S9 locality returned dates on flotation samples of charcoal and burnt bone between 13,800 BP and 8,500 cal BP (Liu, Li, et al., 2011) (see

Appendix 4 for presentation of dates). The site is interpreted as transitional between the Palaeolithic and Neolithic based partially on microliths present in the upper 17,000 to 11,900 cal BP layers of the site (Xia, Z., et al., 2002; Shizitan kaogudui 2010).

Several grinding slabs were recovered from the Shizitan S9 site and these were analysed for plant residue and usewear by Professor Liu (Liu, Li, et al., 2011). I also assisted in this research including in making taxonomic identifications. This research is discussed but not presented here as Professor Liu did the bulk of the identification and analysis. Large amounts of acorn (*Quercus* sp.) starch grains were present on the Shizitan S9 site grinding implements and acorn grinding was interpreted as a major function of the artefacts. Starch from several grass taxa (Pooideae and Panicoideae subfamily) as well as beans and yams were also present, suggesting the implements were multifunctional. Fragments of haematite on the slabs were consistent with haematite pigment processing (Liu, Li, et al., 2011) and rock art located nearby was colored with hematite ochre.

4.3.6 Tieshenggou

The Tieshenggou site dates to the Peiligang period. It is located in a hilly area of Gongyi County, Henan Province (see also Liu, Li, et al., 2002-2004; Kaifeng Diqu, 1980). The site was excavated in the 1970s and 1980s (Fu, 1980; IACASS 1986; Gongyishi, 1992; Kaifeng Diqu, 1980) with excavations revealing a house foundation, animal bones, and stone and pottery artefacts. Over 100 ground stone tools were recovered including grinding implements and stones, spades, axes and sickles, many of which were subsequently stored in the Gongyi Museum. Excavation records with information about the recovery of these artefacts have since been lost.

The lithic implements found at Tieshenggou were made of limestone, quartzite and sandstone (Gongyishi, 1992; Kaifeng Diqu, 1980). These lithic types are all available in nearby rocky mountainous areas (Gongxian, 1991: 66-68) and in the riverbed of the Wuluo River (Liu, Li, et al., 2002-2004: 82). The stone tools were probably locally produced (Kaifeng Diqu, 1980). Carbonised fruit kernels were also recovered, although details about these are unknown.

A flotation sample taken from the Tieshenggou site did not produce any identifiable seed or nut remains. More than twenty of the grinding *mopan* and *mobang* implements which were stored in the Gongyi City Museum were analysed for plant residues as part of this

thesis research (see Chapter 9). Large amounts of acorn starch were present on these implements.

4.3.7 The Yiluo Basin Region

A number of small sites in the Yiluo Basin were sampled. As a heartland of Chinese civilization, the Yiluo region in the Middle Yellow River valley (Figure 4-1; Table 4-1) has been a focus of interdisciplinary investigations in order to understand the trajectory of social-economic development from the Neolithic to the Bronze Age. The Yiluo Archaeology Project, a Sino-Australian program led by Li Liu and Xingcan Chen has made a significant contribution to this research topic (e.g., Bestel, 2006; Ford, 2004; Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007; Liu, Li & X. Chen, 2007; Liu, Li, et al., 2002-2004). Almost 13 years of research on the project have led to a clearer understanding of the factors involved in increasing social complexity and the eventual establishment of the first state in China (see Liu, Li, & X. Chen, 2007). Multidisciplinary research expanding on these basic themes includes geomorphological and phytolith analysis, showing the environmental backdrop of the region, as well as providing evidence for environmental change across the early Holocene (Rosen, 2007b; Rosen, 2008). Lithic studies indicate that stone tools such as spades were created for export at Huizui in Henan Province, China (Ford, 2001, 2004, 2007; Webb, et al., 2007). These may have been used to create the increased agricultural productivity of the region noted by Qiao (2003, 2007).

The Yiluo Basin Region is recognised by both Chinese and western scholars as an area of early social complexity in North China. Chinese scholars generally view it as the location of the mythical Xia Dynasty which is referred to in written records dating from the Shang Dynasty (Xia-Shang-Zhou, 2000). However, not all western scholars agree that Erlitou was the center of the Xia Dynasty, partly due to concerns about the accuracy of historical records (e.g. Bageley, 1999:131; Liu, Li & X. Chen, 2003). Other issues in the debate related to discussions regarding whether the Erlitou site was a complex chiefdom (Thorp, 1991) or a state level society (Liu, Li, 2004).

The Yiluo River valley is a large and agriculturally fertile river basin (Liu, Li, et al., 2002-2004: 76). The Luo River in the south joins the Yi River in the north and they join together to become the Yiluo River which empties into the Yellow River (Liu, Li, et al., 2002-2004: 76). Surveys in this region during the early part of the 2000s aimed to identify Neolithic sites in the area (Erlitou Working Team, 2005; Liu, Li, et al., 2002-2004). These surveys

were carried out by two separate groups who used slightly different recording and surveying methodologies. Dr. Hong Xu's team surveyed the western half of the Yiluo Basin near to the city of Luoyang (Erlitou Working Team, 2005). Professor Li Liu (now at Stanford) and Professor Xingcan Chen (IACASS) used a full coverage survey method to survey in greater detail the eastern half of the Yiluo Basin closer to Yanshi (Liu, Li, et al., 2002-2004). This led to the recovery of substantial numbers of stone spades from the Huizui site (Ford, 2001, 2004, 2007) and eventually this site was excavated (Chen, X., et al., 2010a, 2010b, 2010c).

Some of the smaller sites identified during these surveys were sampled for bulk sediment samples. A total of seven Peiligang sites and four Yangshao period sites (ten flotation samples) from the Yiluo Region surveys were analysed as part of this project. This included two samples from the Erlitou Working Team's survey and 8 samples from Professors Li, Liu and X. Chen's survey. Other research on Yiluo Basin flotation samples has been done by Lee (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007).

4.3.7.1 PEILIGANG PERIOD SITES IN THE YILUO BASIN

Peiligang period sites in the Yiluo region were between 0.2–0.7 ha wide and had a site depth or 'thickness' of 0.5–1m. (Liu, Li, et al., 2002-2004: 81). Four of these small sites were located in the upper Wuluo valley on a floodplain. They include the Beiyang, Liujianhe Shuiku, Tieshenggou and Wuluo Xipo sites, all of which were sampled for this thesis (see Chapter 8). The site of Tieshenggou was previously excavated (see above) (Fu, 1980; IACASS, 1986; Gongyishi, 1992; Kaifeng Diqu, 1980). At Wuluo Xipo four carbonized grains of *Setaria* sp. millet were recovered without the dorsally flattened backs of wild green foxtail grass (*Setaria italica* ssp. *viridis*). These were interpreted as intermediate between wild and domesticated foxtail millet forms (Liu, Li, et al., 2002-2004: 82). Given the small size and thin cultural deposits at these sites, Li Liu and colleagues (2002-2004:81) have suggested that these represent seasonal occupation.

The Fudian Dong site is located along the Gan'gou River which runs to the west of the Wuluo River (Liu, Li, et al., 2002-2004: 82). It was also relatively small but several ash pits were present and bulk sediment was collected from one pit. Thin black pottery wares which are difficult to make and which therefore suggest a high degree of technical competence in pottery, were recovered from the Fudian Dong site as well as Wayouzui, also in this region (Liu, Li, et al., 2002-2004: 82-83). This may suggest some initial craft

specialization occurred at the site but it is unclear whether the pottery was locally made or whether it was traded from nearby sites (Liu, Li, et al., 2002-2004: 82-83).

In addition, two small sites from the western side of the Yiluo Basin were floated and their charred remains examined. Due to minimal reporting (Erlitou Working Team & CASS, 2005), few details are known about these sites other than their plotted map locations.

4.3.7.2 YANGSHAO PERIOD SITES IN THE YILUO BASIN

Thirty-seven sites in the Yiluo Basin were recorded during the Yiluo survey (Liu, Li, et al., 2002-2004: 84-85) and four of these were sampled for macro remains. These sites were all in the eastern part of the Yiluo Basin and included Bucun, Didong, Tianpocun and Yulinzhuang. Little is known about the Bucun, Didong and Tianpocun sites but the Yulinzhuang site preserved rice phytoliths (Liu, Li, et al., 2002-2004: 85). Yulinzhuang is situated on the tablelands near the Shengshui River which would have been draining the Yiluo Basin during the Yangshao period although it is now a dry gully (Liu, Li, et al., 2002-2004: 85). Burials, pits and other features were visible in the eroded terrace cuts (Liu, Li, et al., 2002-2004: 85).

4.4 Summary

The study region covers parts of Henan and Shanxi Provinces including the central China loess plain and plateau. After the last glacial maximum and deglaciation a dry steppe environment prevailed that was interspersed with broadleaved taxa. The Holocene in North China dates to around 11,000 cal BP and the mid-Holocene hypsithermal covers the period from c. 9,800–4,500 cal BP (An, Z., et al., 2000). This includes both the Peiligang and Yangshao periods and coincides with the emergence of agriculture in North China.

A small number of Late Palaeolithic and early Neolithic sites were examined as part of this research. Flotation samples were taken from two localities from the Late Palaeolithic Shizitan site in Shanxi Province. Flotation samples were also collected from 7 Peiligang and 4 Yangshao Yiluo Basin sites in Henan Province. In addition artefacts including grinding implements and stone sickles from previous excavations in Henan Province were examined from the Egou, Tieshenggou, Shigu and Jiahu sites. Full details of the sampling methodologies used are given in Chapter 5.

Chapter 5: Sampling and Analysis Methodology

5.1 Overview

A range of archaeological samples were collected during field seasons in November 2007 and in September–October 2008 in the Henan area of North China. Initially the project was designed to investigate subsistence using a range of archaeobotanical techniques in the Middle Yellow River region of Henan and Shanxi provinces. The initial temporal scope of the project was to span the entire range of the Neolithic in North China from the initial agricultural Peiligang period (9,000 – 7,000 cal BP in Henan province) to the first state level Erlitou civilisation (*c.* 3,900–3,500 cal BP; see Liu, Li, and X. Chen, 2003). The research focus was altered to investigate subsistence across the initial two cultural periods evident in the Yiluo Region, the Peiligang and Yangshao periods (9,000 – 5,000 cal BP)³. During research, macrobotanical flotation samples were made available from the Palaeolithic site of Shizitan, in Shanxi province (north of Henan), and these were included for analysis. The Shizitan site cluster dates between *c.* 20,700 – 20,000 cal BP to 8,470–8,210 cal BP ($8,340 \pm 130$ cal BP in Shizitan kaogudui 2010: 16), hence it is ancestral to the Peiligang period in the Yiluo area. The Palaeolithic data provides useful baseline subsistence data prior to a research focus on Neolithic subsistence and the transition to food producing, sedentary communities in the Neolithic of the Yiluo Region.

Different types of samples were collected from various Peiligang and Yangshao period sites (Table 5-1; Table 5-2). Many of the sites accessible for research were located by the Yiluo Archaeology Team and the Erlitou Team as part of the Yiluo Basin survey (Erlitou Kaogudui, 2005; Liu, Li, & X. Chen, 2007). Samples collected include bulk flotation samples for macrobotanical analysis, soil sections for palaeoenvironmental analysis and residue samples. Residues were collected from a range of artefacts stored in museums and other cultural heritage institutions and included grinding implements and denticulate stone sickles. In this chapter, the field or museum collection techniques for each type of sample will be described. Additionally, the laboratory analysis and residue extraction methods used to analyse the samples for plant remains will be explained in detail.

³ In Henan Province the Peiligang period is considered to last from 9,000–7,000 cal BP including the site of Jiahu. In the Yiluo Region the single date available for the Peiligang period is from the Fudian Dong site (see Appendix 4). This site dates to 7,504–7,812 cal BP (NZA 33139), which represents the late Peiligang. This date is consistent with pottery typologies in the area which show late Peiligang characteristics.

Table 5-1 Summary of Sampling Strategies

Sample Context	Method and Date of Collection	Intended Analytical Methods	Types of Samples
Soil from ash pits or other cultural features	Bulk soil samples collected during Nov 2007 field season and floated at Huizui Field Station in China, before posting to Australia.	Starch, pollen, phytoliths, flotation samples to be used for macrobotanical research	Soil samples, flotation samples
Soil from non-cultural areas	Collected during Sept–Oct 2008 field season.	Pollen and palaeoenvironment	Soil samples
Grinding slabs and mullers/pestles	Collected in previous excavations and held in museum. Sampled Nov 2007 field season.	Starch, phytoliths	Residue samples
Stone sickles	Collected during previous excavations and surveys, and held in museum. Sampled Sept–Oct 2008 field season.	Starch, phytoliths	Residue samples

Table 5-2 Inventory of Flotation Samples by Age

Site Age	Approximate Time (Years cal BP)	Total No. of Sites for This Age	Total Litres of Soil Floated for this Age	Abbreviation of Age
Late Palaeolithic	c.20,700–20,000	1	45	Late pal
Late Palaeolithic	c. 13,800–8,500	1	124	Late Pal
Late Peiligang	c. 7,500–7,000	7	90.5	L. PLG
Yangshao	c. 7,000–5,000	4	42	YS

Note: There are no flotation samples for the Peiligang sites of Egou, Jiahu, Kangjia or Shigu available for this study despite the fact that there are many residue samples from these sites. This is because these sites were excavated in previous years and are not now accessible for sampling (see Chapter 4 for details of sites including those previously excavated). See Chapter 4 for reference details of dates.

Two fieldwork seasons of one month each were undertaken in 2007 and 2008, in Henan Province, North China. A total of 11 sites in the Yiluo River basin region of Henan Province that had been identified as part of the Yiluo Regional Survey Project (see Liu, Li, & X. Chen, 2007) were sampled for flotation and archaeobotanical analysis during the 2007 field season (see Appendix 1; see also Figure 4-1 for map of sites sampled). Bulk soil samples of up to 3 litres were taken from features of various ages at these sites. Local field workers carried out flotation using an SMAP-style device (Figure 5-1). When completed, floated and dried light fraction samples were sent to Melbourne, Australia and San Francisco, USA, for analysis. Unfortunately, heavy fraction samples were misplaced and so were not available for analysis. Small bags of sediment from profiles or sections of

terraces from five of these previously visited sites during the Sept–Oct 2008 field season were also collected for palynological analyses.

Large scale excavations of sites could not be carried out. Therefore artefacts previously collected from surveys or excavations in Henan province, which are now stored in museums or archaeological institutes were sampled. Grinding slabs or bases known as *mopan* and hand stones or mullers known as *mobang* in China were sampled from three previously excavated Peiligang aged sites (Egou, Shigu and Tieshenggou). These artefacts were stored in the Zhengzhou Institute (Egou and Shigu) and the Gongyi Museum (Tieshenggou). Stone sickles characteristic of the Peiligang period which had been excavated or collected from the sites of Egou, Jiahu and Shigu in previous decades were also sampled. Details of the sampling methodology will be discussed below.

In summary, flotation, palaeoenvironmental and artefact residue samples were obtained from two localities at the Palaeolithic site of Shizitan (17 samples). Ten Peiligang samples from seven sites and four Yangshao sites were also sampled (see Appendix 1 and Appendix 2 for complete list of Palaeolithic, Peiligang and Yangshao samples available for analysis). Various sampling techniques were applied. Details of how the various sites were sampled and for what purpose, are discussed below.

5.2 Macrobotanical Samples

Prior to the advent of the new ‘scientific’ archaeology in the 1960s, plant remains from non-waterlogged or non-dessicated archaeology sites were generally recovered by hand (Pearsall, 2000: 12). This meant that only those seed or plant remains visible to the naked eye were collected (Pearsall, 2000: 12, 20). Flotation is still not routinely carried out at archaeology sites in many parts of the world despite increasing awareness of the valuable archaeological remains that may be obtained from this procedure (Zhao, Z., 2004). Initially Struever (1968) in the USA and then Jarman and colleagues (1972) in Britain developed water flotation methods to extract the light, floating fraction containing charred plant remains from sediments. Where creek access is not readily available and tap or piped water is plentiful, it is now common to use a modified version of the SMAP (Shell Mound Archaeology Project) machine first described by Watson (1976) (see also Crawford, 1983) (see Figure 5-1). A description of the history of flotation is beyond the scope of this thesis. Details of the history of flotation in China may be found elsewhere (Liu, C. J., et al., 2008).

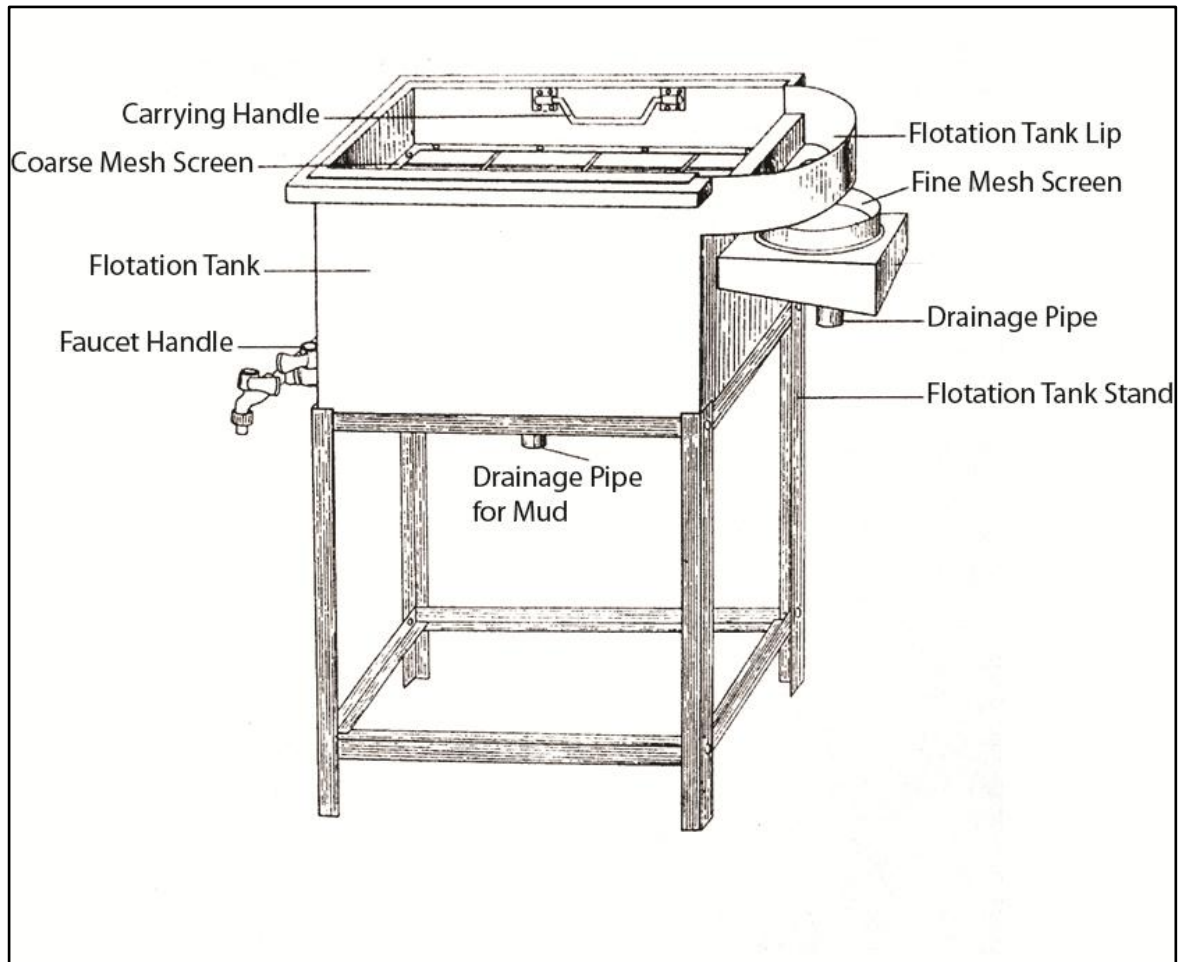


Figure 5-1 Flotation machine used to process Yiluo region flotation samples (Zhao, Z., 2004: 82, figure 1. See also Bestel, 2006). Note that the base is an inverted pyramid which allows mud to drain from the tank.

The collection of bulk sediment samples for macrobotanical analysis and then laboratory sampling, sorting and identification methods will be described. Samples from the Palaeolithic site of Shizitan and from the Peiligang and Yangshao period sites in the Yiluo River region will be discussed.

5.2.1 Macrobotanical Samples—Field Sampling

Bulk sediment samples of up to 25 kg of sediment were floated in buckets of water in China at the Shizitan site localities 9 and 14 by Ms. Yanhua Song (see

Appendix 5) and the dried flotation samples were subsequently sent to Melbourne and San Francisco for analysis. During the 2007 fieldwork season bulk sediment samples were collected from multiple sites in the Yiluo River Basin area of Henan Province in north China and floated in China prior to being sent overseas for analysis.

In common with other Palaeolithic sites in China, ash pits were not present at the Shizitan site. Ash pits are generally thought to be a Holocene or Neolithic development reflecting some degree of sedentism evident in the archaeological record (cf. Cohen, D. J., 2011; Jiang, L. & Li, Liu, 2006: S281). Sediment samples from the Shizitan localities that were floated were taken from intact cultural layers rather than from ash pits, meaning their depositional context is slightly different to some of the later Peiligang and Yangshao period sites analysed.

Flotation samples from the Neolithic sites of the Yiluo region were mainly taken from ash pits (see Appendix 6) for list of all flotation samples collected from the Yiluo Region during 2007 and 2008 fieldwork seasons). Ash pits are common features of the Chinese Neolithic landscapes (Figure 5-2) and were thought to be pits initially dug for storage (Chang, K. C., 1986: 90; Lu, H., et al., 2009a), but their actual function is uncertain. They were eventually filled with refuse including domestic refuse such as ashes, pot sherds, animal bones and other cultural material. Sediments from these pits make excellent samples for macrobotanical analysis and flotation because the ashy sediment contains abundant seeds, wood charcoal and other charred remains (e.g., Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007). For this reason ash pits are commonly sampled in Chinese Neolithic archaeobotany. However, where sites did not preserve ash pits or ash pits were inaccessible (high on a terrace for instance), cultural layers identified by diagnostic Peiligang period pottery were sampled instead. These usually contained charred wood charcoal and other charred material.

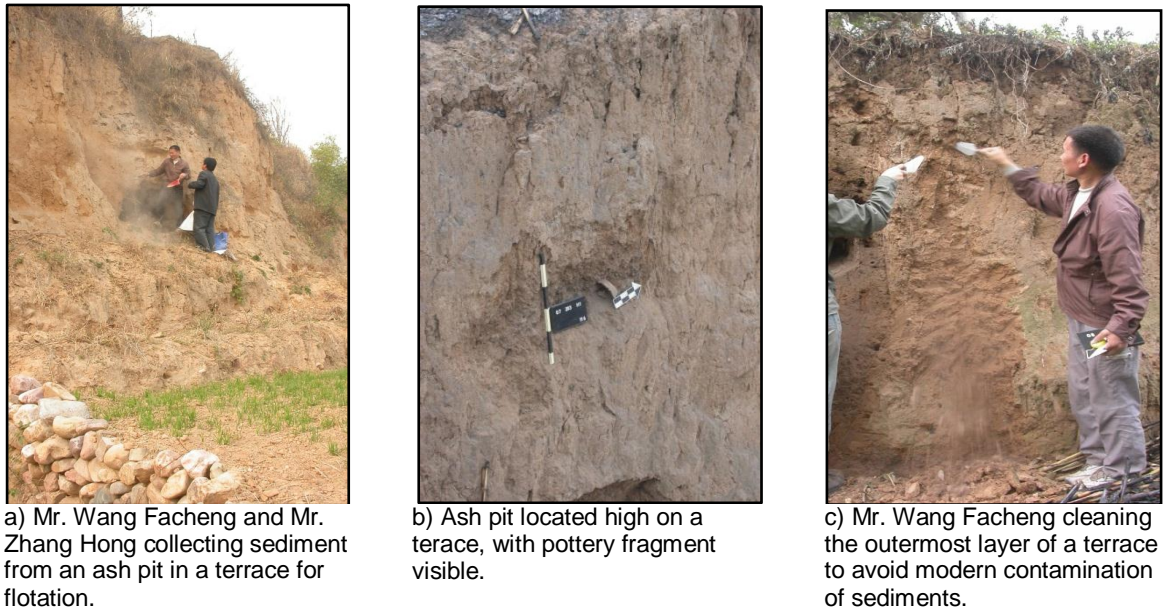


Figure 5-2a–c Collection of bulk sediment samples from ash pits for flotation. Photos: Sheahan Bestel

Flotation samples from the Peiligang and Yangshao periods in the Yiluo region were collected during fieldwork in 2007 and 2008 (Figure 5-2) at sites that had been previously located and identified as part of the Yiluo Survey Project (Liu, Li, & X. Chen, 2007). A total of five sites from the Peiligang period and 37 from the Yangshao period were located as part of this survey (Liu, Li, et al., 2002-2004: 81-84). Two more Peiligang sites were subsequently identified by Professors Li Liu and X. Chen (Qiao, 2007) and local archaeologists identified two more (Liu, Li, 2011a). Four more Peiligang sites were recovered during Dr. Xu Hong's survey in the western half of the Yiluo Basin (Erlitou Kaogudui, 2005). This brings the total of Peiligang sites in the Yiluo Region to thirteen.

Collection of flotation samples involved relocating a site noted in previous surveys, often with the help of field technician Mr. Wang Facheng of the Huizui Field Station, and Mr. Hong Zhang from the Erlitou Field Station, who participated in initial surveys. When an ash pit or other layer suitable for sampling was located at the site, the terrace surface was scraped back by at least 10 cm to reveal an uncontaminated fresh surface. An ashy part of the pit or cultural layer was collected in 10 litre plastic sacks. To preserve sites for future research only one or two samples were taken from each site, meaning that sites had less than 20 litres of sediment collected. Consequently samples sizes are small, but have preserved important materials for future archaeological research. This is an important part of archaeological conservation and modern archaeological ethics.

After collection sediments were laid on sacks on the roof of the Huizui Field Station to dry slowly. Sediments that are too dry may allow seeds and other remains preserved in them to crack and break. When sediments were almost dried they were floated by local workers. A modified version of the flotation methodology detailed in Crawford (1983) was used with a SMAP flotation machine similar to that depicted in Z. Zhao (2004) (Figure 5-1). For this procedure hoses were attached to a large tank filled with cold water and sediment bags emptied into the tank. The heavy fraction of the sediment will sink to the bottom of the tank and large nutshells, bones and stones as well as other small fragments contained in the sediment will remain trapped by the 2 mm screen. The sediment is stirred gently to release charred material trapped by the soil. The lighter fraction of the sediment containing carbonised plant remains, seeds, rootlets and other organics, floats to the top of the tank and is swished off into a cloth bag placed over a small 0.212 mm sized sieve. After flotation the sample was sealed in cloth bags and dried slowly in the shade to limit cracking or breaking of fragile charcoal and seed specimens (Pearsall, 2000: 43). Samples were sent to La Trobe University in Melbourne and also to Stanford University in San Francisco for identification and analysis.

5.2.2 Macrobotanical Samples—Laboratory Methods

Samples received in the archaeology laboratory in Melbourne and in San Francisco were weighed and sieved through a set of nested sieves (2 mm, 1 mm, 0.425 mm, 0.212 mm and sieve pan). The two most common crops in ancient Neolithic North China, broomcorn and foxtail millet tend to separate out in the 2 mm and 1 mm screen respectively, and this makes sorting and identification of seed remains easier. Modern organic remains including roots were removed and lithic or small sediment particles were separated out from the faunal (shell or insect and other small animal), charcoal, seed and vegetative or other plant remains. A Nikon or a Zeiss microscope was used to sort remains using a low power x10–20 power objective. Plant remains were photographed using a Nikon DS–5 camera and DS–5 software or a Zeiss AxioCam HRc camera and Zeiss Axioskop 4.8 software. Statistical tests and graphs were carried out using the JMP program version 2004.

Identification of macrobotanical remains was carried out using a modern reference plant collection of over 1,000 accessions including seeds (see Chapters 6 and 7). Dr. Gyoung-Ah Lee and Professor Gary Crawford assisted with identifications and seed photography.

Professor Gary Crawford's seed reference collection at the University of Toronto was utilised for comparative reference material. Some seed and plant remains were examined and compared with modern references using a Neoscope JCM 5000 SEM.

5.3 Microfossil Samples

Microfossils refer to small plant or other remains including phytoliths, pollen and starch grains that are usually examined by magnifying the sample 200 or more times.

Microfossils may be safely extracted from residues remaining on previously excavated artefacts (Barton, H., 2007; Kealhofer, et al., 1999) provided potential contamination issues are adequately addressed. Survey artefacts examined by Hart (2011) preserved few post depositional contamination remains, suggesting that this is unlikely to complicate or confound artefact residues. Residue samples frequently contain sediment, among other organic and microfossil remains. The difference between sediment and residue samples is that residues are taken off an artefact, whereas sediment samples are merely taken or collected straight from the ground.

In the case of microfossil samples, field or museum sampling here refers to the extraction of residues from previously collected or excavated artefacts. The artefacts under analysis were stored in museums or archaeology institutes after their initial excavation in previous decades. Residues taken from stored artefacts have different post depositional or post collection contamination issues than recently collected samples in the field. Methods of resolving possible post excavation contamination issues were assigned particular importance during this research and these are discussed below.

Residues were collected using several different methods from a range of artefacts. These artefacts include pot sherds, grinding *mopan* and *mobang* implements, stone sickles or knives and human and animal teeth. Methods of extracting a residue sample include scraping off sediment adhering to an artefact (Piperno, et al., 2009), extracting a sample from an artefact using water and pipette (Fullagar, et al., 2006: 597; Piperno, et al., 2009), or sonicating an artefact in an ultrasonic bath (Fullagar, et al., 2006: 597; Piperno, et al., 2009). I will discuss the collection of samples for microfossil analysis below, including the type of artefacts examined, the field or museum method of residue collection and the laboratory protocol for residue extraction. Reasons for the choice of laboratory protocol and other published and unpublished protocols made available will be examined and evaluated.

5.3.1 Museum Collection of Grinding Implement Residues

Samples from grinding *mopan* and *mobang* were taken from the artefacts stored in two separate museum collections (see Table 5-3; for full list of grinding implements sampled see Appendix 1). The Gongyi City Museum held in its collection 27 grinding *mopan* or *mopan* fragments and 22 *mobang* collected from the Tieshenggou site. Excavation and surveys were carried out there in the 1970s (Fu, 1980; IACASS, 1986). The Tieshenggou grinding implements were not found during the excavation but were found by local villagers when digging soil for making bricks. The tools were subsequently handed to archaeologists. Therefore, the cultural context of these tools is unclear. But they seem to have come from a relatively small area, perhaps a burial site. Grinding artefacts from Peiligang sites tend to be found in burials rather than residential areas (Henansheng, 1981). The Institute of Archaeology in Zhengzhou held six grinding *mopan* and eight grinding *mobang* recovered from burials during excavation at the Egou site carried out in the 1970s and 1980s (Henansheng, 1981). The Zhengzhou Institute also held three grinding *mopan* slabs and three *moban* roller/pestles style implements unearthed from burials discovered during excavations in the 1970s at the Shigu site (Henan Institute 1987). Multiple samples were taken from all these artefacts. Where possible complete or whole artefacts were sampled, especially those recovered from known contexts including specific tombs rather than from surface surveys.

Table 5-3 Grinding Stones Sampled

Site	Site (Chinese)	No. <i>Mopan</i> Grinding Slabs	No. <i>Mobang</i> Roller /Pestles	Collection Provenance	Age of Site
Egou	莪沟	6	8	Excavation	PLG
Shigu	石固	3	3	Excavation	PLG
Tieshenggou	铁生沟	27	22	Excavated by locals and collected by archaeologists	PLG

Prior to wet methods of residue extraction artefacts were brushed or cleaned of dust and loosely adhering sediment. Prior to residue sampling, any visible dry soil residues on an artefact were gently scraped using a soft plastic pipette tip or plastic spatula. Plastic is less likely than metal to leave wear traces which may hinder future research, or to damage the artefact. Residue samples were taken from multiple locations on the artefact and stored in plastic zip locked bags or in microcaps for secure storage prior to processing and analysis. Studies have shown differences in the wet or dry types of residues collected (Liu, Li, et al.,

2011; Piperno & Holst, 1998). Piperno and Holst (1998: 772) found fewer starch grains in dry samples scraped from the top of artefacts and more starch granules extracted by wet-pipetting residue from underneath a dry sediment residue. This was used to indicate a lack of post depositional contamination of microfossils from surrounding sediments (Piperno, et al., 2009: 5021; Piperno & Holst, 1998: 772). Hart (2011) has suggested that contamination does not penetrate to the deepest levels of survey artefacts. This suggests that artefact or residue contamination is unlikely to be of concern.

Wet sample or water pipette residue collection involved dropping distilled water onto the artefact, allowing it to soak in for a minute or more and then gently scratching the artefact. The residues dislodged by this process were extracted in a drop of water and remained suspended until starch lab extractions were processed. A small, soft object such as a plastic pipette tip was used to scrape the artefact and dislodge residues. Piperno and colleagues (2009: 5024) used a needle inserted into cracks and crevices for this type of sampling, although it is not clear whether metal objects such as needles or spatulas may create striations on a slab which confuse subsequent use-wear analyses.

A total of 36 grinding *mopan* slabs and 33 *mobang* rollers were sampled for this study. Multiple samples, including both wet and dry residues, were taken from some slabs as control measures. Duplicates of some of these samples were extracted and published as part of a pilot study into Peiligang North Chinese grinding implements (Liu, Li, et al., 2010c). Dual samples of these were subsequently extracted and analysed for use in this thesis, with all work presented in this thesis being carried out by the author unless stated otherwise⁴.

5.3.2 Laboratory Extraction of Phytolith and Starch Residues

Some wet samples collected from grinding artefacts exhibited relatively few sediment particles and so did not need processing prior to being mounted on a slide and examined for residues (cf. Aranguren, et al., 2007: 848; Piperno, et al., 2009: 5024). However, other residue samples contained high amounts of particulate matter that would have obscured viewing and hindered recognition of microfossils under microscopic examination. To

⁴ The only research forming part of this thesis that was jointly carried out, relates to the collection of modern reference samples. This is outlined further in Chapter 6.

concentrate the microfossils extracted from a sample and allow for more efficient recovery, heavy liquid separation procedures were used.

The aim of microfossil extraction procedures is to release the starch or phytolith from the sedimentary matrix and also to remove unwanted portions of sediment, such as clays, carbonates and in some cases organics, from this matrix (cf Piperno, 2006: 60). The basic rule adhered to during the current research is that more processing means more possibilities for loss of microfossils through density separation of sediments or through chemical or heavy density extractions. Thus the need for minimal processing was weighed against the need to easily and in a time effective manner examine the samples mounted on several hundred residue slides. Published extraction procedures frequently relate to large sediment samples rather than smaller residue samples. The smaller numbers of phytoliths and possibly starch grains in residue samples, mean that care should be taken not to lose microfossils from the sample during excessive laboratory processing or preparation.

Initially, it was proposed to extract starch and phytoliths in separate laboratory protocols. However, time constraints for the project, the numbers of samples involved, and in some cases the small amount of residue collected from the artefact did not allow separate extractions to be carried out. The literature describes several methods of simultaneous microfossil extraction procedures (e.g., Horrocks & Barber, 2005; Lentfer & Boyd, 2000). Following a protocol adapted by Field from Kealhofer (Field, Judith, n.d.), the non-toxic heavy liquid sodium polytungstate was used in a dual starch-phytolith extraction process (see Appendix 3). Sodium polytungstate has several advantages when compared to other high density liquids. It is less toxic than other heavy liquids such as zinc bromide, sodium iodide (Six et al., 1999) and tetrabromoethane (Savage, N. M., 1988) and it can be mixed to create a range of densities as required (Six et al., 1999:1193). Despite the initial expense it is also recyclable (Savage, N. M., 1988; Six, et al., 1999). For the research presented in this thesis recycled sodium polytungstate was not used.

The wet and dry residue samples collected from grinding mopan and mobang were treated in different ways in the lab. Dry sediment samples were weighed (where possible) and then underwent a sedimentation settling process prior to being centrifuged with a heavy liquid to simultaneously extract phytoliths and starch grains. Wet samples, if clean enough, were placed immediately on a slide for observation; if dirty they were treated with a heavy

liquid to extract phytoliths and starch prior to mounting. Details of the two procedures will be given below.

5.3.2.1 MICROFOSSIL EXTRACTION FROM DRY SEDIMENT SAMPLES

Following protocols detailed in Rosen (2000) approximately 0.8000 mg sediment was weighed out and placed in a beaker, with lumpy or hard sediment being lightly squashed to release microfossils (heavy grinding of soil in this step may ruin or break silica aggregates). Roots or other organic particles were removed from the sample by hand. Some researchers use a sieve to remove roots and other particles greater than 106 μm (Field, Judith, n.d.) or greater than about 250 μm (cf Piperno, 2006: 91). Given the preliminary nature of residue extractions from my sites in China and the fact that it was not clear whether large aggregations of silica bodies or clusters of starch would be present in the samples, use of sieves to remove roots and to help break up the sample was initially avoided. Subsequent research has revealed large (>250 μm) clusters of starch gathered along fibres, as well as feather barbs over 300 μm in these samples, justifying a cautious approach.

The deflocculation or disaggregation step that Piperno (2006: 91) advocates to release microfossils from adhering carbonaceous or other sedimentary particles was not carried out for my samples due to the small amounts of residue being processed and also due to the fine grained structure of the loess sediments enclosing the microfossils. Deflocculation increases the time it takes to process an entire sample, with some researchers deflocculating samples for up to a week (Kealhofer, et al., 1999: 533). Sonication of artefacts to collect microfossil samples may aid in the release and break-up of small sedimentary particles (cf Lentfer & Boyd, 2000: 31). Where artefacts were small enough to be placed inside a 50 ml centrifuge tube they were sonicated to remove residues. This method of removal of microfossils preserved in cracks and crevices of the artefact is roughly equivalent to deflocculation but has the added advantage of not allowing microfossil loss through multiple transfers of the sample. Grinding implements while being too large to sonicate, may still preserve large quantities of starch grains. This suggests that deflocculation and sonication are not entirely necessary for recovery of large amounts of starch.

The gravity settling or sedimentation process used to remove clays and fine soil particles from the dry residue samples followed Stokes' law (see also Piperno, 2006: 91).

Approximately 0.8 mg of sediment was weighed out and placed in a 1,000 ml beaker filled to the 8 cm line with distilled water following Rosen (2000). Each sample was stirred once and then allowed to sit for one hour to allow small sediment and clay particles to settle. After this the water was decanted and the process began again. Sedimentation settling was carried out as many times as necessary for each sample, with fine grained loess samples typically requiring two sedimentation procedures before the sample was visibly cleaner. Lentfer and Boyd (1999) recommend centrifuging as a comparable alternative to reduce time spent in sedimentation. However, this was not used for the research presented here.

After sedimentation the sample was placed in a 10 or 15 ml centrifuge tube and a solution of 6 percent hydrogen peroxide (H_2O_2) was transferred to each tube to oxidise and clean the sample (Field, Judith, n.d.). Samples were continuously shaken for about 10 minutes and then centrifuged at 1,500 rpm for 5 minutes. After this two subsequent water rinses removed hydrogen peroxide from the sample. About 5 mls of 10 percent hydrochloric acid was placed in each tube to remove carbonates (Piperno, 2006: 94; Rosen, unpub.). The sample was then centrifuged at 1,500 rpm for 5 minutes. Where the original sample size was small both these steps were omitted to avoid possible residue loss.

For microfossil extraction the non-toxic heavy liquid sodium polytungstate (hereafter SPT) was made up to a specific gravity of approximately 2.4 and added to the tubes containing the sediment sample. After centrifuging for 15 minutes at a slow speed of 1,000 rpm the part of the sample containing starch and phytoliths was pipetted or poured into a new clean tube and rinsed with water between two to five times to remove any remaining SPT.

5.3.2.2 MICROFOSSIL EXTRACTION FROM WET SEDIMENT SAMPLES

Where possible if the sample was clean and very few residues were visible, residues were mounted directly on a slide (cf. Perry, 2004). For more dirty samples with a greater proportion of sediment particles in the sample, both dry and wet residue samples were transferred to a centrifuge tube with the aid of water. These were then treated in the same way as dry sediment samples (see above). Sodium polytungstate mixed to a specific gravity of approximately 2.4 was used to allow extractions of phytoliths and starch, with samples centrifuged and rinsed multiple times in distilled water after being sorted in a heavy liquid. In cases of especially dirty residue samples a 6 percent hydrogen peroxide solution was used to clean the sample of dirt particles before the heavy liquid separation

and rinsing procedures were carried out. In certain cases an acetone rinse was used to help dry the samples prior to mounting.

5.3.2.3 MOUNTING MICROFOSSIL EXTRACTIONS

There is some disagreement among microfossil experts as to the most appropriate mounting medium to use for both ancient and modern reference slides. For example, in a survey of recent literature a range of mounting media were used including several toxic compounds. Fullagar and colleagues (2006: 597) used karo syrup and benzyl benzoate to mount starch and phytoliths respectively. Pearsall and colleagues (2004) and Perry (2004) used glycerin or a 50 percent solution of glycerol. Rosen (2000) used the toxic compound entellan for long term preservation of mounted material. The use of toxic compounds or mounting media was avoided where possible.

Several non-toxic mounting media are known to be used including karo syrup and water (Henry et al., 2011: 490). Differing concentrations of glycerol are also used, as it is a relatively non-toxic compound that may be purchased at a local pharmacy. Piperno and Dillehay (2008: 19696) note that a mounting medium of 50 percent glycerol did not appear to alter starch morphology. Several different mounting media were compared for visual clarity and long term storage considerations. The media included permount, karo syrup, water and different concentrations of glycerol. Of concern was the fact that karo syrup is said to 'melt' on the slide after some time in storage. The problem with a water mount is that the constant rehydrating of slides may cause granules to move around on the slide, and so not be relocatable for reevaluation. It seemed that 50 percent glycerol provided the best optic results to take clear and precise photographs of starch grains.

Evaluation of slides two years after they had been prepped and mounted in 50 percent glycerol with a nail polish seal showed some problems with this method. For example, a poor nail polish seal or air bubbles on the slide may cause the slide to dry out after some months of storage. However, this problem may be rectified by rehydrating the slide with the addition of a few drops of distilled water prior to viewing under transmitted light. Other slide sealants include Canada balsam (Ge, et al., 2010) which is toxic and should only be used in a fume hood. It appears that mounting samples in 50 percent glycerol with a secure nail polish seal and a slide without air bubbles is an effective and non-toxic method of sample preparation.

The same mounting medium was used throughout the project to minimise possible differences in starch or microfossil morphology due to the effects of mounting media, hence 50 percent glycerol was used for both reference and ancient samples. Microfossils from both sediment and residue samples were mounted on slides in 50 percent glycerol and sealed with nail polish. Scanning was carried out using half cross-polarised filters at a magnification of 400. This enables clear recognition of both large and small starch grains but also allows phytoliths and other identifiable microfossil to be recognised. Slides were scanned using a Zeiss AxioVision microscope and Zeiss AxioCam HRc camera. Zeiss Axioskop version 4.7 or 4.8 software was used to photograph and measure microfossils.

During the research process it was observed that starch tended to degrade in wet samples. After this observation was noted, care was taken to allow samples to dry out and stabilise prior to storage. However, some wet samples may have had reduced starch numbers due to the late realization of this property of starch.

A range of microfossils were visible in grinding artefact residue samples, including pollen grains, starch grains, phytoliths, fibres, feather barbs and other plant remains including fragments of plant cuticle and bordered pits. Identifiable microfossils, whether they were plant or animal, were noted wherever possible but identification and analysis concentrated on phytoliths and starch grains.

5.3.2.4 IDENTIFICATIONS

Identifications of microfossils recovered from the extraction procedure were made using a reference collection of over 1,000 relevant plant accessions (see Chapters 6 and 7).

Comparisons were made with modern reference slides prepared for both phytoliths and starch residues (see chap 6 for details of these preparation methods).

5.3.3 Museum Collection of Stone Sickle Residues

During the 2008 field season, access to 23 stone sickles dating to the Peiligang (9,000–7,000 cal BP) period was made possible. The sickles came from three sites that had been previously excavated (Egou, Shigu and Jiahu). Artefacts from these excavations were retained in storage at the Zhengzhou Institute of Archaeology, Henan, China (Table 5-4).

Residue samples were taken from all 23 of the sickles, and where possible, from the cutting or denticulate edge of the sickle. This was most easily achieved when the sickle tip

or a fragment of sickle was small enough to be held in a 200 ml beaker of water and sonicated. Sonication was done using a small jewellery cleaner ultrasonic bath. All sonicated samples were sonicated for 3 minutes at 45 kHz.

Sonation is currently held to be useful in dislodging small microfossils which may have lodged in pores and cracks on an artefacts' surface (Fullagar, et al., 2006: 597; Piperno, et al., 2009: 5024). However, sonication is not always an option for all artefacts including those that are too fragile or too large to fit into the sonicator. If a sickle was too large to be sonicated easily residues from it were sampled by the water pipette method of residue extraction or by removing a dry sediment sample from the stone as outlined above.

Table 5-4 Stone Sickles Sampled

Sample No	Site Name	Site Name (Chinese)	No. of Associated Residue Samples	Feature No.
SK001	Shigu	石固	3	AT65(E):6
SK002	Shigu	石固	2	survey 1979 area B:7
SK003	Shigu	石固	4	AT33:H122:1
SK004	Shigu	石固	1	Shigu T1H1:1
SK005	Egou	莪沟	2	M47:2
SK006	Egou	莪沟	1	T4:1
SK007	Jiahu	贾湖	2	WJT109[3B]:25
SK008	Jiahu	贾湖	1	T12[3]:2
SK009	Jiahu	贾湖	2	M356:4
SK010	Jiahu	贾湖	2	T105[3]:5
SK011	Jiahu	贾湖	1	WJT120[30]:7
SK012	Jiahu	贾湖	1	T8H20:3
SK013	Jiahu	贾湖	1	T109[3B]:36
SK014	Jiahu	贾湖	1	34M414:1
SK015	Jiahu	贾湖	1	T101H106:1
SK016	Jiahu	贾湖	1	T11H25:5
SK017	Jiahu	贾湖	1	T33[3]:1
SK018	Jiahu	贾湖	1	T12H57
SK019	Jiahu	贾湖	1	T23[3]:3
SK020	Jiahu	贾湖	1	T16[3]:5
SK021	Jiahu	贾湖	1	H101:1
SK022	Jiahu	贾湖	1	T6[1]:13
SK023	Jiahu	贾湖	1	T109[3B]:23

5.3.4 Field Collection of Small Sediment Samples

For the September–October 2008 field season sections of loess terraces were scraped clean and then sampled at 10 cm intervals. This was done with the aim of creating a pollen data set to allow the interpretation of the palaeoenvironment in the study region. It was also intended to provide an environmental or palaeobotanical context within which to place archaeobotanical plant remains.

Sets of up to 25 sediment samples for palaeoenvironmental study were collected from five sites⁵. For these types of samples, a section visible in an eroding loess cliff or terrace was sampled: wherever possible, this section continued both above and below an obvious cultural feature such as the opening of an ash pit. Small amounts (<100 g) of sediment were collected along a vertical transect that was sampled at intervals of 10 cm. The trowel used to collect the sediment was cleaned between each sample to avoid cross-contamination or mixing of samples. Sections up to 250 cm deep were thus sampled, with up to 25 individual bags of sediment collected.

A section of sediment samples taken from one of the soil sections at Jianxicun was sent for analysis but was found to contain insufficient pollen for analysis (Kale Sniderman, 2010, Pers. Comm.). Published pollen records from sites within or near to the study region were utilized instead.

5.4 Summary of Methodology

A range of methods were used to obtain archaeobotanical samples for analysis, including both macrobotanical and microfossil techniques. This allows for different size classes of plant remains to be recovered, including those identifiable under magnifications of between ten to 200 times, and those identifiable under greater magnifications of between 200 to 1,000 times. A comparison of residues from different classes of artefacts, including ash pits full of domestic refuse, cultural layers and individual museum artefacts such as grinding implements and stone sickles allows for the recovery of different types of archaeobotanical remains.

5.4.1 Summary of Macrobotanical Methodology

Bulk sediment samples from ash pits or cultural layers were floated either in buckets (Shizitan site) or using a SMAP flotation machine (Yiluo Region sites). Flotation samples were sorted in either Melbourne or Stanford using a set of nested sieves in the lab to aid in sorting. Identification of seeds and plant remains was made using the plant reference collection available at La Trobe and at Stanford. Dr Gyoung-Ah Lee and Professor Gary Crawford assisted with identifications.

⁵ The term 'site' here refers to an analytical unit, rather than the extent of area of an assemblage of material culture artefacts. It is used to refer to cultural features that are units of analysis, so two ash pits from the one location or village, if they are of different ages, will be referred to as different 'sites' throughout.

5.4.2 Summary of Microfossil Residue Extraction

Microfossil residue samples were taken from grinding implements and stone sickles (Table 5-5). Both wet and dry residues were taken, and in some cases where artefacts were small enough to be placed into an ultrasonic bath, sonication samples were taken for maximum recovery of microfossils. In many cases extractions were carried out in the same way for the different types of artefacts.

Table 5-5 Summary of Microfossil Residue Collection in the Field

	Wet Sample	Dry Sample	Sonication	Contamination Control
Grinding <i>mopan</i> slabs and <i>mobang</i> rollers	Wet samples were taken from some artefacts and stored in microcaps	Dry scraped residues of sediment seen visibly adhering to artefacts were collected in plastic bags or in microcaps	Not taken as grinding implements generally too large (and would collect too much water from sonication that would then require lab processing to a manageable size)	Dust from storage papers and string
Stone sickles or knives	Taken where possible but frequently not much sediment adhered to working edge or any other part of sickle	Typically taken for each sickle	Working edge of some smaller fragments sonicated	Residues from working and non-working edge sampled; also (where possible) hafted and non-hafted areas of sickle

Laboratory preparation and extraction methods for samples relied heavily on the Field protocol (Field, Judith, n.d.) for dual starch and phytolith extraction. Preparation methods differed according to the amount of sediment in the residue sample and the type of cleaning of the residue deemed necessary (Table 5-6).

Table 5-6 Summary of Laboratory Preparation and Microfossil Extractions

	Wet Sample	Dry Sample	Sonication	Contamination Control
Grinding artefacts	Dual extraction after Field and Kealhofer	Sedimentation for some dry samples after Rosen (2000) then dual extraction after Field and Kealhofer	N/A	
Sickle	Dual extraction after Field and Kealhofer	N/A	Dual extraction after Field and Kealhofer	

5.4.3 Conclusion of Methodology

Sediments from over 13 sites and localities in North China were sampled to allow extraction of both macrobotanical and microfossil plant remains, consistent with a research focus on issues surrounding the origins of agriculture in North China. Both Palaeolithic and early-middle Neolithic (Peiligang and Yangshao) flotation samples were processed for carbonised macro-seed remains, while microfossil residues were extracted from a range of early Neolithic artefacts. The Neolithic artefacts sampled for both starch and phytolith residues included grinding implements and stone sickles (these samples were only available from the Peiligang period sites). All Neolithic artefacts sampled for residues had been in museum or institutional storage since their excavation in previous decades. Successful simultaneous or dual extractions to recover both phytoliths and starch from residues were then carried out. Microfossil residues were mounted on slides in 50 percent glycerol and sealed with nail polish, prior to examination under a Zeiss microscope. Identification was carried out with the aid of an extensive modern reference collection (see Chapters 6 and 7 for details).

Chapter 6: Collection of Plant Reference Material

6.1 Plant Taxonomy

Taxonomy is the science of classifying and ordering living things. Botanical names are assigned according to the International Code for Botanical Nomenclature (ICBN). This was updated in Vienna, from which came the 'Vienna Code' ("ICBN," 2006) and most recently at the XVIII International Botanical Congress in Melbourne, Australia in July 2011. The ICBN code from these last proceedings has not yet been updated and made available online. As of February 2012 the summary of the proceedings and of important changes to the code (see Miller, et al., 2011) still directs readers to the Vienna Code. While this code lists over 24 separate taxonomic ranks for plants (such as genus, family, species) not all of them are frequently used by botanists (Spencer, et al., 2007:22). The classification of cultivated and domesticated plants follows the International Code of Nomenclature for Domesticated Plants (ICNCP) published by the International Society for Horticultural Science (ISHS, 2009).

Current botanical nomenclature used in this thesis follows the Linnean taxonomic system with plants labeled according to the Vienna code ("ICBN," 2006). The taxonomic hierarchy used is exemplified below (Table 6-1).

Table 6-1 Linnean Botanical Taxonomic Hierarchy

Order						
	Family					
		Sub-family				
			Tribe			
				Genus		
					Species	
						Subspecies

6.1.1 The Ordering of Plants

Plants may be classified as either gymnosperms (lit: naked seed) or angiosperms (lit: flowering plants). Gymnosperms include cycads, conifers, firs and pines and are all plants that have only seeds, but no flowers (Tudge, 2005: 71). A relict gymnosperm is the ginkgo

tree (*Ginkgo biloba*) now thought to be extinct in the wild in China. Angiosperms include plants with obvious flowers such as roses (Rosaceae family) and daisies (the Asteraceae family), as well as plants with less obvious flowers such as the grasses (Poaceae). Grasses often have tiny, insignificant flowers, as do reeds (Juncaceae), sedges (Cyperaceae) and many other plants.

Angiosperms were in the past subdivided into monocots (lit: one cotyledon or seed leaf) and dicots (lit: two cotyledons or seed leaves). The former included grasses, sedges and lilies, while dicots included most trees, shrubs and many herbaceous plants. This classification has since been replaced by a system dividing angiosperms into three clades; those of the monocots, basal angiosperms or primitive dicots, and the eudicots (Piperno, 2006: 35; Tudge, 2005: 124-129). Primitive dicots include magnolias and waterlilies (Piperno, 2006: 39; Tudge, 2005: 122-138), while eudicots include over 70 percent of all other flowering plants (Piperno, 2006: 39). Monocots still include lilies, grasses and sedges. Although plants in the Dioscoreaceae (yam) family have eudicot-like broad veined leaves, true yams (Dioscoreaceae) are actually monocots.

Orders are another large classificatory group. An order is a taxonomic grouping that involves similar plant families. Tudge (2005: 128) following (Judd, et al., 2008) lists 49 orders within the angiosperms as a whole. He notes (Tudge, 2005: 125) that there are over 300,000 angiosperms divided into 462 families. However, the exact number of species and taxa changes depending on individual researcher opinions and disputed methods of classifying taxa (see discussion below for examples).

Many of the monocots relevant to this archaeological project are in the order Poales. Poales includes the grass (Poaceae), reed (Juncaceae) and sedge (Cyperaceae) families. In this project, family taxonomic level is most frequently used, with a plant family referring to a group of separate genera that share certain characteristics. Following the current internationally accepted format (see ICBN 2006 division II chapter III section 2 Article 18.4, 18.5 and 18.6) some older botanical terms were been replaced by newer family names. Such families relevant to archaeology include the grass family (Poaceae, formerly and now incorrectly called Gramineae), the bean and legume family (Fabaceae, although formerly known as Leguminosae) and the daisy family (Asteraceae, formerly called Compositae).

The taxonomic level below family is genus (plural genera) and then species. A genus is a group of similar species; for example, the tanoaks, with their hairy caps, all belong to the *Lithocarpus* genus (see example in Table 6-2). The evergreen oaks with concentric circles on their acorn caps belong to the *Cyclobalanopsis* genus. Other whiteoaks belong to the genus *Quercus*. A species is the basic level of taxonomic classification ((IAPT), 2011: Division II Chapter 1 Article 2.1).

A common definition of a species when applied to zoology and in some cases to botany, is an organism that cannot interbreed with a member of a different species; that is, species belong to a group of interfertile individuals (see Judd, et al., 2008: 144-146). Such a definition of species is termed the ‘biological species concept’ (Mayr, 1963). If plant A cannot interbreed successfully with plant B then they are two different species. However, if they can interbreed and produce viable offspring successfully then they belong to the same species. In some cases they may be subspecies of the same plant. For example, there are two subspecies of *Setaria italica* (Table 6-2). *Setaria italica* ssp. *italica* refers to the domesticate foxtail millet and *Setaria italica* ssp. *viridis* refers to the wild ancestor green foxtail grass (Table 6-2). When identifying ancient microfossil or macrobotanical remains it is important to have a clear understanding of where individual species stand in comparison with close plant relatives. This allows for a more accurate identification of ancient plant remains.

Table 6-2 Examples of the Linnean Taxonomic Classification

Order	Family	Genus	Species	Subspecies	Variety	Common Name
Fagales	Fagaceae	<i>Cyclobalanopsis</i>				Evergreen oak
		<i>Lithocarpus</i>				Tan oak
		<i>Quercus</i>	<i>aliena</i>			
		<i>Quercus</i>	<i>aliena</i>	–	var. <i>acutissima</i>	
Poales	Poaceae	<i>Setaria</i>	<i>italica</i>	ssp. <i>italica</i>		Foxtail millet
		<i>Setaria</i>	<i>italica</i>	ssp. <i>viridis</i>		Green foxtail grass
		<i>Setaria</i>	<i>palmifolia</i>			Buddha grass

The exact definition of species is debated and different definitions may be applied in different disciplines (see Judd, et al., 2008: 144–146 for discussion of the definition of species). When applied to plant systematics the biological species concept is not entirely appropriate. For instance, gene flow may occur between different plant species and the lineages may still be unique (Judd, et al., 2008: 147). However, it is a useful concept for distinguishing differences between plants and will be used in general terms in this report.

Hybridisation is contrary to the rule of botanical speciation. For example, many oak trees hybridise extensively (Judd, et al., 2008: 147) making it difficult to reliably identify oaks from their leaves alone. For this reason a reliable oak identification should be made on both fruits and leaves. A hybrid may produce sterile or non-viable offspring. If fruits or seeds develop from a hybrid they may be sickly or unable to bear fruit themselves.

Plants are classified into the Linnean taxonomic hierarchy based on presumed evolutionary relationships between species. These presumed relationships are frequently updated as taxonomists re-examine old herbaria and when new information, such as genetic analyses, becomes available.

6.1.2 Plant Taxonomic References in Use

For the current research the Flora of China (hereafter referred to as FOC) was used as the main botanical reference for plant identification. This is partly because it has been recently revised and updated. It is also easily accessible to both English speaking and Chinese speaking researchers online, which may facilitate consistently used nomenclature.

Some inconsistencies may occur with the use of different classification systems. For example, the FOC recognizes *Cyclobalanopsis* as a separate genus of evergreen oaks within the family Fagaceae (Huang, C., et al., 1999). However, other taxonomic classifications do not recognize *Cyclobalanopsis* as a separate genus but as a subgenus of *Quercus* (e.g., Menitsky, 2005). Throughout this thesis and following the FOC the identifier '*Cyclobalanopsis*' is used.

There are also differences of opinion with the classification of foxtail millet and green foxtail grass. For instance, as stated in Chapter 1, the Flora of China delineates foxtail millet as *Setaria italica*. It also describes wild foxtail grass as a separate species under *Setaria viridis* (Chen, S. L., S. M. Phillips, & S. A. Renvoize, 2006). The FOC then

identifies three subspecies of the wild ancestor of foxtail millet, including *Setaria viridis* ssp. *pachystachys*, *S. viridis* ssp. *pynocoma* and *S. viridis* ssp. *viridis* (Chen, S. L., S. M. Phillips, & S. A. Renvoize, 2006). However, as Rao and colleagues note (Prasada Rao, et al., 1987), foxtail millet crosses naturally with green foxtail (de Wet, et al., 1979) to produce fertile hybrids and thus the two taxa are considered conspecific (Prasada Rao, et al., 1987: 109). This means they are subspecies of the same species and are identified as *Setaria italica* ssp. *italica* and *Setaria italica* ssp. *viridis* for foxtail millet and green foxtail grass, respectively (Prasada Rao, et al., 1987: 109). It is unclear why this is not recognized in the Flora of China. As stated earlier, this thesis will use Flora of China classifications for all taxa apart from foxtail millet and wild foxtail grass. In keeping with international practice and known species hybridization, these two taxa will be recognized as subspecies of the *Setaria italica* taxon.

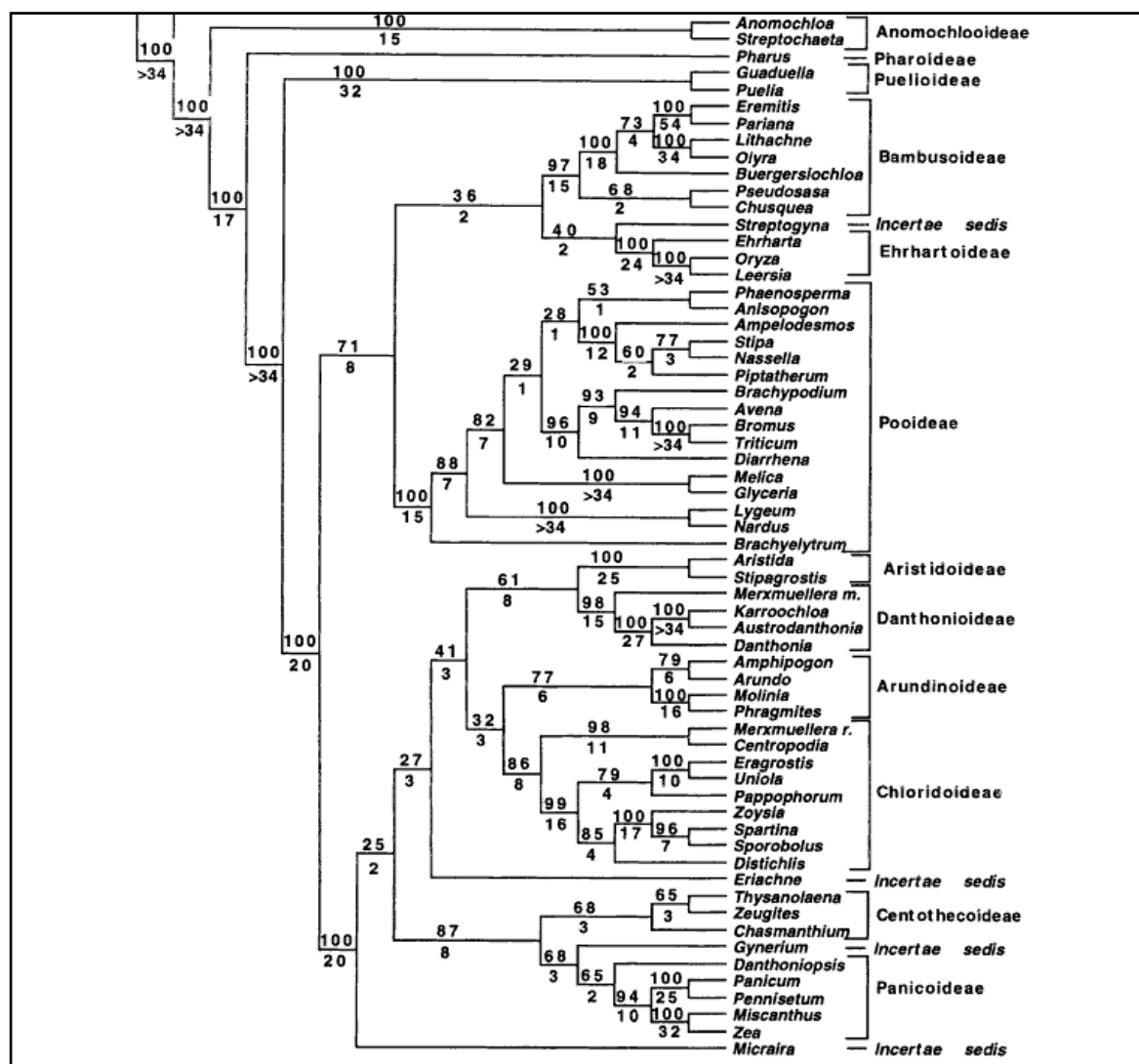


Figure 6-1 Grass subfamilies and phylogeny. After GPWG 2001: figure 2

With regard to the grass family (Poaceae) the recent sub-familial groupings set out by the Grass Phylogeny Working Group (GPWG 2001) are used to allow for consistency with other phytolith researchers (Figure 6-1). Throughout this project grasses are grouped into the approximately 40 tribes identified in the Flora of China, which does not use subfamily groupings but instead has organized grasses by tribe. In this thesis when grasses are grouped into subfamilies the 12 sub-family classifications from GPWG (2001) are used.

6.2 Compiling a Plant Reference Collection

For the current project it was necessary to set up and prepare a comparative reference collection of modern plant specimens. The establishment of a collection of modern plant reference specimens was complicated by several factors including the need to collect material in China and import it into Australia for reference use. Issues around plant identification and difficulties inherent in finding qualified people to assign accurate identifications to specimens also made this complicated. For accuracy purposes, many specimens in the collection are assigned only to genus level but not to species. The use of the collection for varied archaeobotanical references including both macrobotanical and microfossil comparisons, also made collection of specimens more complex.

Some archaeobotanical research and starch identifications rely in part on published images for identifications (e.g. Revedin, et al., 2010: 18819). It is generally preferable for an identifier to use their own plant reference material to ensure accurate identifications (Field, Judith, 2006: 95). Generally an extensive examination of related taxa is preferable for an accurate identification. It is not enough to find a similar looking species and then to 'identify' unknown taxa to that species. Other similar and related taxa should also be examined and if necessary, ruled out before a secure identification can be made. This applies to macrobotanical as well as to starch and phytolith reference specimens.

Setting up a plant reference collection may be time consuming and involve some expense, including obtaining permits, organizing storage space or cabinets and paying for reliable identification and/or reference materials themselves. However, once established, a plant reference collection may be used in multidisciplinary research for decades or even centuries to come. A single, well established reference collection may be used for varied research tasks including DNA comparisons, phytolith, starch, lipid and protein analyses and wood charcoal and macrobotanical references (see Table 6-3; see also discussion in Chapter 7).

The co-operative plant reference research material was mainly collected for use as macrobotanical, starch and phytolith references. However, some specimens have seeds (useful for macrobotanical comparisons) while other specimens have roots present (useful for starchy comparisons) and still others have leaf and stem plant parts represented in the collection (these are useful for phytolith examination). In some cases and when they were collected from the same plant, the varied plant parts (seeds, roots, leaf and stem) are all stored under a single accession number (e.g., *Cyperus* sp. REF413–08C). Other reference material was collected in such a way that it is not able to be used for all types of plant reference comparisons. For instance, some grasses may have been collected while flowering but not while seeding, and these may be used for phytolith leaf and stem references but not for macrobotanical seed comparisons or for starch residue analysis. Where possible, an effort was made to ensure all parts of the plant were collected and preserved.

Table 6-3 Archaeobotanical Reference Material in the Collections

Type of Material	Plant Remains	Available	Notes
Macrobotanical	Wood charcoal	Few	Technique not currently used
	Seeds	Yes	
	Other plant remains	Yes	Technique not currently used
Microfossil	Phytolith	Yes	
	Pollen	Few	Technique not currently used
	Starch	Yes	
Molecular	aDNA	Yes	Technique not currently used
	Lipids	Yes	Technique not currently used
	Proteins	Yes	Technique not currently used
Taxonomic		Yes	For future identification checks

During collecting, a range of taxa were gathered to maximize the families and genera represented in the collection. In some cases the exact species from the study area in China was not available so close taxonomic relatives from Australia or the US were used instead.

6.2.1 Collection of Modern Reference Material

Several methods of identifying plants that were likely to have grown in the study region in Late Palaeolithic and early Holocene times were used. One method of creating a reference collection is to examine useful or edible plants currently growing in the study region. This may involve an examination of online data regarding modern plant distributions or it may involve traveling to the study region. However, climate changes such as the shifting East Asian monsoon belt (An, et al. 2000; Li, Xiaoqiang, et al., 2003) may have altered vegetation in the region, meaning that plants now growing in Henan and Shanxi province may not represent the same floristic ecosystem that was present 10,000 years ago. For example, pollen records show a major decline in oak pollen during the early Holocene (Xia, Z., et al., 2002), with fluctuating pollen levels of various species throughout the 35,000 year pollen study. Subtropical flora and fauna were still present but declining in the Longshan and later periods (Keightley, 2000: 1-4; Shi, Y., et al., 1993). Hence plant remains from sub-tropical Zhejiang Province were included in the reference collection.

Alteration of vegetation across millennia has been linked to various causes, including climate change (Xia, Z., et al., 2002) and human activity (Rosen, 2008). The onset of agriculture and an increase in the area of land used for farming has also been linked to environmental degradation in China during the later Holocene (Li, Xiaoqiang, et al., 2003; Rosen, 2008). Intensive farming and increased human habitation have destroyed much of the indigenous ecosystem in North China. Despite these changes in the climate and vegetation of Henan and Shanxi provinces over the Holocene, general floristic similarities are likely to be present, albeit with local exceptions.

6.2.1.1 PLANTS IN ARCHAEOLOGICAL SITES

Plants were collected based partly on the results of macrobotanical plant remains recovered from relevant archaeological sites (Table 6-4). Such sites may include sites of a similar age or time period (ie. other Peiligang sites) or sites in a similar area (i.e., sites located in Henan province). Although environmental and climatic conditions have changed in the study area since the study period (Rosen, 2008) some plant remains were collected from regions thought to be climatically similar to Peiligang-aged sites in Henan Province, such as Zhejiang Province which is now also sub-tropical.

Table 6-4 Families of Plants Represented in Selected Sites in Henan Province Where Plant Remains were Systematically Collected. p = present.

Site	Yiluo Region	Jiahu	Wangchenggang	Huizui	Egou, Shigu	Zoajiaoshu
Age	PLG–ELG	PLG	LS	ELT	PLG	ELT
Reference	G.-A. Lee, et al., 2007	Z. Zhao and J. Zhang, 2009	Z. Zhao and Y. Fang 2007	G.-A. Lee and Bestel, 2007	Li, Liu, et al., 2010c	Luoyang, 2002
Total plant families	12	14	9	5	4	8
Amaranthaceae			p			p
Asteraceae		p	p			
Boraginaceae	p					
Brassicaceae	p					
Chenopodiaceae	p	p	p	p		p
Cyperaceae	p	p		p		
Dioscoreaceae					p	
Euphorbiaceae	p					
Fabaceae	p	p	p	p	p	p
Fagaceae	p	p			p	
Juglandaceae		p				
Lamiaceae	p		p			p
Nelumbonaceae		p				
Malvaceae		p				
Moraceae		p				
Poaceae	p	p	p	p	p	p
Polygonaceae	p	p	p			
Rhamnaceae			p			p
Rosaceae	p		p	p		p
Solanaceae	p					
Trapaceae		p				
Ulmaceae		p				
Vitaceae		p				p

A review of the literature was undertaken to assess which plants may have been found in previous archaeological studies (macrobotanical, phytolith and starch) in the Henan region of China (Table 6-4). Main studies from the North Chinese Neolithic where extensive and systematic flotation has been carried out and published include research at the Peiligang site of Jiahu (Zhao, Z. & J. Zhang, 2009), various small sites in the Yiluo Region (Lee, G.-A., et al., 2007; Liu, Li, et al., 2002-2004) and the Dadiwan site (Barton, L., et al., 2009; Ji, 2009). Other sites in Henan Province where flotation samples were systematically recovered, analysed and published are listed in Table 6-4. An extensive flotation program was also carried out at Liangchengzhen site which dates to the Longshan period (Crawford, et al., 2005), although as this is in a separate province it is not described in detail.

In the 1970s, Ho (1975: 56-61) wrote that foxtail millet (*Setaria italica* ssp. *italica*) was the main Neolithic crop in ancient China, with broomcorn millet (*Panicum miliaceum*) only a minor player. Recent research has suggested that broomcorn millet may have been cultivated before foxtail millet at several sites in North China including Dadiwan (Barton, L., et al., 2009), Xinglonggou (Zhao, Z., 2005a) and Yuezhuan (Crawford, et al., 2006).

Aside from cereal crop remains, other macrobotanical finds in Neolithic North China include legumes of various types including wild soybean (*Glycine max* ssp. *soja*) and various small herbaceous plants including amaranths and chenopods (Amaranthaceae/Chenopodiaceae) as well as *Polygonum* sp. seeds (see Table 6-4).

Nuts occur in several sites in North China. Nuts such as hackberry (*Celtis bungeana*), hazel (*Corylus heterophylla*) and walnut (*Juglans regia*) from the Cishan site (Handan Wenwu, 1977; Hebeisheng, 1981; Tong, 1984) were not systematically excavated and so are not included in Table 6-4. Systematically recovered nut remains include acorns, walnuts and hackberry fruits from Jiahu (Zhao, Z. & J. Zhang, 2009) and Rosaceae stone fruits and pips from Wangchenggang (Zhao, Z. & Y. Fang, 2007), Huizui (Bestel, 2006; Lee, G.-A. & Bestel, 2007), Zaojiaoshu (Luoyang, 2002) and the Yiluo Region (Lee, G.-A., et al., 2007).

6.2.1.2 PLANTS MENTIONED IN ANCIENT TEXTUAL RECORDS

A review of ancient textual records was undertaken to determine which plants were used in ancient China (Table 6-5; Table 6-6; Table 6-7). Inscriptions on pottery fragments at Jiahu may represent a form of writing (Li, Xueqin, et al., 2003) however these do not provide a useful summary of ancient plant use. A comprehensive writing system is evident on oracle

bone inscriptions at Anyang, dating to the late Shang Dynasty (c. 1,250–1,046 BC). These inscriptions include details of crops planted as well as divination queries relating to the appropriate time to harvest (Keightley, 2000: 9). Crops mentioned (figure 6.4) in the oracle bone inscriptions include several millets and wheat (Keightley, 2000: 9-16) (Table 6-5).

Table 6-5 Selected Ancient Textual References for Cereals in North China

Botanical Family	Probable Genus / Species	Common Name	Ancient Text †	Text or Reference ‡
Poaceae	<i>Setaria italica</i> ssp. <i>italica</i>	Foxtail millet	AY; QMYS; SJ; XXZ	Keightley 2000; Legge; Li, H.; Li, C. J., 2010; Wang, X. G., 2004
	<i>Panicum miliaceum</i>	Broomcorn millet	AY; QMYS; SJ; XXZ	Keightley 2000; Legge; Li, H.; Li, C. J., 2010; Wang, X. G., 2004
	<i>Triticum aestivum</i>	Breadwheat	?AY; QMYS; SJ; XXZ	Keightley 2000; Legge; Li, H.; Li, C. J., 2010; Wang, X. G., 2004

The *Shijing* 詩經 or Book of Songs appears to have been written somewhere between c. 1,000 and 600 B.C. (Loewe, 1993b: 415). It is a compilation of songs, some of which may have originated in earlier times, and includes poems about the Zhou Dynasty and their successful overthrow of the Shang (Loewe, 1993b: 417). In the Legge translation of the text (Legge, 1967) there are numerous mentions of plants in use in ancient China. The major crops mentioned include both foxtail and broomcorn millet as well as wheat and also soybean (Li, C. J., 2010: 150) (Table 6-5). C. J. Li (2010) also discusses some of the herbaceous foods mentioned in the poems (Table 6-6), including thirty-two herbaceous or vegetable foods such as mallows, mustard and hemp (see also Legge, 1967).

Table 6-6 Selected Ancient Textual References for Herbaceous Plants in North China

Botanical Family	Probable Genus / Species	Common Name	Ancient Text †	Text or Reference ‡
Apiaceae	<i>Oenanthe stolonifera</i>	water dropwort	QMYS; SJ; XXZ	Legge; Li, H., 1970; Li, C. J., 2010
Asteraceae	<i>Artemisia</i> sp.?	Artemisia	XXZ	Wang, X. G., 2004
Asteraceae	<i>Lactuca denticulata</i>	lettuce	QMYS	Li, H., 1970
Asteraceae	<i>Xanthium strumarium</i>	corncockle	QMYS	Li, H., 1970
Brassicaceae	<i>Brassica alba</i>	mustard	QMYS	Legge'; Li, H. 1970
Brassicaceae	<i>Brassica rapa/ Brassica chinensis</i>	Chinese cabbage/ field turnip	QMYS	Li, H. 1970

Botanical Family	Probable Genus / Species	Common Name	Ancient Text †	Text or Reference ‡
Brassicaceae	<i>Raphanus sativus</i>	radish	QMYS	Legge; Li, H. 1970
Brassicaceae	<i>Nasturtium indicum</i>	?watercress	QMYS	Li, H. 1970
Convolvulaceae	<i>Convolvulus</i> sp.	bindweed	QMYS	Legge
Cucurbitaceae	Various	gourds	QMYS; SJ; XXZ	Legge; Li, H. 1970; Li, C. J., 2010; Wang, X. G., 2004
Cucurbitaceae	<i>Benincasa cerifera</i>	winter melon	QMYS	Li, H. 1970
Cucurbitaceae	<i>Cucumis melo</i>	honeydew melon/ ?muskmelon	XXZ; QMYS	Li, H. 1970
Cucurbitaceae	<i>Cucumis sativus</i>	cucumber	QMYS	Li, H. 1970
Cucurbitaceae	<i>Lagenaria siceraria</i>	bottlegourd	QMYS	Li, H. 1970
Cyperaceae	?	sedge	XXZ	Wang, X. G., 2004
Fabaceae	<i>Glycine max</i> ssp max	soybean	QMYS; SJ; XXZ	Legge; Li, H. 1970; Li, C. J., 2010; Wang, X. G., 2004
Fabaceae	<i>Medicago sativa</i>	alfalfa	QMYS	Li, H. 1970
Juncaceae	?	reeds	XXZ	Wang, X. G., 2004
Lamiaceae	<i>Perilla frutescens</i>	beefsteak plant	QMYS	Li, H. 1970
Lilliaceae	<i>Allium</i> sp./ <i>Allium nipponicum</i> / <i>Allium bakeri</i> / <i>Allium fistulosum</i> / <i>Allium</i> sp.	various bulbaceous taxa in the onions, leeks, garlic family	QMYS; XXZ	Li, H. 1970; Wang, X. G., 2004
Lilliaceae	<i>Allium ramosum</i>	Chinese leek	XXZ; QMYS	Li, H. 1970
Lilliaceae	<i>Allium sativum</i>	garlic	QMYS; SJ	Li, H. 1970; Li, C. J., 2010
Malvaceae	<i>Malva verticillata</i>	mallow	QMYS; SJ	Legge; Li, H. 1970
Polygonaceae	<i>Polygonum</i> sp.	knotweed	QMYS; XXZ	Legge 1967:95; Wang, X. G., 2004
Polygonaceae	<i>Polygonum hydropiper</i> / <i>Persicaria hydropiper</i>	waterpepper	QMYS; XXZ	Li, H. 1970; Wang, X. G., 2004
Zingiberaceae	<i>Zingiber officinale</i> / <i>Zingiber mioga</i>	ginger	QMYS	Li, H. 1970

† In table 6.6 and 6.7 XXZ refers to Xia xiao zheng 夏小正 (reference from Wang, Xingguang 2004; 114–120). QMYS refers to Qimin yaoshu 齊民要術 (references from Li, Huilin, 1969; 253–260). SJ refers to the Shijing 詩經 (references from Loewe, 1993b). A ? means the identification is uncertain.

‡ In table 6.6 and 6.7 Chang here refers to K. C. Chang 1986:80. Legge here refers to Legge 1967.

Other ancient Chinese textual references include the Dadai Liji 大戴禮記 or ‘Records of ritual matters by Dai Senior,’ which was transcribed during the Han Dynasty (c.206 BCE–8 CE) (Loewe, 1993a: 293). It includes various chapters or almanacs such as the Xia Xiao Zheng 夏小正 which lists some of the plant and animal foods in use at the time it was written (Wang, X., 2004). X. Wang (2004: 112-120) lists nine trees and shrubs mentioned in the Xiaxiaozheng including fruit trees such as plums, apricots and peaches (Table 6-7). He also lists sixteen herbaceous taxa including various gourds and bulbaceous plants such as leeks and garlic (Wang, X., 2004: 112-120) (Table 6-6).

The Qimin yaoshu 齊民要術 or ‘Essential arts for the people’ was written after these two other works in the 5th or 6th century AD (Li, H., 1969: 357). It also lists numerous plants in use in ancient China including vegetables such as amaranths, beefsteak plant and lettuce (Table 6-6). The ancient Chinese names of these vegetables were translated by the botanist Li Huilin (1969) although in some cases Latin names have since changed. His identifications are based on ancient medieval works and illustrations of the plants but in some cases the exact botanical identity of the plant is uncertain (Li, H., 1969: 357-358).

There are sometimes difficulties with translating ancient Chinese words for plants; for an example, see the discussion in X. Wang (2004: 118) regarding the exact translation of yun 芸 and his disagreement with W. Xia (1981: 15-17) over the plant’s actual identification. The use of common names for plant identification does not help the situation and can make it difficult for someone not familiar with local plant names to identify the relevant taxa.

Over half of the plant references utilized were collected or donated from China. However, as researchers were initially based in Melbourne and then in San Francisco, many local grasses and plants were incorporated into the reference collection. This is partly due to ease of access and availability of local botanical experts able to identify specimens. This is a valid method of collection as many plants are now cosmopolitan, such as the *Setaria* sp. group (Dekker, 2003: 641-643). In addition, given the similarities between many microfossils, identification to genus or even family level is sometimes more accurate. As many microfossils are under strong genetic control, plants from a different continent but the same genus or family make reliable comparative references.

Table 6-7 Selected Ancient Textual References for Trees and Woody Taxa in North China

Botanical Family	Probable Genus / Species	Common Name	Ancient Text	Text or Reference
Anacardiaceae	<i>Toxicodendron verniciflua</i> (formerly <i>Rhus verniciflua</i>)	varnish tree; Chinese lacquer	SJ	Chang; Legge; Li, H. 1970
Betulaceae	<i>Corylus avellana</i>	hazelnut	SJ	Legge; Li, H. 1970
Ebenaceae	<i>Diospyros kaki</i>	persimmon		Chang; Li, H. 1970
Fagaceae	<i>Castanea</i> sp.	chestnut	SJ; XXZ	Legge; Li, H. 1970
Moraceae	<i>Morus</i> sp./ <i>Morus alba</i>	mulberry	SJ; XXZ	Legge; Li, H. 1970; Wang, X. G., 2004
Pinaceae	<i>Pinus</i> sp.	pine	SJ	Legge
Rhamnaceae	<i>Zizyphus</i> sp./ <i>Zizyphus vulgaris</i>	jujube date	SJ; XXZ	Chang; Li, H. 1970
Rosaceae	<i>Prunus</i> sp.	plum	SJ; XXZ	Legge; Li, H. 1970; Wang, X. G., 2004
Rosaceae	<i>Prunus armeniaca</i>	apricot	XXZ	Chang; Li, H. 1970; Wang, X. G., 2004
Rosaceae	<i>Prunus persica</i>	peach	SJ; XXZ	Chang; Legge; Li, H. 1970; Wang, X. G., 2004
Rosaceae	<i>Prunus saliciana</i> / <i>mume</i> / <i>pseudocerasus</i>	various plums		Chang; Li, H. 1970
Rosaceae	<i>Pyrus pyrifolia</i>	pear	SJ	Legge; Li, H. 1970
Rosaceae	<i>Crataegus pinnatifida</i>	hawthorn		Chang; Li, H. 1970
Salicaceae	<i>Populus</i> sp.	poplar	XXZ	Wang, X. G., 2004
Salicaceae	<i>Salix</i> sp.	willow	SJ; XXZ	Legge; Wang, X. G., 2004

6.2.2 Accession Numbers and Database of Specimens

As part of setting up a reference collection plant remains obtained had to be accessioned and organised. For this purpose a database was set up with reference to the database fields suggested by participants at a workshop on seed reference collections held at the Institute of Archaeology, UCL, 2000 (Nesbitt, et al., 2003). Each separate plant obtained was given a unique accession number and important characteristics of plants were recorded. In all, up to sixteen characters were recorded for each accession (Table 6-8).

Minimal sets of characters were used in the database as it was convenient to have the database able to be printed out or read on one horizontal A4 sheet of paper. Characters selected were thus most relevant to the database being used by several people, not all with a botanical background, and were characters most likely to be recorded during plant collection. The spontaneous collecting undertaken whilst surveying for archaeological sites necessitated a fairly simple database so that brief notes about where the plant was located and the date of collection could be jotted down on a slip of paper and entered into the database at a later date.

Despite the attempt to make the database as user friendly as possible to people from a wide range of backgrounds, it was found most convenient to have one person assign accession numbers to plant samples integrated into the collection. Later, a card file system was set up so that if the main person to assign accessions was away, accession numbers could still be assigned by all lab personnel and checked prior to entry into the database.

Fields in the database include a unique accession number for each specimen; where duplicate specimens from the same tree or plant were collected at separate times, each was given a separate accession number to prevent confusion (see Bridson & Forman, 1992: 206). This also allows seasonal constraints or influences on starch size, for example, to be recorded, which is a matter for future research. Several fields in the database were created with the initial field being the plant family. An experienced botanist may often readily identify a plant to family without needing to consult plant identification manuals (Tudge, 2005: 128). Separate fields for genus and species were maintained and category for 'name comments' allows details of a name including common names, Chinese names, varieties or queries in relation to naming to be recorded. The use of a single field for this category reduced the size of the database.

The 'verification' field allowed the botanical or taxonomic knowledge of the person identifying the plant to be assessed. For example, an identification made in the field or at a herbarium by an experienced botanist is a secure identification. However, an identification made from online pictures or photographs is less secure and may be only partially correct.

The database also included several fields for the collection location of the plant (country, province or state, and town or archaeology site). This was intended to make it easier to re-collect the plant in future if questions arise about its identification or if lab accessions are destroyed. Sometimes information about plant collection locations are precise, as in the case of a gardener who may be able to state exactly where in her garden the plant was located. For this reason details about the donor or collector were also recorded in the database, so that if questions arise about the plant in future they may be directed to the appropriate person.

No fields for GPS latitude and longitude were maintained in the database, as in certain areas of China GPS units are not permitted. Having accurate latitude and longitude data would have been useful for re-collection and identification checking purposes. However, most people who used the database did not own a personal GPS unit, and so the data would not have been collected frequently enough to justify having a field specifically for GPS coordinates. If this type of GPS data was collected, it was stored in the 'comments' field of the database.

Certain microfossils may be identified to a specific part of the plant, such as the husk (e.g., Rosen, 1992). The collection of different parts of a modern plant, such as the leaves, roots, husk and stems, may allow the identification of these plant parts in the archaeological record. Some plant parts are easier to collect than others. For example, it is often easier to collect the stem and leaves of a plant rather than the roots. Also, plant identification often relies heavily on flowering or fruiting material, if not both. This may necessitate two trips at different times of year to the collection site. This is not always practicable for collection sites in China or elsewhere.

Different parts of plant references were collected and retained to provide references for a range of plant parts and uses, such as archaeological evidence for winnowing out the husks from the grain (see Harvey and Fuller, 2004). To make macrobotanical seed identifications, only the seeds of the plant are necessary to provide comparative

identifications. However, plants set seed only at certain times of year, making seed collection less predictable. This means that not all parts of a single plant accession were able to be represented in the collection. Those plant parts that were collected (tuber, root, seed, leaves, etc) were described and listed in the database under the ‘plant part’ field.

Table 6-8 Fields in Plant Collection and Accessions Database

Database Field	Explanation of Field	Example
Accession no	REF-number-year of addition to database	REF937–09
Family	Family taxonomic level	Poaceae
Genus	Genus taxonomic level	<i>Setaria</i>
Species	Species taxonomic level	<i>italica</i>
Name comments	Common name, Chinese name, ambiguities about name, possible name	Foxtail millet
Type of accession (root, leaf, seed)	Which plant parts are present	Seeds with husks, no leaves or stems
Country	Country of collection, not where grown (notes about where plant originated or grew placed in ‘collected from’ field)	China
Province	Or state/ territory where obtained/ brought	Henan
Town/ Archaeological site		
Name of shop or market where collected		Purchased at Zhengzhou; seller said probably from Hebei Province
Collector/Donor		SB
Collection date		23–5–09
Verification	Includes notes on how secure the identification is – is it insecure, or did an expert see and identify the plant	SB
Ordered into Quarantine lot no.	For plants imported under quarantine restrictions only	Quarantine batch no. 98762354 under La Trobe permit VC2987894
Comments		

6.2.3 Storage of Plant Reference Material

Preservation of plant material for macrobotanical remains, and to ensure the continuity of the collection, revolved around reducing the risk of insect or fungal attack once the collection had been contained in the laboratory. It was also compliant with quarantine regulations which govern the location of potentially contaminating plant remains.

While collecting in the field in China or overseas, plant remains were laid to dry in airy, clean conditions wherever possible. Fleshy tubers and fruits were placed in a courtyard in hot sunshine for several days to dry thoroughly prior to being posted back to Australia. For especially thick or fleshy tubers slicing into thin sections assisted the dessication process (see Bridson & Forman, 1992: 196-198). Alternatively, specimens were placed in alcohol, such as 70 percent ethanol or even 70 percent methylated spirits to dry for a few days prior to storage. Given that the effect of alcohol on plant cellular organelles or structures is unclear, alcohol dried plants were not examined for starch or microfossils for this thesis. In addition, in laboratory conditions silica gel was sometimes used to keep plants dry and prevent the development of moisture or mould.

Plants collected in Australia were collected with roots intact where possible and were washed of soil prior to drying in paper bags for 6 weeks to 3 months. This was necessary before they were more permanently stored. Due to the loss of some specimens from insect attack or mould, specimens were not accessioned until after they were air dried thoroughly. After a thorough drying, specimens were placed in plastic ziplock bags to hinder insect attack and stop the possible spread of mould throughout the collection. They were then accessioned and a paper label was placed inside the bag. The accession number and details were then written on the outside of the bag as well on the tag placed inside.

Specimens were stored in drawers in small plastic cabinets. They were filed in alphabetic order based on plant family. In the case of large families such as Poaceae or Rosaceae specimens were stored in alphabetic order by tribe. Insect prevention measures including the use of naphthalene flakes were used to prevent insect attack. Silica gel was used and changed at regular intervals to ensure plants remained dry and moisture free.

6.3 Preparation of Modern Reference Material

The reference material collected was prepared for examination in different ways, according to the type of comparison required (macrobotanical, starch, phytolith). Macrobotanical samples were generally dried to preserve them for future reference and long term storage while microfossil references were dried for future use and storage where possible. Some tubers and fleshy plant parts may go mouldy during storage so these and other specimens were mounted on a slide as a thin section (TS) or a smear. The different sample preparation methods are outlined below.

6.3.1 Macrobotanical Reference Material

Apart from a limited amount of drying or pressing, macrobotanical reference materials require little preparation. However, adequate preservation is required to ensure the viability of the collection for future use. Prior to examination under a dissecting microscope at magnifications of about x10 to x50, macrobotanical reference material was generally dried and stored in an air tight container or plastic bag. Mounting of specimens on acid free herbarium paper (see Bridson & Forman, 1992: 216-219) was attempted but took up too much storage room so was discontinued.

Identifications of modern reference material were made by various sources including botanists where possible. When collecting in China these included botanists affiliated with the Hangzhou Herbarium. Other specimens donated to Professor Li Liu and integrated into the collection include plants donated by Professor Zhijun Zhao and seeds from the Chinese Agricultural Seed Database (donated by Dr. Wei Ge). Dr. Gyoung-ah Lee and Professor Gary Crawford also generously donated samples. Details of the person responsible for making individual identifications were described in the plant reference database. In addition, a qualified botanist (myself) clarified each accession to determine that it was accurately identified. Where precise identifications to species were not possible, identification was carried out to plant family, tribe or genus level.

6.3.2 Phytolith Reference Material

Preparation of modern phytolith reference material usually requires removal of all parts of the plant or leaf without damage to the phytoliths or silica skeleton of the plant. Much of the phytolith preparation work was carried out at La Trobe University in the generalized archaeology laboratory. The use of a muffle furnace and 10 percent HCL wash of phytolith reference specimens was carried out at Monash University in the wet laboratory. Plant phytoliths were prepared after specialised training in the extraction of ancient phytolith samples (see Rosen, unpub. protocol). Training was carried out at the UCL lab in London between April–May 2009 under Professor Arlene Rosen.

Phytolith reference specimens were prepared using techniques outlined in Piperno (2006: 97). This involved separating the plant into its various components, including stem, leaf, leaf sheath, inflorescence, husk and root, where possible. Specimens were then ashed at 500 degrees C in a muffle furnace to remove organics (Rosen, unpub. protocol; see also Piperno, 2006: 97). Dry ashing of samples removes the need to clean them in nitric acid as

per Piperno's protocol (2006: 92). Samples were then cleaned in a 10 percent solution of HCL prior to being rinsed in water, dried overnight and then mounted.

Grinding or squashing part of a plant and placing the remains or juices onto a slide often produced a sample of cellular remains and phytoliths that would enable identification of silica bodies inside the plant to be made. This is a standard botanical mounting technique. Often other plant parts were also visible including cellular remains and chlorophyll. This is a quick and easy way to check for phytoliths in some more fleshy plant parts such as leaves and stems. In this situation a mortar and pestle was used to grind plant parts such as pine needles or oak leaves prior to mounting. All of the phytolith reference samples used or presented in this thesis were prepped by Sheahan Bestel, although at times Duncan Jones was present to use the muffle furnace facilities at Monash University. Thus any reference slides used in this project and any photographs taken of them were created entirely by myself unless stated otherwise.

6.3.3 Starch Reference Material

Different researchers prepare starch reference material differently (Field, Judith 2006: Box 6.5) and there are several acceptable methods of preparing starchy plant remains for microscopic observation. For this project, starch from a reference specimen was taken from the inner seed or nutmeat, rather than from a seed husk or nut shell, and smeared or 'shaved' onto a glass slide using a razor blade. The slides were subsequently mounted on a slide in 50 percent glycerol or water and sealed with nail polish. Starch was not ground in a mortar and pestle before being sprinkled or placed on a slide and mounted, to minimise the risk of contamination from other starch grains previously ground in the same pestle. The slides prepped and photographed for this project were all made and photographed entirely by myself unless stated otherwise.

Contamination control included minimal use of mortal and pestle during sample preparation. Other anticontamination procedures involved the wearing of a different pair of rubber gloves to process each sample. After Piperno and Holst (1998: 768) the gloves worn are powderless so do not contain starch which may contaminate the samples. Drying samples and slides were covered with parafilm or a plastic petri dish respectively. Careful laboratory practices were also used to ensure contamination did not occur.

6.3.4 Mounting Starch and Phytoliths

Various mounting media are in use among phytolith and starch researchers (Piperno, 2006: 96). The Rosen protocol (unpub.) recommends mounting prepped phytolith samples in the medium entellan. As this is toxic and must be utilized in a fumehood glycerol was used instead given the current university preference for non-toxic chemical usage. Both Pearsall and colleagues (2004) and Perry (2004) use a 50 percent glycerol solution to mount starch grains. After initial testing of four different mounting media (10 percent glycerol, water, permount and 50 percent glycerol) it was decided that good optic qualities were best presented by a 50 percent glycerol solution. Consequently from January 2008 onwards, a 50 percent glycerol solution was used for mounting both ancient and modern reference slides. However, it was later noted that starch grains do not appear stable on these slides over a six to twelve month period. Starch is also not stable in water, so samples stored in microcaps or centrifuge tubes in water were also subject to decay. In subsequent research Piperno (2006: 96) used water mounts because she felt that inadequate research has been done on possible alterations or damage to starch grains mounted in glycerol in the long term. However, the same could be said of water, especially when one considers the likely prolonged effects of drying and re-hydration on slides over a period of some years. Piperno and Holst (1998: 768) note that dessicated starch grains may be 'reconstituted' on adding water to a slide. The need to re-hydrate a slide also means that residues may move position on the slide, making re-locating residues very difficult. However, due to possible damage to starch granules, from January 2011 onwards water was used as a slide mounting medium.

A range of plant taxa were tested for phytoliths (see Chapter 7 section 7.2). However, due to the more advanced state of phytolith research it was not necessary to test as many plants for the presence of phytoliths. A greater number of plants were tested for the presence of starch (see Chapter 7 section 7.3) as this was a newer area of research. A generalized body of knowledge relating to which plant families and plant parts are likely to contain phytoliths is generally available (Mullholland and Rapp, 1992a, b; e.g., Piperno, 2006) whereas the data for plants containing starch is less comprehensive (see Torrence and Barton 2006 for an overview). Phytolith, starch and other microfossil reference slides were scanned using a Zeiss Axioskop microscope with cross polarizing and DIC filters and images were taken using Zeiss AxioVision Rel 4.7 or 4.8 software.

6.4 Summary

The plant reference specimens used for this thesis were collected as part of a large joint project in collaboration with Professor Li Liu. Many individuals donated specimens to the collection and others were retrieved or collected by Professor Liu and myself. The establishment of the reference collection was a joint project. Information regarding the location of specimen collection and other details was kept in a central database which followed the Vienna Code ("ICBN," 2006) for specimen plant taxonomy. The Flora of China (Wu, Z. Y., et al., 2012) was frequently used for plant identifications as it was a readily accessible and recently updated flora.

Specimens were maintained and stored in cool, dry conditions in plastic for long term storage. Specimen preparation for macroscopic and microscopic identification differed between seed, phytoliths and starch references but was standardized as much as possible to avoid discrepancies in specimens due to viewing preparation.

Plants were included in the reference collection due to their known presence in archaeological sites in the study region. Plants mentioned in ancient textual and oracle bone references, including cereals, herbaceous and weedy taxa and woody or tree taxa were also examined. The exact numbers and types of taxa in the collection are set out and described in Chapter 7.

Chapter 7: Plants in the Reference Collection

Plant references used for this thesis include plants collected in and around Melbourne (Australia), Henan and Zhejiang Provinces (China) and San Francisco (USA). The references used amount to over 1,000 specimens. Details of some of the more important references are given in this chapter. Plant reference specimens are divided into macrobotanical references, phytoliths references and starch references. Each of these categories will be discussed below.

7.1 Macrobotanical Remains in Plant Reference Collection

Macrobotanical remains are one of the most commonly studied archaeobotanical remains, partly due to the diagnostic features of seeds that may be visible at low power magnification (Pearsall, 2000: 11). However, the preservation of seeds is not ubiquitous in the archaeological record. In pre-agricultural sites including those in the Yiluo Region during the Peiligang period, seeds remains are rare to non-existent (see Chapter 8). This is perhaps because staple foods during this time did not rely on seed crops but on nut or tuber crops which may be less likely to preserve in a macrobotanically identifiable form. Although modern human diets rely heavily on cereal seed products (wheat, corn, rice and maize are all domesticated grasses) this was not necessarily always the case throughout human dietary history.

In the absence of a carbonizing fire or hearth to preserve seed remains, seed preservation may not be evident in the archaeological record even though plants were present and culturally used at the site. A preservation bias may also be evident against seeds in plants that do not reproduce by seed germination or sexual recombination and reproduction. Plants which reproduce asexually or vegetatively (for example, by sending out runners), include bamboos and domestic bananas (Tudge, 2005: 13). Many other plants and shrubs are propagated by cuttings. Such taxa are less commonly recognized in charred macrobotanical assemblages than are cereal or seed taxa. These types of vegetative plant parts have been important throughout human history and are included in the macrobotanical remains reference collection. Although Hather (1991, 1993, 2000) has identified archaeological parenchyma it is not common for plants to be identified as such in current archaeobotanical practice. However, the presence of vegetative taxa may be identified by starch or phytolith microfossil (see discussion in Chapter 7.2 and 7.3).

The macrobotanical plant reference collection includes over 150 types of seeds as well as wood, tubers, twigs, pods and other plant parts. Macrobotanical seed remains were a focus of the collection as these may be identified to species or even subspecies level (this has been done but to varying levels of accuracy in microfossil plant identifications). Secure identification of macrobotanical seed remains also allows the presence of domesticated seeds to be acknowledged. These provide definitive evidence of sustained cultural plant use. Macrobotanical specimens in the collection are discussed below.

7.1.1 Seeds

Given that there are almost 300,000 flowering plants in the world (Tudge 2005: 19)⁶ they are divided into families for ease of reference. The main families relevant to archaeobotanical seed remains for this project include the grasses (Poaceae). Important plants in other herbaceous families include Amaranthaceae/ Chenopodiaceae (amaranth/ goosefoot families), Brassicaceae (mustards), Cyperaceae (sedges), Juncaceae (reeds) and Polygonaceae (*Portulaca* sp.).

Seeds from a range of families were collected as plant reference material (Table 7-3). Published seed reference manuals were also examined for initial suggestions regarding seed identification, including C. J. Liu and colleagues (2008), Martin and Barkley (1961), Nesbitt (2006) and Renfrew (1973). Seeds from over 30 families and over 100 relevant species were included as part of the reference collection. This included over 20 genera and over 50 species of grasses. Grasses are among the most important staple foods in the world today, hence their prevalence in reference material.

When they are fertilized by pollen, each ovule inside an ovary may develop into a seed (Bell, 2008: 194). For the purpose of this research, a seed is defined (after Judd, et al., 2008: 78-79) as being a mature ovule containing an embryo and nutritive tissues such as endosperm. The seed is covered by a seed coat or testa (Judd, et al., 2008: 79) and this may have patterning that is archaeobotanically diagnostic (Pearsall, 2000: 135). The embryo of the seed includes an epicotyl which will develop into the shoot and a radicle which will develop into the root of the plant. The hypocotyl will connect the shoot to the root (Judd, et

⁶ There are systems of classifying plants that are still debated; some of the issues include hybridation and polyploidy (see Tudge 2005: 10-17 for discussion on identification issues and Judd *et al.* 2008: 144-146 as well as Tudge 2005: 10-17 for discussions about a botanical definition of plant species).

al., 2008: 79). A hypocotyl-radicle may preserve archaeologically and be indicative of certain types of plants such as beans (see Lee, G.-A., et al., 2007). A brief outline of the seeds in the collection is given below.

Table 7-1 Selected Seeds Present in the Macrobotanical Reference Collection

Family	Genus	No. Specimens	Common Name
Amaranthaceae	<i>Amaranthus</i>	3	Amaranth
Brassicaceae	<i>Brassica</i>	3	Mustard
Brassicaceae	<i>Capsella</i>	3	Shepherds' Purse
Chenopodiaceae	<i>Chenopodium</i>	5	Chenopod/ Quinoa
Cyperaceae	<i>Cyperus</i>	2	Sedge
Juncaceae	<i>Juncus</i>	4	Reed
Lamiaceae	<i>Leonurus</i>	1	Motherwort
Piperaceae	<i>Piper</i>	2	Pepper
Polygonaceae	<i>Fagopyrum</i>	3	Buckwheat
Polygonaceae	<i>Polygonum</i>	3	Polygonum
Polygonaceae	<i>Rumex</i>	1	Dock
Typhaceae	<i>Typha</i>	3	Reeds

7.1.1.1 GRASS SEEDS

The Poaceae (grass) family is one of the largest angiosperm families, with almost 10,000 species (Judd, et al., 2008: 297). To help keep track of the taxa in this family it is typically divided into lower taxonomic groupings. There are currently twelve sub-families recognized (GPWG, 2001)(Figure 6-1), although only ten subfamilies occur in China. The Anomolochlooideae and the Puelioideae grass subfamilies are not present in China (Chen, S. L., D. Z. Li, et al., 2006). There are only five large subfamilies of grasses which do occur in China and these include the Bambusoideae, Ehrhartoideae, Chloridoideae, Panicoideae and Pooideae (see Judd, et al., 2008: 300). These subfamilies include the bamboos, rices, chloridoid and love grasses, millets and wheats respectively. In total there are approximately 226 genera and 1795 species of grasses in China (Table 7-2) (Chen, S. L., D. Z. Li, et al., 2006). Within these subfamilies plants are divided into tribes. There are approximately 28 tribes in the grass family that are present in China (Chen, S. L., D. Z. Li, et al., 2006) and half or 14 of these tribes are represented in the reference collection (Table 7-3).

Table 7-2 Grass Taxa in China Organised by Tribe (after Chen, S. L., D.Z. Li, et al., 2006: 4)

Andropogoneae	<i>Andropogon Apocopis Apluda Arthraxon Bothriochloa Cymbopogon Capillipedium Chionachne Chrysopogon Coix Dichanthium Dimeria Eremochloa Eulalia Eulaliopsis Germainia Hackelochloa Hemarthria Heteropogon Hyparrhenia Imperata Ischaemum Microstegium Miscanthus Mnesithea Ophiuros Phacelurus Pseudopogonatherum Pogonatherum Polytoa Polytrias Pseudanthistira Pseudosorghum Rottboellia Saccharum Schizachyrium Sehima Sorghum Spodiopogon Themeda Zea</i>
Aristideae	<i>Aristida Stipagrostis</i>
Arundineae	<i>Arundo Molinia Phragmites</i>
Arundinelleae	<i>Arundinella Garnotia</i>
Aveneae	<i>Agrostis Aira Alopecurus Anthoxanthum Arrhenatherum Avena xAgropogon Beckmannia Calamagrostis Cinna Coleanthus Cyathopus Deschampsia Deyeuxia Helictotrichon Holcus Koeleria Phalaris Phleum Polypogon Trisetum</i>
Bambuseae	<i>Acidosasa Ampelocalamus Arundinaria Bambusa Bonia Cephalostachyum Chimonobambusa Chimonocalamus Dendrocalamus Drepanostachyum Fargesia Ferocalamus Gaoligongshania Gelidocalamus Gigantochloa Himalayacalamus Melocalamus Melocanna Neomicrocalamus Indocalamus Indosasa Oligostachyum Phyllostachys Pseudosasa Pleioblastus Pseudostachyum Sasa Schizostachyum Semiarundinaria Sinobambusa Shibataea Thamnocalamus Thyrsostachys Yushania</i>
Brachyelytreae	<i>Brachyelytrum</i>
Brachypodieae	<i>Brachypodium</i>
Bromeae	<i>Bromus Littledalea</i>
Brylkinieae	<i>Brylkinia</i>
Centothecaeae	<i>Centotheca Lophatherum</i>
Cynodonteae	<i>Bouteloua Buchloe Chloris Cynodon Enteropogon Eustachys Lepturus Microchloa Perotis Spartina Tragus Zoysia</i>
Danthonieae	<i>Cortaderia Danthonia Elytrophorus Schismus</i>
Diarrheneae	<i>Diarrhena</i>
Ehrharteae	<i>Ehrharta</i>
Eragrostideae	<i>Aeluropus Acrachne Cleistogenes Crypsis Dactyloctenium Desmostachya Dinebra Eleusine Eragrostiella Eragrostis Harpachne Leptochloa Muhlenbergia Neyraudia Orinus Sporobolus Tripogon</i>
Eriachneae	<i>Eriachne</i>
Isachneae	<i>Coelachne Isachne Sphaerocaryum</i>
Meliceae	<i>Glyceria Melica Schizachne</i>
Oryzeae	<i>Chikusichloa Hygroryza Leersia Oryza Zizania</i>
Paniceae	<i>Acroceras Alloteropsis Axonopus Brachiaria Cenchrus Cyrtococcum Digitaria Echinochloa Eriochloa Hymenachne Ichnanthus Melinis Oplismenus Ottochloa Panicum Paspalidium Paspalum Pennisetum Pseudechinolaena Pseudoraphis Sacciolepis Setaria Setiacis Spinifex Stenotaphrum Thuarea Urochloa</i>
Pappophoreae	<i>Enneapogon</i>
Poeae	<i>Aniselytron Briza Catabrosa Colpodium Cynosurus Dactylis Festuca Lolium Milium Parapholis Poa Pseudosclerochloa Puccinellia Sclerochloa Scolochloa Vulpia</i>
Phaenospemateae	<i>Phaenosperma</i>
Phareae	<i>Leptaspis</i>
Stipeae	<i>Achnatherum Duthiea Orthoraphium Piptatherum Psammochloa Ptilagrostis Sinochasea Stephanachne Stipa Trikeria</i>
Thysanolaeneae	<i>Thysanolaena</i>
Triticeae	<i>Aegilops Agropyron Elymus Elytrigia Eremopyrum Hordeum Hystris Kengyilia Leymus Psathyrostachys Pseudoroegneria Secale Triticum</i>

Grass seeds (Poaceae family) in the collection come from the main grass subfamilies in the research area. These include the arundinoid, chloridoid, ehrhartoid, panicoid and poooid subfamilies. In total six grass sub-families are represented by seed and macrobotanical remains in the collection (Table 7-3). The arundionid, bambusoid and chloridoid subfamilies are not known to have been represented by seed or macrobotanical remains in ancient China. Seeds of these taxa were not recovered from the flotation samples analysed for this thesis and grass seed or macrobotanical remains in these subfamilies will not be discussed further. Where these subfamilies are represented by other plant remains such as phytoliths this is discussed in later sections of this chapter. Grass seed and macrobotanical remains in ancient North China may usually be referred to the ehrhartoid, panicoid and poooid subfamilies which are discussed below.

Table 7-3 Grass Taxa Present in Reference Collection

Subfamily	Tribe	Genera
Arundinoideae	Arundineae	<i>Phragmites</i>
Bambusoideae	Bambuseae	<i>cf. Phyllostachys</i>
Chloridoideae	Cynodonteae	<i>Chloris</i>
	Eragrostideae	<i>Eleusine, Eragrostis</i>
Danthonoidieae	Danthonieae	<i>Cortaderia, cf. Danthonia</i>
Ehrhartoideae	Ehrharteae	<i>Ehrharta</i>
	Oryzeae	<i>Oryza, Zizania</i>
Panicoideae	Andropogoneae	<i>Coix, Cymbopogon, Hackenochloa, Imperata, Miscanthus, Saccharum, Sorghum, Themeda, Zea</i>
	Paniceae	<i>Cenchrus, Digitaria, Echinochloa, Panicum, Paspalum, Pennisetum, Setaria, Spinifex</i>
Pooideae	Avenaceae	<i>Avena, Calamagrostis, Holcus, Phalaris</i>
	Bromeae	<i>Bromus</i>
	Poeae	<i>Briza, Dactylis, Poa</i>
	Stipeae	<i>Stipa</i>
	Triticeae	<i>Aegilops, Agropyron, Elymus, Hordeum, Leymus, Secale, Triticum</i>

7.1.1.1.1 Ehrhartoid Subfamily of Grasses (Including Rice)

The Ehrhartoideae subfamily is important archaeologically in China. It includes the tribe Oryzeae which includes rice (*Oryza* sp.) and this is a major food source for much of the world today. Several types of wild rice and other wetland species that may be found as part

of the weed complex in rice crops are also included in this tribe. While many would agree that rice appears to have been domesticated in South China (Balter, 2009: 1550) this is debated as rice was also found in North China during the Peiligang at sites such as Jiahu (Liu, Li, G.-A. Lee, et al., 2007; Zhao, Z. & J. Zhang, 2009). Rice seeds were not recovered during research for my thesis.

7.1.1.1.2 Panicoid Subfamily of Grasses

The Panicoideae subfamily is also important archaeologically. This subfamily includes several tribes in China such as the Andropogoneae (sorghum, Job's tears and corn) tribe and the Paniceae (millet) tribe. While Andropogoneae tribe seeds have not been identified from the Peiligang or Yangshao periods in North China Paniceae tribe seeds are common components of Neolithic North Chinese sites (Lee, G.-A., et al., 2007). For this reason Paniceae tribe grasses are well represented in the collection. This tribe includes genera such as *Setaria* and *Panicum* (Figure 7-1) both of which occur as domesticated taxa in the early Neolithic Peiligang period in North China. The genus *Echinochloa*, which includes barnyard millet, is also a member of the Paniceae tribe (Figure 7-1) and was domesticated during the Jomon period in Japan (Crawford, 1983: 31; 2011). *Echinochloa* sp. grass seeds also occur in the Palaeolithic (see Chapter 8) and Neolithic (Lee, G.-A., et al., 2007) periods in the study region including at Jiahu (Zhao, Z. & J. Zhang, 2009).

Paniceae tribe grasses tend to have small (<3 mm) seeds in comparison to some other grasses, such as the wheat tribe (Triticeae). As Paniceae grasses comprise the main Neolithic crops in China the sets of nested sieves typically used for Chinese flotation samples (cf. Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007) include a 2 mm and a 1 mm specifically to separate broomcorn from foxtail millet in the samples. Broomcorn millet grains are approximately 2 mm long while foxtail millet grains are smaller (Samuel, 2001: 399) meaning the sieving process allows them to be separated out more easily and efficiently. The other main difference between broomcorn and foxtail millet is in the length and shape of the embryo scar (Figure 7-1). Broomcorn millet has a short and triangular shaped embryo scar while foxtail millet exhibits an elongate embryo scar typically covering $\frac{1}{2}$ to $\frac{3}{4}$ of the seed length. Barnyard millet has a keyhole shaped embryo with a double outline around the embryo itself (Figure 7-1).

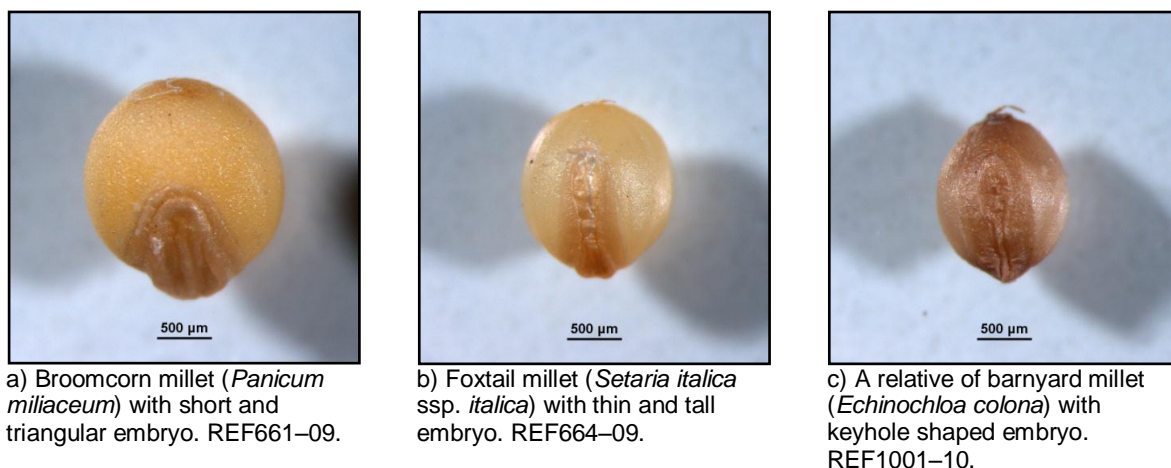


Figure 7-1a–c Paniceae tribe grass seeds showing variation in grass embryos

7.1.1.1.3 Pooideae Subfamily of Grasses (Including Wheat)

The Pooideae subfamily includes several tribes in China such as the Bromaeae, Pooeae and Triticeae. The most archaeologically and economically useful of these tribes is the wheat (Triticeae) tribe. Wheat and barley are both members of the Triticeae tribe and were domesticated in the Near East (Zohary & Hopf, 2000). Based on macrobotanical evidence wheat (*Triticum aestivum*) is thought to have been introduced to China during the late Neolithic around 4,500 cal BP (Zhao, Z., 2009). Starch grains recovered from several Neolithic grinding slabs have similarities to wheat (*Triticum* sp.) and were identified as a likely wild wheat such as *Agropyron* sp. (crested wheat-grass) or *Elymus* sp. (wheatgrass) (Liu, Li, et al., 2011; also chapter 8). A small number of pooide grasses occur at Jiahu (Zhao, Z. & J. Zhang, 2009) but these were not further identified to tribe or genus. More research is needed to identify them with certainty.

Plants from the wheat tribe Triticeae in the collection now include genera such as *Triticum* (wheat), *Hordeum* (barley), *Aegilops* (goat grass) as well as several other wild wheat tribe taxa. Macrobotanical pooide or Triticeae taxa were not recovered from the flotation assemblages studied.

7.1.1.2 SEEDS FROM HERBACEOUS TAXA

Seed remains other than grasses are included in the collection. These include vegetable or herbaceous seeds such as those from the mustard family (Brassicaceae), the buckwheat family (Polygonaceae), and the goosefoot family (Chenopodiaceae). A lot of macrobotanical research emphasizes crop seeds, meaning that wild or herbaceous seeds such as those listed above may be overlooked in site reports. In cases where systematic

archaeobotany or flotation is not carried out such plants may not even be collected, contributing to their absence in the literature. The above families feature in Neolithic Chinese flotation samples (e.g., Lee, G.-A., et al., 2007) hence their inclusion in the collection. It is often unclear whether seeds feature in an archaeological site through accidental inclusion in a fire, through dietary intake, or through dung fuel. For this reason a range of plants that were not necessarily edible were included in the plant collection.

7.1.1.3 SEEDS FROM WATER PLANTS INCLUDING SEDGES AND REEDS

Sedge and reed seeds also occur in the ancient Chinese archaeological record (Lee, G.-A., et al., 2007) and the reference collection includes over ten sedge (Cyperaceae) and reed (Juncaceae) specimens. Cyperaceae family seeds occur at Jiahu (Zhao, Z. & J. Zhang, 2009) but were not recovered from the assemblages studied.

7.1.2 Nut Remains

A ‘nut’ has many definitions in the vernacular and may be loosely defined as a one-seeded, dry and indehiscent fruit with a hard outer coat (Woodland, 2009: 632). This is usually the pericarp or endocarp of the fruit. However, many plant remains that some archaeologists describe as ‘nuts’ do not easily fit this definition. The Rosaceae family, which includes many fruits such as apricots, apples, pears and numerous berries including strawberries and raspberries, is one such example. Fruits and berries are a common component of archaeological sites in north China (see Lee, G.-A., et al., 2007) hence members of the rose family were included in the collection. Technically speaking, few members of the Rosaceae family are true nuts and many are fleshy fruits which may have a hard seed in the center. However, it is difficult to separate small archaeological fragments of nut from small fragments of stone fruit or pips so these are sometimes included in a general ‘nut’ or ‘fruit’ category. In total, over 150 individual specimens may be utilized as archaeological ‘nut’ or ‘fruit’ reference specimens and examples from the collection are tabled below (Table 7-4).

Nutshell is frequently noted in ancient Chinese samples (Lee, G.-A., et al., 2007) although it may be difficult to identify it to genus or species level. More typical ‘nuts’ include reproductive structures such as walnuts and hickory nuts (*Juglans* and *Carya* sp. respectively, in the Juglandaceae). Of particular interest to North Chinese research are nuts in the Fagaceae family, including chestnuts (*Castanea* sp.) and acorns (*Cyclobalanopsis* sp., *Lithocarpus* sp. and *Quercus* sp.). *Carya* sp. hickory and *Quercus* sp. acorns were both recovered from Jiahu (Zhao, Z. & J. Zhang, 2009). Li Liu (2010c) has raised the issue of

nuts or acorns being a staple food source in ancient China and a focus of the current research has been to test and evaluate this suggestion through starch and residue analysis.

Table 7-4 Plants with Nuts and Heavy or Large Reproductive Structures in the Reference Collection

Family	Genus	No. Specimens	Common Name
Anacardiaceae	<i>Mangifera</i>	1	Mango
Aquifoliaceae	<i>Ilex</i>	2	Holly
Betulaceae	<i>Betula</i>	2	Birch
Cupressaceae	<i>Cypress</i>	2	Cypress
Cupressaceae	<i>Chaemycyparis</i>	1	Cypress
Ebenaceae	<i>Diospyros</i>	2	Persimmon
Fabaceae	<i>Arachis</i>	2	Peanut
Fagaceae	<i>Castanea</i>	9	Chestnut
	<i>Castanopsis</i>	8	Chinquapin
	<i>Cyclobalanopsis</i>	9	Evergreen oak
	<i>Fagus</i>	2	Beech nut
	<i>Lithocarpus</i>	9	Tan oak
	<i>Quercus</i>	40	Oak
Gingkoaceae	<i>Gingko</i>	3	Gingko
Juglandaceae	<i>Carya</i>	3	Pecan
	<i>Juglans</i>	5	Walnut
Lecythidaceae	<i>Bertholletia</i>	1	Brazil nut
Myristicaceae	<i>Myristica</i>	2	Nutmeg
Nelumbonaceae	<i>Nelumbo</i>	5	Lotus
Nymphaeaceae	<i>Euryale</i>	5	Foxnut
Pinaceae	<i>Pinus</i>	6	Pines
Rosaceae	<i>Eriobotrya</i>	1	Loquat
	<i>Prunus</i>	10	Apricot, plum, peach, cherry
	<i>Pyrus</i>	2	Pear
	<i>Rosa</i>	2	Rose hip
	<i>Rubus</i>	3	Blackberry/ raspberry †
Smilacaceae	<i>Smilax</i>	2	Greenbrier
Rhamnaceae	<i>Zizyphus</i>	3	Jujube date
Vitaceae	<i>Vitis</i>	1	Grape

† Small achenes preserve as a nut-like object when charred.

7.1.3 Charcoal or Wood Remains

The term ‘charcoal’ may refer to the remains of charred, secondarily thickened or lignified plant stems (‘tree trunks’) but it is also used in a more general sense to refer to any charred plant remains. Charred wood remains may have been used in archaeological sites for building or other materials. As such, they may provide evidence for cultural use or merely for environmental reconstructions. An examination of charred wood from the Yiluo and surrounding regions is beyond the scope of this thesis hence wood remains in the collection are minimal. The reader is referred to published references on the subject of wood identification (Carlquist, 2001; Schweingruber, et al., 2006). There are, however, small amounts and fragments of both angiosperm and gymnosperm wood and bark available for reference as needed. The presence of both coniferous and flowering plant charcoal was noted in the flotation samples collected from the study sites but was not analysed or recorded in any detail. This is a topic for future research.

7.1.4 Parenchymatous Plant Tissues

Plant tissues are not often identified archaeologically (although see Hather, 1991, 1993). However, some parenchymatous tissues were retained in the reference collection. Fragments of yam (e.g., Dioscoreaceae) were thinly sliced prior to thorough drying and storage, while other tissue fragments include root or underground storage organs (e.g. bracken fern or fiddleback *Pteridium esculentum*) and corms (e.g. *Fritillaria* sp.). Water chestnuts (*Trapa* sp.) and lotus tubers as well as seeds (*Nelumbo* sp.) were also included in the collection. Both water chestnut and lotus tubers (Figure 7-2) were recovered from Jiahu site (Zhao, Z. & J. Zhang, 2009).

Other plant remains also periodically occur in flotation samples including possible pods from legumes (cf. Fabaceae or bean family) and rind fragments (cf Cucurbitaceae). While Cucurbit seeds such as bottle gourd (*Lagenaria siceraria*) have been recovered from early Chinese sites such as the 7,000–6,500 year old Hemudu site (Crawford, 1992) and the 6,900 – 6,600 year old Tianluoshan site (Fuller, et al., 2009; 2010) they are not known from North China during the Neolithic period. The reference collection provides over 100 specimens useful in vegetative plant comparisons such as lotus roots, taro tubers and jujube dates (Figure 7-2). However, these specimens are not listed in any detail here. This is because only one tuber fragment was recovered from the sites studied (see Chapter 8) and it was too small to be considered diagnostic.



Figure 7-2a–c Vegetative, parenchymatous and berry modern references. Scale in millimeters at base.

7.2 Phytolith Plant Specimens in Plant Reference Collection

Microfossils are another well known set of plant remains which may be preserved archaeologically. Microfossils include both phytoliths and starch remains and are generally examined using high power microscopy. They do not need to be carbonized or waterlogged for preservation. The different taphonomic and site preservation factors relating to microfossils may allow entirely different assemblages of plant remains to occur. Phytoliths and starch microfossils in the reference collection will be discussed below.

Phytoliths are silica bodies which form in the inter-and intra-cellular spaces of certain plants (Mulholland and Rapp, 1992: 1; Piperno, 2006: 5). This occurs after a plant takes up mono-silicic acid from groundwater through their roots and it precipitates out in the leaves and stems of a plant (Piperno, 2006: 13). Increased water taken up by plants that typically form phytoliths may result in increased phytolith abundance, thus irrigated crops are likely to produce more phytoliths than non-irrigated or dryland crops of the same species (Rosen & Weiner, 1994).

Different plant parts (leaf, leaf sheath, husk and stem) produce different types of phytoliths (e.g., Harvey & Fuller, 2004). This is reflected in the phytolith slide preparations where different parts of the plant were mounted on different slides (see also Chapter 6). This also allows food processing areas and techniques such as threshing, winnowing and de-husking to be identified in the archaeological record (Harvey & Fuller, 2004; Weisskopf, 2010).

Phytolith identifications and descriptions in this project follow the International Guide to Phytolith Nomenclature (ICPN 2005) which sets out a standardized set of phytoliths descriptors.

The main groups of phytolith producing plants relevant to Chinese archaeology sites include grasses, sedges and eudicots⁷ (Table 7-5). Grass subfamilies may be recognized by their phytoliths such as pooid grasses (rondels), panicoid grasses (bilobes and crosses) and chloridoid grasses (saddle shaped phytoliths)⁸. Sedges have conical phytoliths (see Piperno, 2006: figure 1.1a) while eudicot trees are generally thought to produce non-diagnostic phytoliths (Piperno, 2006: 6-7) although this is not always the case. Eudicots include trees and shrubs such as oaks (*Cyclobalanopsis*, *Lithocarpus*, *Quercus* spp.), walnuts (*Juglans* sp.) and a great many other tree/shrub taxa. Eudicots also include the Asteraceae or daisy family which may produce diagnostic phytoliths in the form of opaque, perforated platelets (Bozarth, 1992: figure 10.5a; Piperno, 2006: 196).

Various other groups of plants including some gourds (Cucurbitaceae) also produce diagnostic phytoliths (Piperno, et al., 2009). Bottle gourds (*Lagenaria siceraria*) have not been located in Chinese Palaeolithic or Neolithic sites in the study area. Certain pine needles (*Pinus* sp.) have also been found to produce diagnostic phytoliths (Piperno, 2006: figure 2.5b) and may be present in the study area (see Chapter 10).

Various plants produced minimal or no phytoliths and therefore there is a preservation bias against such plants being detected through phytolith analysis. For a complete list of plants with and without phytoliths the reader is referred to published references on the subject including Piperno (2006: table 1.1). Relevant plant families that rarely or never produce phytoliths include Alismataceae (water plantains including *Sagittaria* sp.), Amaranthaceae (amaranths), Araceae (taro), Chenopodiaceae (chenopods/ goosefoot), Dioscoreaceae (yams), Juglandaceae (walnuts), Juncaceae (reeds), Liliaceae (onions and some bulbs), Nymphaeaceae (water lilies), Polygonaceae (*Polygonum* sp. and buckwheat), Rhamnaceae (including jujube date), Rosaceae (rose and fruit family including apples, plums and peaches), Theaceae (tea) and Typhaceae (cattail (*Typha* sp.) reeds). Whilst lacking in phytoliths, some, but not all of these plants exhibit starch grains. Thus their presence in the

⁷ Angiosperms were previously divided into monocots and dicots but dicots now include basal angiosperms and eudicots (Tudge, 2005: 123-124). See Chapter 6 for more details.

⁸ Starch researchers frequently, but not always, identify starch grasses by grass tribe, which is a more exact taxonomic definition, and not by subfamily.

archaeobotanical record may be detected by the application of diagnostic research techniques.

Table 7-5 Relevant Phytoliths for the Study Region

Common Name	Details of Taxa/Tribe	Diagnostic Morphotypes	References	Notes
Grasses	Arundinoideae	Plateaued saddles	Ollendorf, et al. 1988; Piperno 2006:33	Plateaued saddles distinctive to Phragmites reeds; noted by H. Lu, et al., 2009 at Cishan
	Bambusoideae	Bilobate	GPWG, 2001	Not recovered from study area
	Chloridoideae	Saddles	Piperno, 2006: 29	Not recovered from study area
	Ehrhartoideae	Crosses; Double Peaked glume husks	Rosen, 2008; Z. Zhao, 1998	Not recovered for this research. Found in Yangshao period study area by Rosen, 2008
	Panicoideae	Bilobes; Panicum miliaceum type husk wave pattern	H. Lu, et al., 2009	Present at Cishan
	Panicoideae	Crosses; Setaria type husk wave pattern	H. Lu, et al., 2009	Present at Cishan
	Pooideae	Rondels; wave patterns with papillae	Rosen, 1992; 2005	Present in Longshan – Kangjia samples not presented in thesis
Sedges	Cyperaceae	Cones and hexagons	Ollendorf, et al., 1992	Not recovered from study area
Eudicots	Trees including acorns, chestnuts	Platey forms including possible hair bases	See Bozarth, 1992; Piperno, 2006	Present on Jiahu sickles (see Chapter 10); present in Weisskopf (2010)
Daisies	Asteraceae	Opaque perforated platelets	Bozarth, 1992; figure 10.5a; Piperno, 2006: 196	Not recovered from study area
Pines	Pinaceae	Spiny long cells	Piperno, 2006: 190;	Possibly present in study area
Gourds	<i>Lagenaria siceraria</i>	Scalloped phytoliths	Piperno, et al., 2000; 2002; 2006:206; 2009	Not recovered from study area

Table 7-6 Number and Genera of Grass Sub-families

Grass Sub-Family	Tribes Present in China	Genera in China	Species in China	Genera in Collection	Genera per Subfamily in China
Aristidoideae	Aristideae	2	12	0	2
Arundinoideae	Arundineae	3	6	1	7
	Eriachneae	2	1	0	
	Thysanolaeneae	2	1	0	
Bambusoideae	Bambuseae	34(1)	534(3)	1	35(1)
	Phaenospermateae	1	1	0	
Centothecoideae	Centothecae	2	3	0	2
Chloridoideae	Cynodonteae	12(3)	27(6)	1	30(3)
	Eragrostideae	17	92(3)	2	
	Pappophoreae	1	2	0	
Danthonioideae	Danthonieae	4(1)	6(1)	2	4(1)
Ehrhartoideae	Ehrhartoideae	1(1)	1(1)	0	6(1)
	Oryzeae	5	13(2)	2	
Panicoideae	Andropogoneae	41(1–2)	204(7–8)	9	73(3–4)
	Arundinelleae	2	25	0	
	Isachneae	3	20	0	
	Paniceae	27(2)	145(12)	8	
Pharoideae	Phareae	1	1	0	1
Pooideae	Aveneae	20	144(11–12)	4	67(1)
	Brachyelytreae	1	1	0	
	Brachypodieae	1	5	0	
	Bromeae	2	59(3)	1	
	Brylkinieae	1	1	0	
	Diarrheneae	1	3	0	
	Meliceae	3	34	0	
	Poeae	16	212(9)	3	
	Stipeae	10	67	1	
	Triticeae	13(1)	175(8)	7	

† Sub-families in this table follow the GPWG (2001) phylogeny. Tribes, genera and species present in China follow S. L. Chen, D. Z. Li and colleagues (2006) in the Flora of China online.

‡ Bracketed figures refer to introduced genera or species included in the total count. Thus 1(1) means that there is only one genus/species in that group and it is an introduction and not native, to China. Archaeological period introductions to China are not included as introduced taxa.

Over 150 plants were collected for use as phytolith or cellular reference specimens (see Table 7-5). Phytolith reference slides represent over fifty genera in over twenty families. The main phytoliths or cellular identifications used for this project are discussed below and include grasses, sedges and reeds, eudicots and other phytoliths.

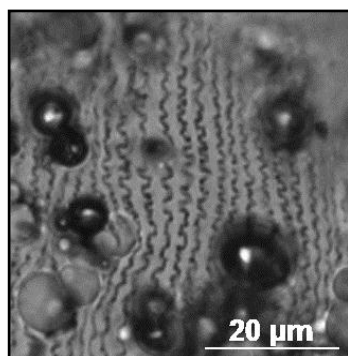
7.2.1 Grass Phytoliths

In grasses, as in other plants, phytoliths occur as both single and multi-celled forms. Multi-celled silica skeletons with both long and short cells are more diagnostic and more likely to be identified to a specific taxonomic level. Multi-celled silica skeletons may include stomates (clusters of cells that allow pores in a leaf epidermis to ‘breathe’) (Mullholland & Rapp, 1992c: 67) or hair bases such as papillae (Rosen, 1992). Phytoliths from the husks surrounding grass seeds are also highly diagnostic and may be used to identify a plant to genus (e.g. Rosen, 1992) as well as species (Lu, H., et al. 2009b). Note that while ancient grass starches are typically identified to tribe taxonomic level, grass phytoliths are typically identified to subfamily taxonomic level.

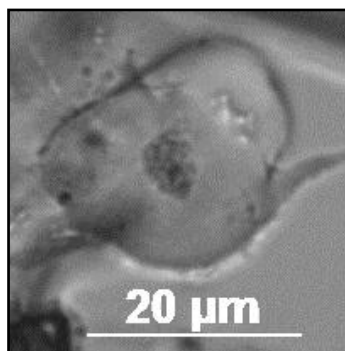
Grass phytoliths may be relatively diagnostic. The most archaeologically relevant subfamily in North China in the early Neolithic is the Panicoideae subfamily which includes the Paniceae or millet tribe. Of the ten grass subfamilies present in China specimens from seven are included in the plant reference collection (Table 7-3). The subfamilies not included typically have few genera (Table 7-6) and were not considered economically important in the study region.

7.2.1.1 ARUNDINOIDEAE PHYTOLITHS

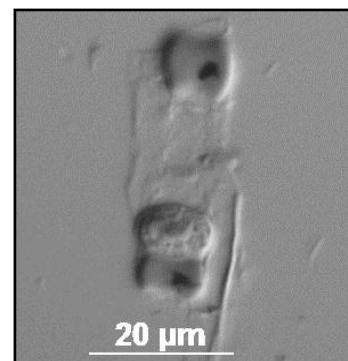
The Arundineae tribe includes a small number of reed like grasses such as *Arundo* sp. and *Phragmites* sp. reeds (Piperno, 2006: 33). Plateaued saddles are diagnostic to *Phragmites* sp. reeds (Ollendorf, et al., 1988; Piperno & Pearsall, 1998). *Phragmites* sp. reeds were identified by H. Lu and colleagues (2009a) at Cishan dating to between 10,300 and 8,700 cal BP. H. Lu and colleagues suggested that mats of reeds had been placed between layers of stored millet grains in ash pits. Although Cishan site is not within the study region, it is part of the Peiligang and related cultures described by K. C. Chang (1986: 91-93) and typically grouped together for ease of reference. Few, if any, phytolith studies have been carried out on other Peiligang and related culture sites so reference specimens of *Phragmites* sp. reeds were examined (Figure 7-3). They were not detected in the study region.



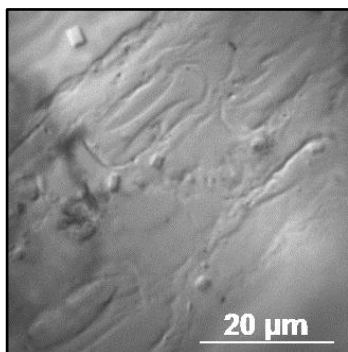
a) Non-diagnostic ashed stem long cell multi-cellular phytolith under a brightfield filter



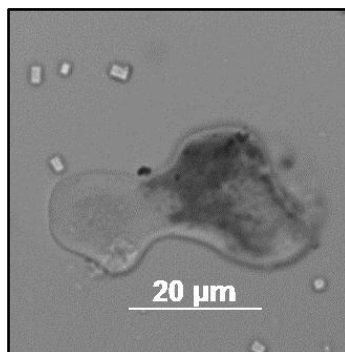
b) Ashed leaf sheath plateauead saddle taken under a DIC filter



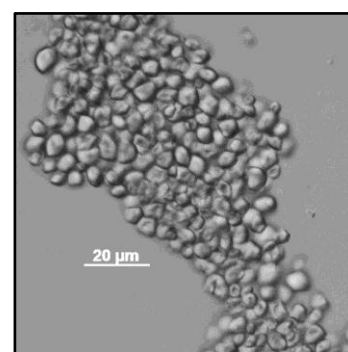
c) Plateauead saddles from leaf taken under a DIC filter



d) Stomates from the modern reference of a leaf sheath taken under a DIC filter



e) Bilobe from the modern reference of a leaf sheath taken under a DIC filter



f) Starch from underground stolons taken under a DIC filter

Figure 7-3 Arundinoideae tribe phytoliths from *Phragmites karka* (REF587–09) reeds

7.2.1.2 BAMBUSOIDEAE PHYTOLITHS

Bamboo has been used for centuries as a tool in Asia although the exact age of its use is unknown (West & Louys, 2007: 512). Given the poor preservation of wooden artefacts including bamboo, less direct methods are available to detect the presence of bamboo residues or tools. The origin of cut marks on bone, and whether the tool used was made of bamboo or stone, is one such possible method of detection (West & Louys, 2007). Bamboos exhibit phytoliths diagnostic to both tribe and genus level (see Piperno, 2006: 33). It was hoped that phytoliths identifiable as bamboo would provide information on the antiquity of wooden bamboo tools in Asia. However, none were recovered in the study area.

7.2.1.3 CHLORIDOIDEAE PHYTOLITHS

The chloridoid subfamily is one of the larger grass sub-families. High concentrations of chloridoid sub-family grasses mainly occur in arid or semi-arid regions (Twiss, 1992: 117-118) and these grasses are typically drought adapted (Piperno, 2006: 28). The goose

grasses or crowfoot grasses from the Chloridoideae tribe include several species of *Eleusine* which was domesticated in Africa (Hilu & de Wet, 1976). *Eleusine indica* (crowfoot grass) is the ancestral progenitor of the domesticated African finger millet (*Eleusine coracana*) (Hilu & de Wet, 1976) and probably represents an early state or historic period introduction to China. Although this plant is commonly described as ‘millet’ it is not closely related to the panicoid subfamily of millet which includes the Paniceae or millet tribe. The chloridoid subfamily was included in the reference collection based on the evidence for long term use and domestication of chloridoid grasses in Africa and elsewhere (Hilu & de Wet, 1976). These chloridoid grasses typically exhibit saddle shaped phytoliths (GPWG 2001 in Piperno 2006: figure 2.2 page 30). Although chloridoid phytoliths have not been identified in phytoliths from the study area the presence of chloridoid grasses in the reference collection allows for the exclusion of certain taxa.

7.2.1.4 EHRHARTOIDEAE PHYTOLITHS

The Ehrhartoid and Oryzoid tribes together make up the Ehrharotideae subfamily. The Ehrharteae tribe is not native to China but is a modern introduction (Chen, S. L., & Phillips, 2006a) meaning that only the Oryzeae (rice) tribe is indigenous to China. Rice is typically considered to have been domesticated in South China (Balter, 2009; Crawford & Shen, 1998; Fuller, et al., 2009; Konishi, et al., 2006) although this is debated (see discussion in Chapter 3). Macrobotanical grains of rice are known from the Jiahu site in North China during the Peiligang period (Zhao, Z. & J. Zhang, 2009). Early macrobotanically identified grains of rice are also known in North China from the Yuezhuang site of the Houli culture located in Shandong province (Crawford, et al., 2007). In the study area microfossils from rice husks were identified in a Yangshao period rice paddy near Huizui (Rosen, 2007b). Given these early uses of rice in North China phytoliths of rice were examined (Figure 7-4; Figure 7.5).

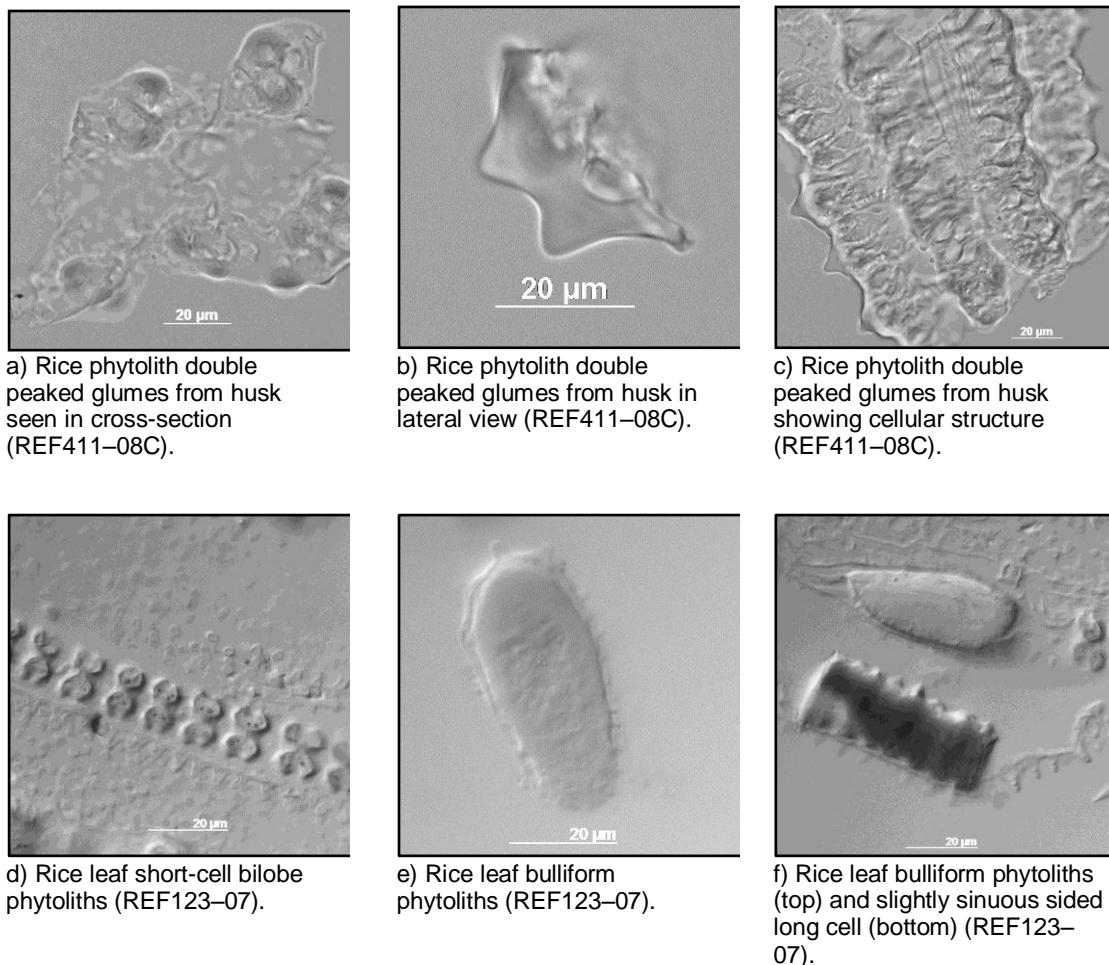
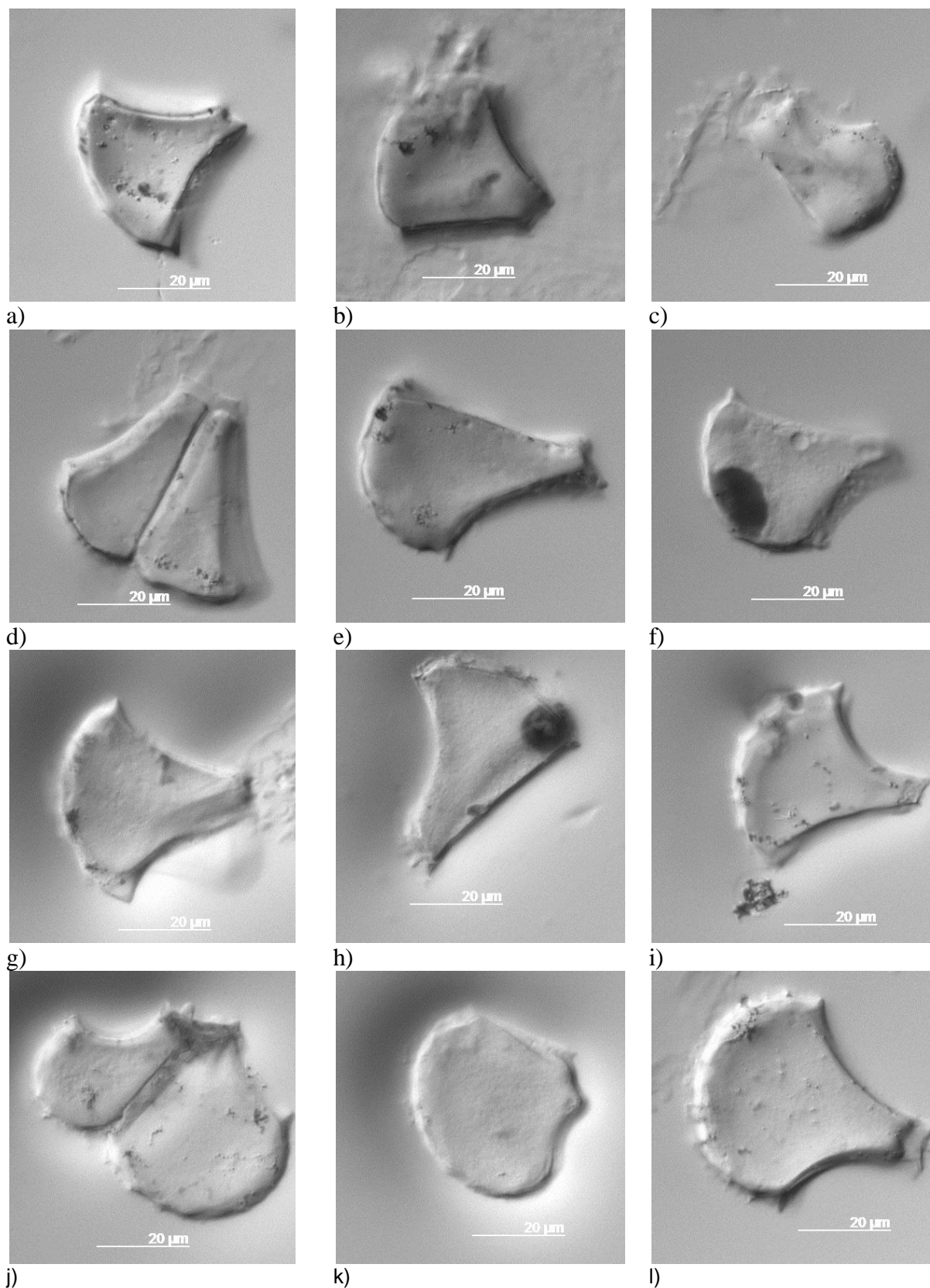


Figure 7-4 a-f Rice (*Oryza* sp.) phytoliths under DIC filter including (a-c) double-peaked glume cells, (d) bilobes, and (e-f) non-diagnostic bulliform cells and a long cell.

Genetic evidence suggests that subspecies of rice may be distinguished by their phytoliths (Zheng, Y., et al., 2003). Husk phytoliths from the Oryzeae tribe are diagnostic to the genus *Oryza* (Pearsall, et al., 1995) with double-peaked glume cells being especially diagnostic (Figure 7-4). Other phytoliths found in rice, including bilobes, bulliform cells and long cells (Figure 7-4) are not considered particularly diagnostic. Fan shaped phytoliths may be indicative of the *Oryza* genus, but they are not considered diagnostic (Pearsall, et al., 1995). Fan-shaped cells recovered from rice vary considerably in shape, with some having scalloped edges while others appear to have smooth edges (Figure 7-5). Despite examination of possible rice harvesting sickles from the Jiahu site (see Chapter 10) diagnostic rice phytoliths were not recovered from the study region.



j) Figure 7-5 Possible variation in fan-shaped phytoliths from one *Oryza* sp. reference specimen

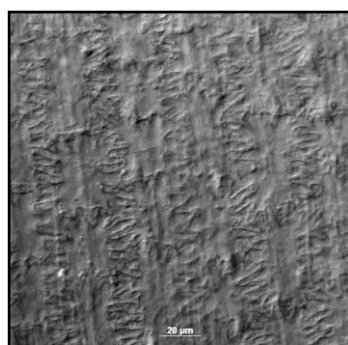
7.2.1.5 PANICOIDEAE PHYTOLITHS

The Panicoideae sub-family includes the Andropogoneae, Arundinelleae, Isachneae and Paniceae tribes. Of these the Andropogoneae and Paniceae tribes are most archaeologically

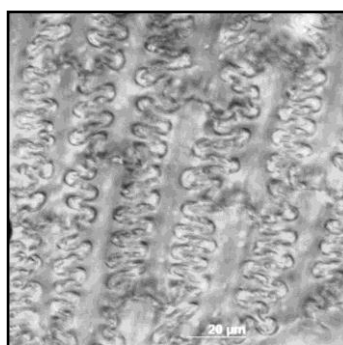
relevant. The Andropogoneae tribe includes several taxa that were domesticated in other countries such as sorghum (*Sorghum bicolor*) and maize (*Zea mays*). Andropogoneae tribe taxa that were useful in ancient China include Job's tears (*Coix lacryma jobi*). However, diagnostic Andropogoneae tribe phytoliths were not recovered from the study area.

The Paniceae tribe includes several types of millet including broomcorn and foxtail millet. Twenty-seven genera of Paniceae tribe grasses are listed in the FOC (Chen, S. L., S. M. Phillips, & S. A. Renvoize, 2006) and several of these genera were examined for phytoliths. Several studies have identified Paniceae tribe phytoliths in the archaeological record in China (Li, Xiaoqiang, et al., 2007: 558; Lu, H., et al., 2009a). Such studies typically rely on husk phytoliths which may be diagnostic. The husk phytoliths of *Setaria* sp. have a diagnostic wave pattern (Figure 7-6) and H. Lu and colleagues (2009b) have described this in detail. According to their research the *Setaria* type husk phytoliths differ from *Panicum* sp. husk phytoliths due to cellular pattern wave style and amplitude (Figure 7-6; Figure 7-7). They have used this to distinguish domesticated foxtail millet from broomcorn millet (*Panicum miliaceum*) at the Cishan site, although not without controversy (see Chapter 8). Xiaoqiang Li and colleagues (2007: 558) claim to have identified 'dendritiform millet phytoliths' from domesticated broomcorn and foxtail millet at the Xishanping site in China. Dendritic phytoliths are not often diagnostic so it is unclear how this identification was made.

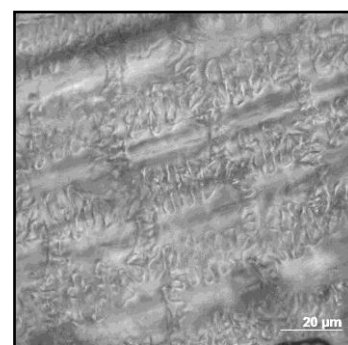
Bilobe phytoliths (Figure 7-8) also occur in numerous panicoid grasses as well as in other grass subfamilies such as bamboos (GPWG 2001 in Piperno 2006: figure 2.2 page 30). Based on intensive morphometric analyses of broomcorn and foxtail millet phytoliths H. Lu and colleagues (2009b) suggest that these are also diagnostic although they only examined four other wild species of Paniceae tribe grasses in this study. Further research may be required to identify short cells to species and domesticated subspecies level in an archaeological situation where the likelihood of other wild grasses being present is high. Short-celled phytoliths were examined for my research (Figure 7-8).



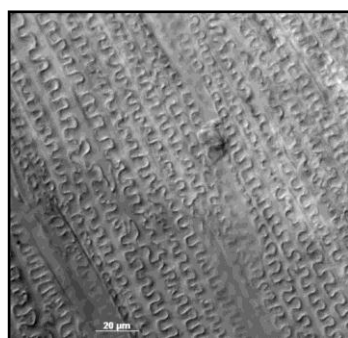
a) *Setaria palmifolia* husk (REF2001–10).



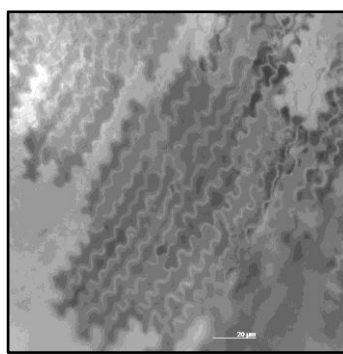
b) *Setaria italica* ssp. *italica* husk (REF601–09)



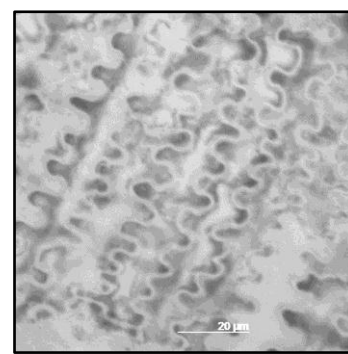
c) *Setaria italica* ssp. *viridis* husk (REF1037–10).



d) *Setaria palmifolia* non-diagnostic husk (REF2001–10).



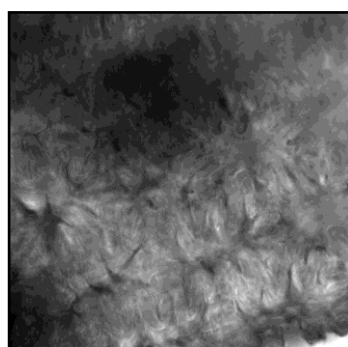
e) *Setaria italica* ssp. *viridis* leaf (REF1037–10)



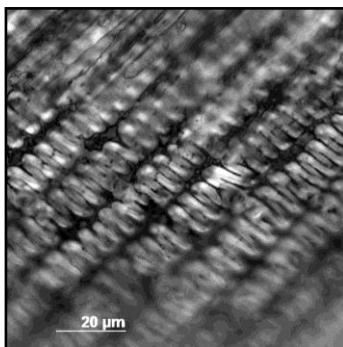
f) *Setaria italica* ssp. *viridis* leaf long cell (REF1037–10)

Figure 7-6a–f *Setaria* type wave pattern from various sections of husk, including (a–c) typical *Setaria* husk wave pattern and (d–f) less diagnostic wave patterns from long cells of *Setaria* sp.

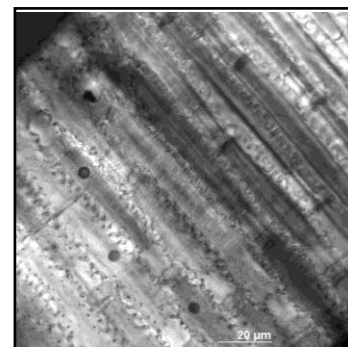
Bilobes were evident in the broomcorn millet specimens examined (Figure 7-8). A range of cross to bilobe-shaped short cells were evident in the foxtail millet specimens examined (Figure 7-8). Wild foxtail grass exhibited elongate bilobate short-celled phytoliths (Figure 7-8). This suggests that there may be small differences between these samples which further research may find diagnostic.



a) *Panicum miliaceum* husk phytoliths (REF661–09)



b) *Panicum bisulcatum* husk phytoliths (REF944–09)



c) *Panicum maxima* showing cross-shaped short cells (REF945–09)

Figure 7-7a–c *Panicum* sp. grass husk wave patterns including (a) typical *Panicum* husk wave pattern and (b) less diagnostic husk wave pattern similar to those of *Setaria* husks. The cellular structure in (c) exhibits short cells typical of some *Panicum* sp. grasses.

Bamboo was thought to exhibit bilobate phytoliths, but the cf. *Phyllostachys* sp. specimen examined exhibited cross-shaped phytoliths dissimilar to Paniceae grasses (Figure 7-8). This suggests that future archaeobotanical research may find it possible to differentiate between these important taxa (see also differentiation between these taxa in Piperno, 2006: Table 2; Wang, Y. and H. Lu, 1992).

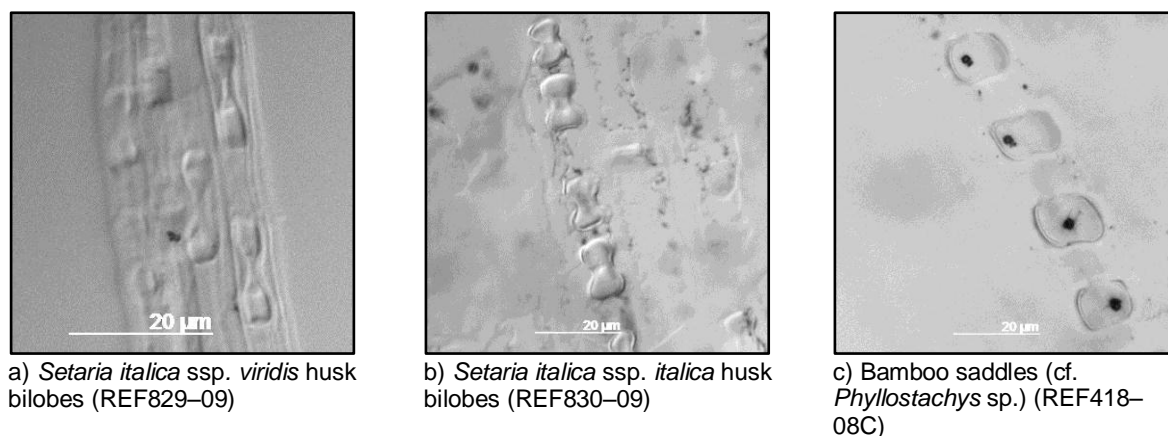


Figure 7-8a–c Short cell bilobes and crosses in the Paniceae and Bambuseae tribes

7.2.1.6 POOIDEAE PHYTOLITHS

The pooid subfamily includes tribes such as the Aveneae (oats), Bromeae (brome grass), the Poeae (poas) and the Triticeae (wheats and barleys). Extensive archaeobotanical research has been carried out on Triticeae tribe phytoliths for at least twenty years (Rosen, 1992; Rosen & Weiner, 1994). This is partly due to the domestication of wheats and barleys in the Levant and their connection to the origins of agriculture in that region. Wheat (*Triticum* sp.) and barley (*Hordeum* sp.) as well as other Triticeae grasses have diagnostic husk phytoliths (Rosen, 1992; Rosen, 2005). These include a wavy pattern of husk silica cells interspersed with papillae (Figure 7-9) which may be diagnostic to genus (Rosen, 1992). Although starch from the cf. Triticeae tribe was present in the study region (Liu, Li, et al., 2011; see also chapter 9) phytoliths from the tribe were not detected. Some dendritic or ‘branched’ long cells more typical of pooid husks were observed but they were not considered diagnostic. Short-celled pooid rondel type phytoliths were not observed.

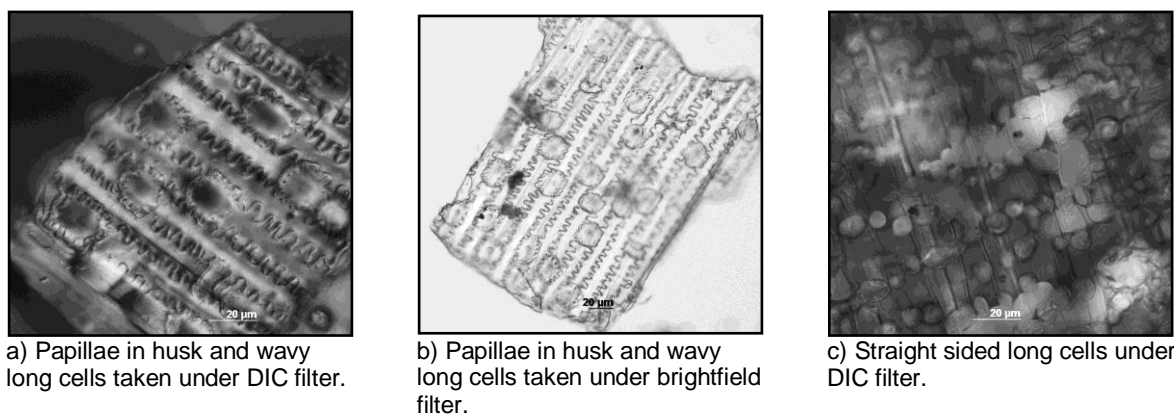


Figure 7-9a–c Typical Pooid grass husks from *Bromus cf. japonicus* (REF904–09) showing (a-b) rounded papillae within the cellular skeleton

7.2.2 Sedge and Reed Phytoliths

Sedge phytoliths (Cyperaceae) generally have cones (Figure 7-10) and may or may not have hexagonal-type silica skeletons (Figure 7-10). They are indicative of moist or slightly damp environments and may grow along waterways or river banks as well as in less obviously damp locations. Sedges may provide fodder for animals (such as water buffalo) and may also have starchy tubers that are eaten. Sedge seeds occur in Neolithic archaeological sites in the study region (Lee, G.-A., et al., 2007) hence sedges were collected for a range of comparative purposes including seeds (macrobotanical reference), tubers (starch) and phytoliths (leaf and stem references). The presence of baskets or matting is evident as impressions on the bottom of pots at the Jiahu site (Henansheng, 1999: 883).

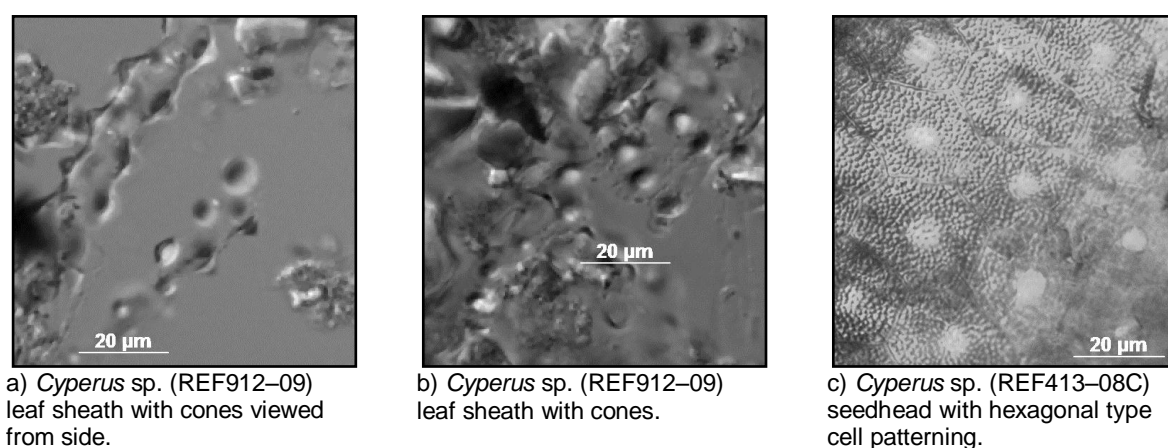


Figure 7-10a–c Cyperaceae sedge phytoliths

Juncaceae reeds are roughly similar to Cyperaceae sedges in habitat; furthermore, they were probably used to make baskets and matting in antiquity, as shown in the archaeological record (Jiang, L. & Li Liu, 2005). For this reason they were ashed and

prepped for phytolith examination. However, as Piperno (2006:7) predicted, there were few phytoliths present in the leaf sheathes or stems of the specimens examined (REF220–09 and REF934–09).

Cattails (*Typha* sp. reeds) were also examined for phytoliths. Cattail reeds produced few phytoliths when ashed in a muffle furnace and prepped (following procedures described in Piperno, 2006: 96-97; see also Chapter 5). Both *Typha orientalis* (REF224–09) and *Typha latifolia* (REF2066–11) were examined as well as a *Typha* specimen (REF911–09) not identified to species level. Whilst experimental sickles used to harvest *Typha* sp. reeds produced cellular remains it appeared that these were not silicified phytoliths but represented cellular, non-silicified plant cell remains only (see Chapter 10).

7.2.3 Eudicot Phytoliths

Eudicots make up approximately 75 percent of all land plants in the world today (Piperno, 2006: 16). They may have formed part of the leafy or vegetable component of the ancient diet or palaeoenvironment in the study area. Although they are not especially diagnostic, they still represent an otherwise overlooked part of ancient subsistence and dietary practices. Therefore trees with edible nut crops thought to have been present in the study region during the late Palaeolithic and early Holocene were collected and prepped (Table 7-7). Nuts present in the collection but not thought to be relevant to ancient China, such as Brazil nuts or pistachios, were not examined for phytoliths. Temperate and broadleaved forest species collected include oak (*Cyclobalanopsis* sp., *Lithocarpus* sp., *Quercus* sp.), chestnut (*Castanea* sp., *Castanopsis* sp.), walnut (*Juglans* sp.) and hackberry (*Celtis* sp.). Phytoliths from the leaves and nuts of these and other related trees were prepped as phytolith reference specimens. Platy phytoliths, hairs, tracheids and leaf hair bases were present in some taxa.

While not diagnostic to genus or even family or taxonomic order in some cases, platy phytoliths from eudicots and dicots may still be indicative of certain types of environments. For instance, eudicot phytoliths residues may indicate shrub or tree processing as opposed to cereal usage, such as the eudicot hair base phytoliths recovered from sickle residues (see Chapter 10).

Table 7-7 Trees with Nuts

Family	Genus	No. Specimens	Common Name
Fagaceae	<i>Cyclobalanopsis</i>	8	Evergreen oak
	<i>Fagus</i>	5	Beech
	<i>Lithocarpus</i>	9	Tan oak
	<i>Quercus</i>	40	Oak
	<i>Castanea</i>	8	Chestnut
	<i>Castanopsis</i>	5	Castanopsis
Juglandaceae	<i>Juglans</i>	10	Walnuts
	<i>Carya</i>	4	Hickory
Pinaceae	<i>Pinus</i>	6	Pine
Ulmaceae	<i>Celtis</i>	3	Hackberry
	<i>Ulmus</i>	8	Elm

7.2.4 Other Diagnostic Phytolith References

Other phytolith references that relate to North China include *Lagenaria siceraria* (bottle gourd) gourd shell or rind phytoliths. *Lagenaria siceraria* subspecies *siceraria* bottle gourds are indigenous to Africa but occur in the New World by 8,000 cal BP (Erickson, et al., 2005; Fuller, et al., 2010). This has led to suggestions that these, along with dogs, were early domesticates brought into the American continent by early Palaeoindian groups (Erickson, et al., 2005). Bottle gourds also occur in Japan during Jomon times at the Sannai-Maruyama site (Habu, 2004) and at the Awazu site by 11,700 – 10,900 cal BP (Tsuboi 1994, cited in Crawford, 2011: S335). The known occurrence of bottle gourds in Japan is much earlier than in China (Crawford, 2011: S342) where they occur by c. 8,000 BP at Kuahuqiao in Zhejiang Province, South China (Zhejiangsheng, 2004). Genetic evidence (Clarke, et al., 2006) suggests a dual domestication for Polynesian species of bottle gourd, with chloroplast markers being exclusively Asian but nuclear genetic markers being a mix of Asian and American. Bottle gourd seeds were accessioned in the reference collection and prepped for phytoliths but were not recovered in the study area.

Certain taxa in the Asteraceae (daisy) family have opaque perforated platelets (Bozarth, 1992: 203–205; Piperno, 2006: 195 figure 2.15b) which are diagnostic to the family (see also 2011). As well as angiosperm taxa, selected gymnosperms including pine tree needles

(*Pinus* sp.) were included in phytolith references as these may be used to identify ancient pines (Piperno, 2006: 36).

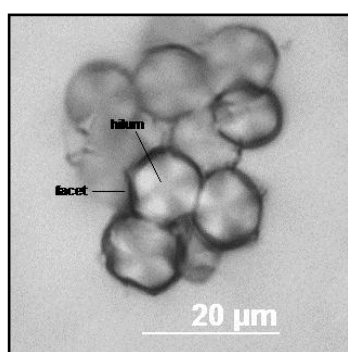
7.3 Starch in the Reference Collection

Starch research is a relatively new archaeobotanical technique. The first manual on starch research in archaeology was published less than a decade ago (Torrence & Barton, 2006). For this reason it was necessary to undertake extensive work to investigate starch occurrence, size range and morphology. More is already known about macrobotanical remains including archaeological seeds and macro remains (Pearsall, 2000: chapter 3; Renfrew, 1973), wood anatomy and charcoal, archaeological parenchyma (Hather, 1991, 1993, 2000) and phytoliths (Mulholland & Rapp, 1992; Piperno, 2006) than ancient starch, despite Torrence and Barton's (2006) book. Research on the modern reference collection aimed to determine which broad categories of plants had starch present in storage organs such as seeds, nuts and tubers. Research also aimed to determine which starch grains were diagnostic and could reliably be used as taxonomic identifiers.

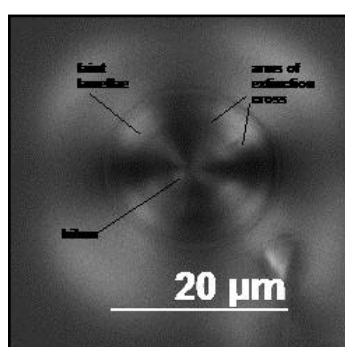
There is considerable debate about the best method of identifying starch grains, and of their most diagnostic features (Collins & Copeland, 2011; Lentfer, 2009; Torrence, et al., 2004). For the purpose of this project, both size and morphological elements of the starch grain including shape were taken as diagnostic (Table 7-8; Figure 7-11). Features considered secondarily important include the presence or absence of fissures, lamellae, surface features and hilum location (Figure 7-11; Table 7-8) (Henry, et al., 2009: Table 2; Lentfer, 2009: Table 2; Yang, X. Y., et al., 2012: 250). The main diagnostic features used were starch shape, with graphic evidence and statistical measurements of size used to further support starch classification by shape. To identify ancient starch when the sample is collected as a residue from an artefact, starch granules are typically placed on a slide and examined under a microscope. Standard non-toxic mounting media currently used for ancient samples, such as glycerol, do not permit substantial movement or rotation of the granule to identify 3D shape. Under the current methodology it is not practical nor is it possible to examine ancient starch granules recovered in this manner and identified on slides, under an SEM as an alternate method to provide evidence of their 3D shape. Starch granule categories used in this dissertation were based on 2D shape measurements however future research may utilise 3D shapes to further clarify ancient starch types.

Table 7-8 Diagnostic Attributes of Starch Grains

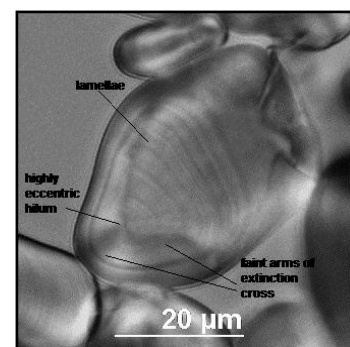
Feature	Details
Size	Size in microns, measured through hilum
2D shape	Perfectly round, perfectly angular or part round and angular
Details of shape	If perfectly round, choose from circular, oval or irregularly round.
Number of facets	If perfectly angular or partly round and partly angular, count number of facets.
Lamellae	Prominent, visible or not present
Hilum	Centric or eccentric
Fissures	Prominent, visible or not present
Arms of cross under cross-polar filters	Straight or not straight (e.g. curved or crooked)



a) Modern *Sorghum bicolor* (REF842–09) starch grain showing round and faceted grains, with facets and hilum evident



b) Modern *Triticum turgidum* var *durum* (REF1049–10) starch grain showing faint lamellae, centric hilum and arms of extinction cross



c) Modern *Dioscorea-opposita* (REF432–08C) starch grain showing lamellae, eccentric hilum and the faint arms of a crooked extinction cross

Figure 7-11 a–c Diagnostic features of starch grains showing (a) facets, (b) central hilum and lamellae and (c) lamellae and highly eccentric hilum.

Not all plants have starch and some plants have storage organs that do not contain starch. The murnong yam daisies of southern Australia (*Microseris lanceolata* and *Microseris scapigera*) are examples of plants without starch (Gott, 2008). Plants which do have starch often store their grains in tubers, nuts, or seeds, where the starch may be metabolized as required to provide energy and sugars for the plant. Transient starch granules, also called ‘transitory’ in the recently published online International Guide to Starch Nomenclature (ICSN, 2011) may also be present in a plant. The morphology of such granules is likely under some form of genetic control despite the description stating otherwise (see ICSN, 2011, following Denniston, 1907, Reichert, 1913) in the above mentioned guide. Transient granules may be located in stems or leaves of the plant but are not usually considered diagnostic to taxon.

In line with current hypotheses about the use of Peiligang grinding implements (see Chapter 9) cereals in the grass family Poaceae and acorns from the oak and chestnut family Fagaceae were examined and feature heavily in the plant reference collection. This is based on assumptions that grinding stones in Neolithic China signal cereal processing (e.g., Chang, K. C., 1986: 92-93; Tao, et al., 2011). Grinding slabs are generally considered proxies for cereal based agriculture in Neolithic China (see Liu, Li, et al., 2002-2004: 81-82) despite their occurrence by the late Palaeolithic in the Xiachuan and other cultures (Chung, 2000; IACASS, 1978; Shi, X. B., 1989; Wang, J., et al., 1978). Recent residue and usewear studies by Li Liu and colleagues (2010a; 2010b; 2010c) have suggested these early Neolithic grinding implements were multifunctional tools geared in part towards acorn processing.

Research on ancient Chinese grinding residues has only recently been published (Li Liu, et al., 2010a; 2010b; 2010c; 2011; Tao, et al., 2011; Yang, X. Y., et al., 2009a). The most commonly identified taxa in samples taken from grinding implements include yams, beans, acorns (*Quercus* sp.), and grasses (Liu, Li, et al., 2010a; 2010b; 2010c; 2011; Tao, et al., 2011; Yang, X. Y., et al., 2009a,b). The grasses may be roughly divided into two groups; the pooid grasses (Triticeae tribe) and the panicoid grasses (including those from the Paniceae or millet tribe and those from the Andropogoneae or sorghum/maize tribe) (Liu, Li, et al., 2011). These taxa form part of the reference collection and will be discussed below.

7.3.1 Yams and Tubers

Roots and tubers frequently function as storage organs for plants. A collective term for such plant parts is underground storage organ (USO). This includes bulbs, corms, tubers, roots, yams and other underground plant parts which store energy or food for the plant. Ethnographic evidence indicates that some hunter-gatherers frequently utilized such plant parts (Southgate, 1992: 123). A range of tubers and underground storage organs (USO) are thought to have been used by hunter-gatherers and other people in prehistoric times including in Palaeolithic and Neolithic contexts in China (Chang 1986) although there is frequently limited archaeological evidence to back this up. Potentially useful economic species from North China or their close relatives known to have useful USOs were examined for starch (Table 7-9). Some of these families include the Araceae (taro) family, the Dioscoreaceae (yam) family, the Liliaceae (lilies and bulbs) family, the Nelumbonaceae (water lily) family, the Solanaceae (potato) family and the Trapaceae

(water chestnut) family. Many members of these families have starch grains and are discussed below.

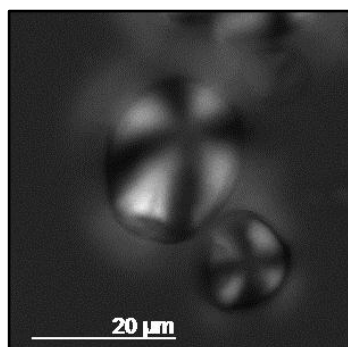
Table 7-9 Examples of Starchy Yams, Tubers and USOs in the Reference Collection

Family	Taxon	No. Specimens	Common Name	Starch Description
Araceae	<i>Alocasia macrorhiza</i>	2	Giant Taro	Small; typically smaller than 5 μm . May have raphides.
Araceae	<i>Colocasia esculenta</i>	5	Taro	Small; typically smaller than 5 μm . May have raphides.
Cucurbitaceae	<i>Trichosanthes kirilowii</i>	4	Tianhuafen	Typical USO starch that may be medium-large sized (5–40 μm). Some grains rounded and others bell-shaped. Fissures may be present across or under eccentric hilum.
Cyperaceae	<i>Cyperus</i> sp.	3	Sedges	Small grains less than 10 μm . Similar to small grained grasses.
Dioscoreaceae	<i>Dioscorea oppositifolia</i>	15	Shan yao/ mountain yam	Often ovate or bell-shaped with a hyper-eccentric hilum. Some yams may have lamellae present. Starch grains typically large, over 20 μm .
Dioscoreaceae	<i>Dioscorea</i> sp.	10	Yams	Often ovoid or bell-shaped tuberous starch; some small grains but diagnostically large (20-40 μm).
Liliaceae	<i>Fritillaria rediviva</i>	1	Fritillary	Often bell-shaped or oval and typically tuber-like. Hilum hyper-eccentric. Lamellae not visible. May have wrinkles radiating downwards from hilum. Granules large 3–39 μm .
Nelumbonaceae	<i>Euryale ferox</i>	3	Foxnut	Tiny starch grains from seeds approximately 2 μm on average. May form small rounded clusters c. 20 μm across.
Nelumbonaceae	<i>Nelumbo nucifera</i>	5	Water lily tuber	Relatively thin or elongate grains, sometimes oval shaped. Hilum eccentric. Between 5–25 μm .
Solanaceae	<i>Solanum tuberosum</i>	2	Potato	Typically not faceted but with many non-diagnostic round to oval grains. Some very large. Between 6–69 μm .
Trapaceae	<i>Trapa</i> sp.	5	Water chestnut	Grains rarely bell-shaped; arms of cross thin. May have prominent lamellae. Facets uncommon in population. Between 5–25 μm .
Typhaceae	<i>Typha</i> sp.	3	Reeds	Partly faceted and partly rounded granules; less than 10 μm .

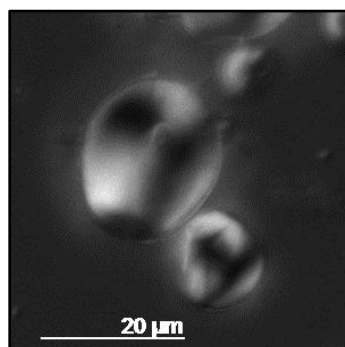
7.3.1.1 FAMILY ARACEAE

Small and faceted taro starch (*Colocasia esculenta*) was a staple food at the c. 9,000–7,500 year old Zengpiyan site in Guilin, South China (IACASS, 2003: 287-289). Crowther (2005) identified cooked taro from pot sherds at Anir, New Ireland at c. 3,300 cal BP.

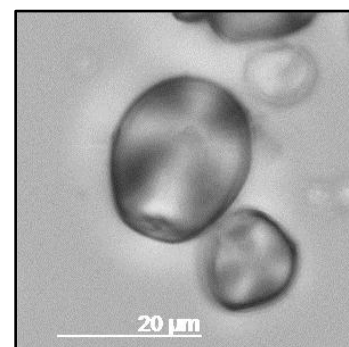
7.3.1.2 FAMILY CUCURBITACEAE



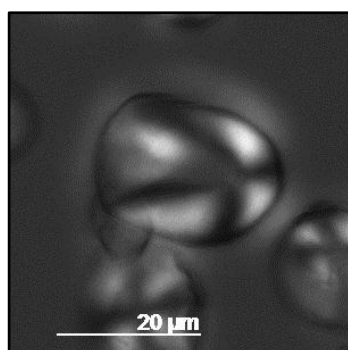
a) Tianhuafen (*Trichosanthes kirilowii* REF1159-10) starch under a cross-polarising filter



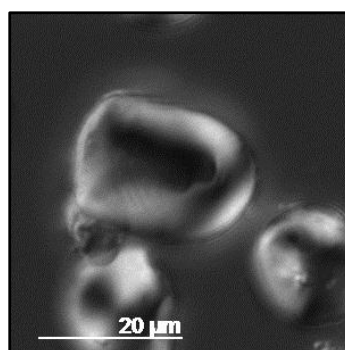
b) Tianhuafen (*Trichosanthes kirilowii* REF1159-10) ovoid starch under a DIC filter



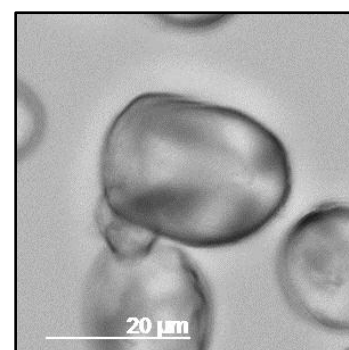
c) Tianhuafen (*Trichosanthes kirilowii* REF1159-10) ovoid starch under a brightfield filter



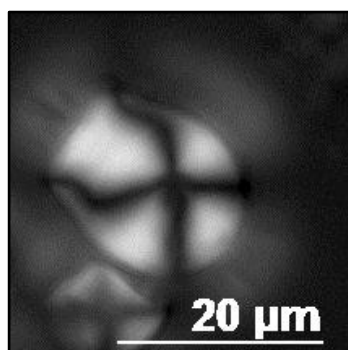
d) Tianhuafen (*Trichosanthes kirilowii* REF1159-10) bell-shaped starch grains under a cross-polarising filter



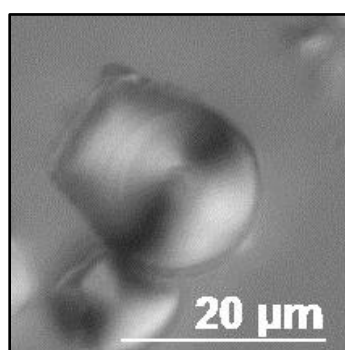
e) Tianhuafen (*Trichosanthes kirilowii* REF1159-10) bell-shaped starch grains under a DIC filter



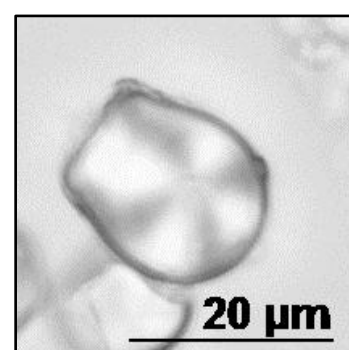
f) Tianhuafen (*Trichosanthes kirilowii* REF1159-10) bell-shaped starch grains under a brightfield filter



g) Tianhuafen (*Trichosanthes kirilowii*) starch granules under a cross-polarising filter



h) Tianhuafen (*Trichosanthes kirilowii* REF1085-10) granules under a DIC filter



i) Tianhuafen (*Trichosanthes kirilowii* REF1085-10) granules under a brightfield filter

Figure 7-12 Tianhuafen (*Trichosanthes kirilowii* REF1085-10) starch grains from underground storage organs with (a-c) an ovoid starch grain, and (d-i) a bell-shaped grain with eccentric hilum and faint lamellae

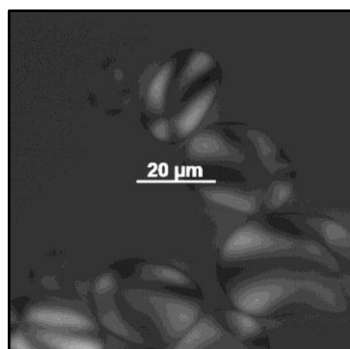
Cucurbit starch from several gourds was examined but was rare to non-existent in the species studied. A range of cucurbit plants were examined including tubers (Figure 7-12). Starch grains were not detected in the seeds of bottlegourd (*Lagenaria siceraria*), rockmelon (*Cucumis melo*) or pumpkin (*Cucurbita pepo*). The flesh of pumpkin (*Cucurbita pepo*) exhibited rare, tiny ($<4\ \mu\text{m}$) starch grains but these were not present in the flesh of the related bitter melon (*Momordica charantia*). The root of Tianhuafen (*Trichosanthes kirilowii*), which is a traditional Chinese medicine, exhibited relatively large, yam like starch grains (Figure 7-12). At the present stage of research these were difficult to distinguish from Dioscoreaceae yam starch.

7.3.1.3 FAMILY DIOSCOREACEAE

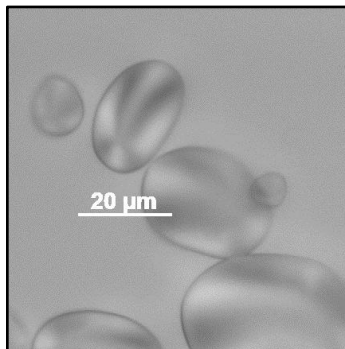
Dioscoreaceae starch grains have been identified as residues on stone tools from Papua New Guinea including the Ivane Valley dated over 40,000 cal BP (Summerhayes, et al., 2010). Fullagar and colleagues (2006) also identified early *Dioscorea* sp. yam starch at the early Holocene Papua New Guinea site of Kuk Swamp. In China starch grains from Dioscoreaceae yams were identified at the Late Palaeolithic Shizitan site on grinding implements (Liu, Li, et al., 2011). They were identified as residues on grinding implements from other early Neolithic sites in North China (Liu, Li, et al., 2010b; 2010c). Starch from the Dioscoreaceae (yam) family may be identified by the typically ovoid to bell shape of granules and hyper-eccentric hilum. Granules come in a range of irregular shapes and sizes and are typically large (Figure 7-13). A 'trough' type of depression may be present in the section of the grain under the hilum when the grain is oriented along its longitudinal axis.

According to the FOC there is one genus and 52 species of *Dioscorea* yam that grow in China today (Ding & Gilbert, 2000). In North China the most common yam is the shanyao yam *Dioscorea oppositifolia*, so research focused on this species. Climatic and environmental conditions in the region may have been different in the past so several published sources of *Dioscorea* sp. starch were examined. Other modern Dioscoreaceae were examined (Table 7-9) although not all yams in the collection are listed in this table.

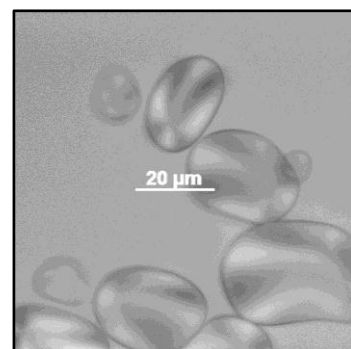
Starch from underground storage organs or tubers in the yam (Dioscoreaceae) and cucurbit (Cucurbitaceae) family may be similar. Bell-shaped granules with an eccentric hilum and non-linear extinction cross arms occur in both families and make precise identifications difficult. For this reason ancient starch grains were grouped together under the heading of underground storage organ (USO) starch.



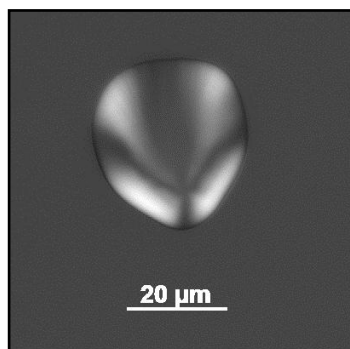
a) Ovoid shaped *Dioscorea oppositifolia* (REF431–08C) under a cross-polarising filter



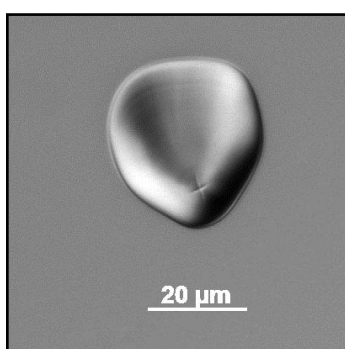
b) Ovoid shaped *Dioscorea oppositifolia* (REF431–08C) granules under a DIC filter



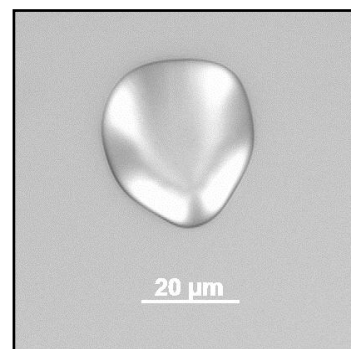
c) Ovoid shaped *Dioscorea oppositifolia* (REF431–08C) granules under a brightfield filter



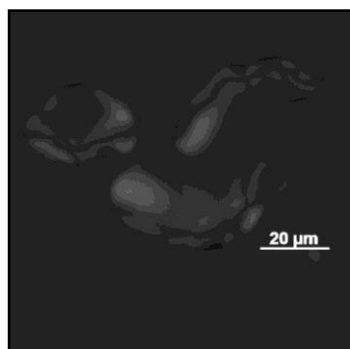
d) Bell shaped *Dioscorea oppositifolia* (REF430–08C) starch under a cross polarizing filter



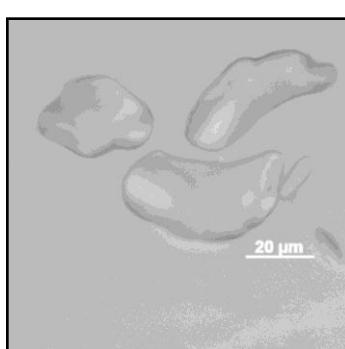
e) Bell shaped *Dioscorea oppositifolia* (REF430–08C) starch granules under a DIC filter



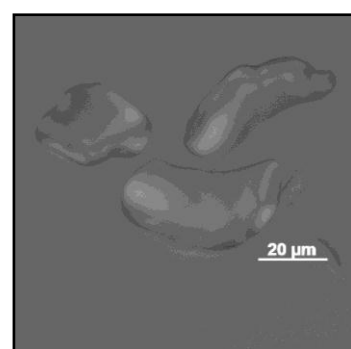
f) Bell shaped *Dioscorea oppositifolia* (REF430–08C) starch granules under a brightfield filter



g) Irregularly shaped *Dioscorea oppositifolia* (REF479–08C) starch under a cross polarizing filter



h) Irregularly shaped *Dioscorea oppositifolia* (REF479–08C) starch granules under a DIC filter



i) Irregularly shaped *Dioscorea oppositifolia* (REF479–08C) starch granules under a brightfield filter

Figure 7-13 *Dioscorea oppositifolia* (shan yao or mountain yam REF430–08C) starch grains. Figures a–c) are ovoid while granules d–f) are ovoid with an eccentric hilum. Granules (g–i) exhibit a varied morphology.

7.3.1.4 FAMILY LILIACEAE

Other families also share tuber like starch characteristics. For instance, in the Liliaceae family, the corm or underground storage organ of *Fritillaria rediviva* has large, bell-shaped starch grains similar in shape to those of *Dioscorea* sp. (Figure 7-13) and *Trichosanthes kirilowii* (Figure 7-12). Some *Fritillaria* sp. bulbs are used in traditional Chinese medicine

(Chen, Xinqi & Mordak, 2000) where they may be processed in a number of ways, including grinding, prior to consumption. However, there are distinct differences in starch between *Dioscorea* sp. and *Fritillaria* sp. tubers. Diagnostic differences between starch granules in the two families include small ‘fissures’ or ‘tucks’ in the base of *F. rediviva* granules (Figure 7-14) which were not evident in the *Dioscorea* sp. yams examined.

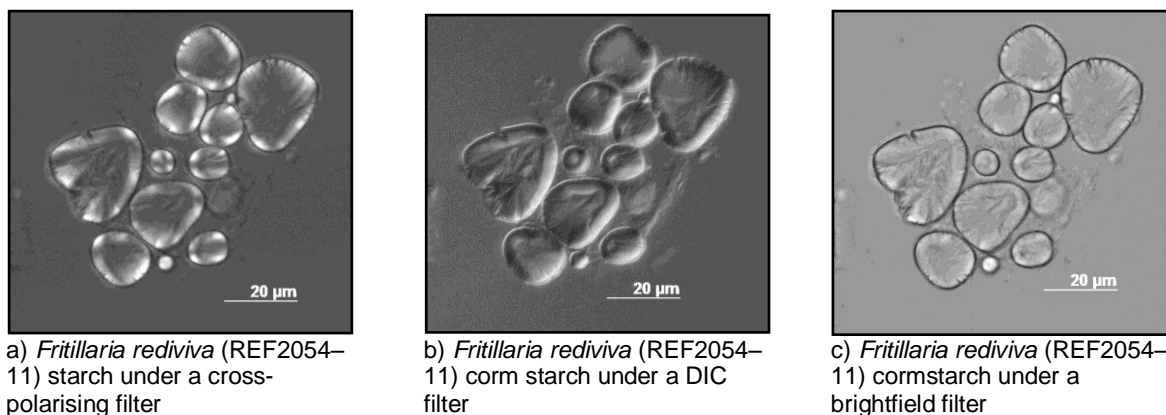


Figure 7-14 *Fritillaria rediviva* (fritillary REF2054–11) corm starch

7.3.1.5 FAMILY NELUMBONACEAE

Water lily tubers (*Nelumbo nucifera*) may be distinguished from Dioscoreaceae starch grains on the basis of the more elongate, narrower shape of the granules and a smaller size range. Despite the presence of water lily tubers at the Jiahu site (Zhao, Z. & J. Zhang, 2009: 93) they were not identified in the study region.

Starch grains from the seeds of foxnuts (*Eryale ferox*) exhibit tiny starch grains that may be rounded or faceted (Figure 7-15). These grains are often found in clusters, including small rounded clusters of tiny granules. Foxnuts were recovered from probable storage pits at waterlogged sites such as Tianluoshan, in Zhejiang province, South China (Fuller, et al., 2009: 1607).

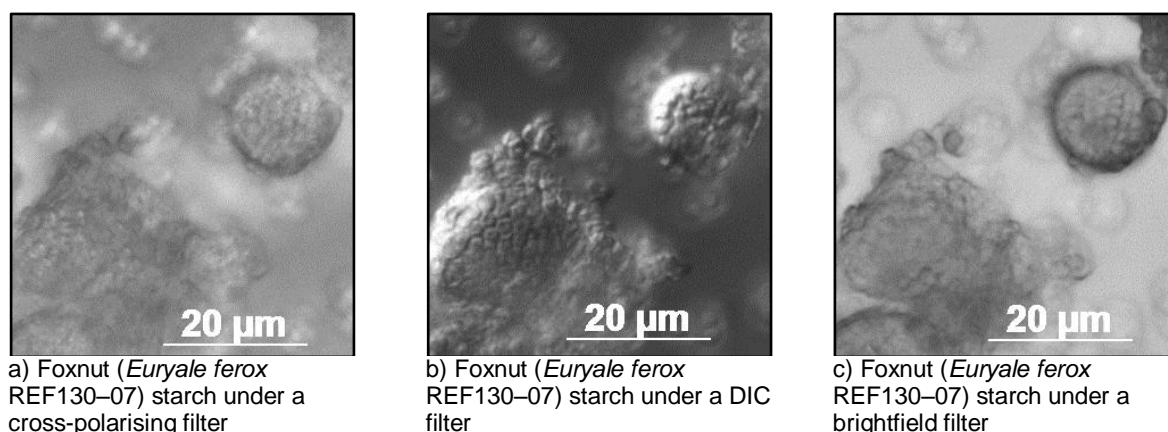


Figure 7-15 Foxnut (*Euryale ferox* REF130-07) starch grains

7.3.1.6 FAMILY TRAPACEAE

Tubers from water chestnuts were tested for starch grains. Starch grains from the *Trapa* sp. taxa examined were frequently rounded with unfacetted margins. They had a distinctive, thin-armed extinction cross and in some cases lamellae. Despite being present at Jiahu (Zhao, Z. & J. Zhang, 2009: 94) they were not detected in the study region.

7.3.2 Bean and Legume Starch (Fabaceae Family)

The bean family is a large family including over 18,000 species in 630 genera worldwide (Tudge, 2005: 177). To accommodate these large numbers it may be further divided into three subfamilies (Judd, et al., 2008: 374-376) with 29 tribes occurring in China (Xu, L., et al., 2010). Several taxa in this family are thought to have been ground or pounded in ancient times and used for textiles or clothing, hence their inclusion in the reference collection.

The paper mulberry (*Broussonetia papyrifera*) is used throughout Polynesia for clothing (Cambie & Ferguson, 2003; Horrocks, et al., 2004) hence *Broussonetia* sp. seeds (also termed *Sophora* sp. in the Flora of China) were included in the collection. Seeds of the paper mulberry were recovered from the Jomon Torihama site in Japan (Crawford, 2011: 335) and also at Jiahu (Zhao, Z., & J. Zhang, 2009). Roots of the Kudzu vine (*Pueraria lobata*) are also used throughout Polynesia for clothing and textiles (Bodner & Hymowitz, 2002). Kudzu vine is a traditional Chinese medicine (Wong, et al., 2011) and may be pounded for use in clothing and textiles in certain parts of China (Bodner & Hymowitz, 2002; Tanner, et al., 1979). The antiquity of this process is uncertain (Bodner & Hymowitz, 2002) hence the inclusion of the taxon in the reference collection. Evidence for the use of paper mulberry or kudzu vine was not detected in the research area.

Despite extensive testing, starch was not observed in soybean seeds. Soybeans are an important crop worldwide and are extensively processed and ground to create tofu and soy sauce (Lee, G.-A., et al., 2011). The antiquity of this process is uncertain hence the inclusion of multiple *Glycine* sp. taxa in the collection. Soybean seeds may have multiple domestication centers in East Asia (Lee, G.-A., et al., 2011) and soybean appear to have been an important resource in Neolithic North China. G.-A. Lee and colleagues (2011: e26720) suggest that selection of domestication related traits in soybean occurred in East Asia from 9,000 – 5,000 BP. The earliest soybeans found in North China date to between 9,000 – 8,600 cal BP at Jiahu (Zhao, Z., & J. Zhang, 2009).

Fabaceae family taxa ‘usually’ have starch grains (Judd, et al., 2008: 371-372) although it appears that this is not always the case with soybeans (Stevenson, et al., 2006). Certain plants degrade starch at maturity including soybeans (*Glycine* sp.) (Stevenson, et al., 2006). A literature search revealed that soybean seeds do have starch (Stevenson, et al., 2006) although mature soybeans are comprised of less than 1 percent starch (Wilson, L. A., et al., 1978). About 20 days prior to harvest soybeans have between 10–15 percent starch (Yazdi-Samadi, et al., 1977). Soybeans cultivated under elevated carbon dioxide and temperature levels may contain up to 20 percent starch at maturity (Thomas, et al., 2003). Reasons for the degradation of soybean starch at late crop maturity are not known (Stevenson, et al., 2006: 509). Soybean starch has not been detected in the archeological record and due to its reabsorption into the plant prior to harvest it is unlikely to be archeologically visible.

Bean starch has been identified at several archaeological sites. Starch grains from *Phaseolus* sp. beans were identified at the Nanchoc Valley site in northern Peru dating to 11,200–6,000 cal BP and may have been cultivated (Piperno & Dillehay, 2008). Bean starch has also been identified on grinding implements in North China at sites such as Shangzhai site, near Beijing (Yang, X. Y., et al., 2009a) and at Shizitan (Liu, Li, et al., 2011: 828-829). Grains from both these sites were identified as being similar to *Vigna* sp. bean starch. *Vigna* sp. bean starch exhibits a range of granule shapes (Figure 7-16), not all of which are diagnostic. Diagnostic bean type starch grains are typically large, up to 40 µm in maximum dimension, and may be shaped somewhat like a bean. A crooked fissure may be present and lamellae may be prominent. The combination of these features makes Fabaceae type starch relatively easy to identify to family taxonomic level.

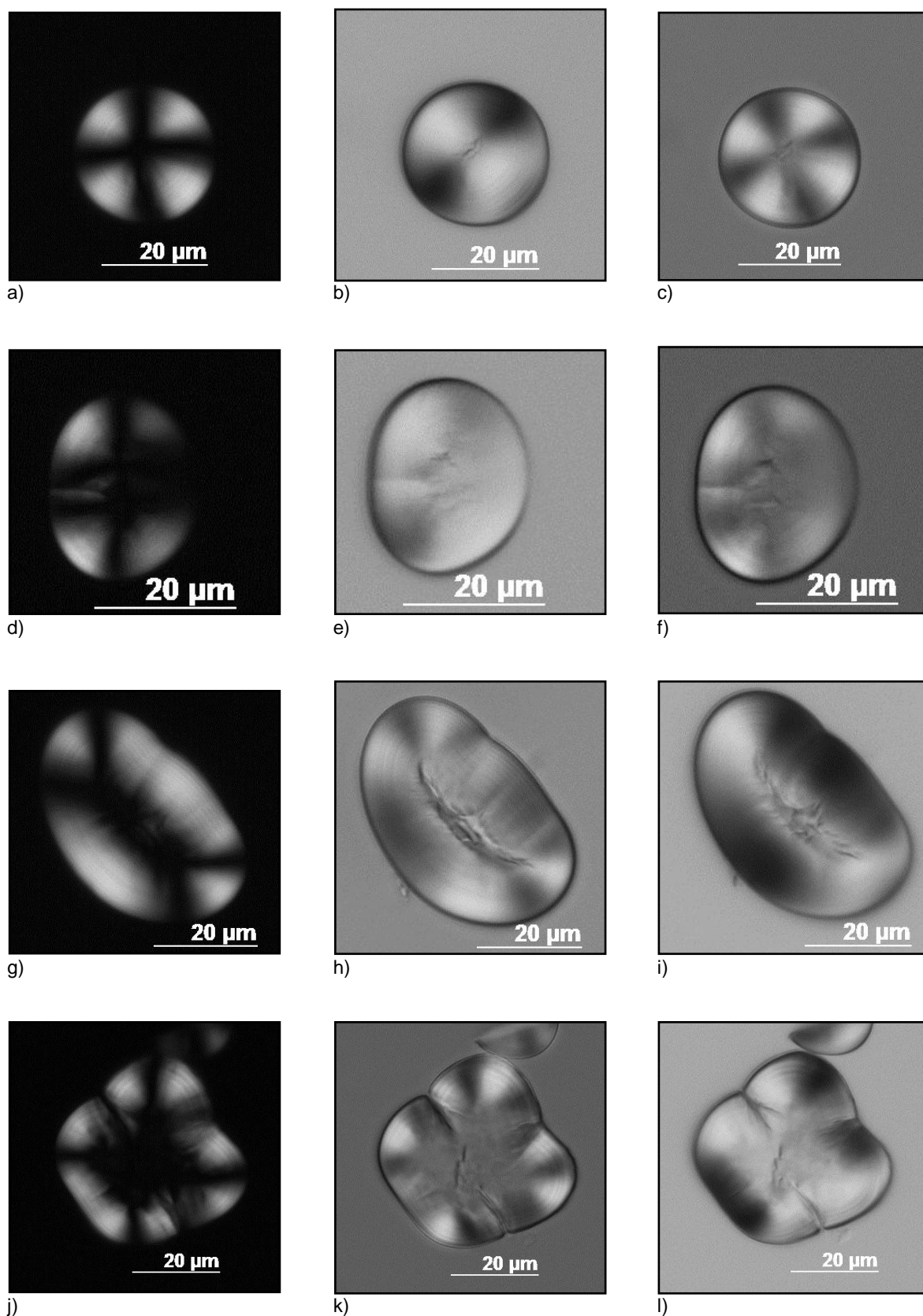


Figure 7-16a-l Adzuki bean (*Vigna angularis* REF312-08) with a range of starch morphotypes. From left to right images were taken under polarizing, DIC, and brightfield filters respectively

A range of beans and legumes were included in the reference collection (Table 7-10) and several of these were examined for starch grains (Table 7-11). Both seeds (bean or pea)

and roots of plants in the Fabaceae family are economically useful. Both seed and root storage organs were tested for starch grains. Among the bean seeds tested a range of different sizes were evident (Figure 7-17) with some of the more diagnostic bean starch grains $>30\text{ }\mu\text{m}$. A range of morphotypes were also evident (Figure 7-16) with several variations on rounded and lobed grains, sometimes with jagged diagnostic fissures or prominent lamellae, present as a diagnostic bean seed feature.

Table 7-10 Some of the Fabaceae Family Taxa in the Reference Collection

Taxon	Plant Part in Collection	No. Specimens	Common Name
<i>Caragana purdomii</i>	Beans, pod	1	Peashrub
<i>Chaemaecrista</i> sp.	Leaves, fruits, pods	1	Cassia
<i>Glycine max</i> ssp. <i>max</i>	Beans and pods	20+	Soybean
<i>Glycine max</i> ssp. <i>soja</i>	Beans and pods	5	Wild soybean
<i>Laburnum anagyroides</i>	Flowers, seeds, pods, leaves	1	Laburnum
<i>Lespedeza formosa</i>	Flowers, leaves, roots	1	Taiwan bush clover
<i>Lespedeza tomentosa</i>	Seed	1	Bush clover
<i>Pisum sativum</i>	Peas, pods	2	Snow pea
<i>Pueraria lobata</i>	Root tuber (sliced and dried)	5	Kudzu vine
<i>Sophora davidii</i> var. <i>chuanensis</i> †	Seeds, pods, twigs	1	Unknown
<i>Tipuana tipa</i>	Leaves, stems, winged seeds	1	Rosewood tree
<i>Trigonella foenum-graecum</i>	Seeds	1	Fenugreek
<i>Vicia faba</i>	Beans	4	Broad bean
<i>Vigna angularis</i>	Beans	6	Adzuki bean
<i>Vigna radiata</i>	Beans	8	Mung bean

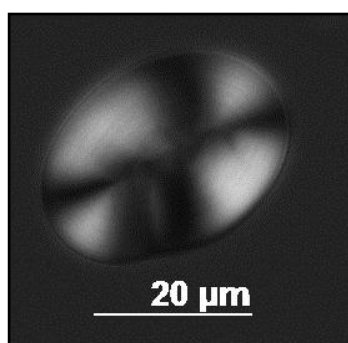
† There are some difficulties with the correct nomenclature for this specimen. According to the Flora of China it was previously termed *Sophora viciifolia* (Xu, L., et al., 2010). According to GRIN (USDA, et al., 2012) the genus *Sophora* is an incorrect synonym of *Broussonetia*. Following the Flora of China revised taxonomy it is here termed *Sophora* for consistency throughout this thesis.

Beans tested generally exhibited rounded starch grains grouped loosely within bean cells (Figure 7-18). Rounded starch grains without facets appeared to be typical of many of the bean seeds tested. However, root storage organs from the kudzu vine (*Pueraria lobata*) exhibited more tightly packed starch grains with a range of pressure facets (Figure 7-19). This is possibly from the close packing of these granules. More research needs to be done to determine whether there is a consistent difference in starch grain types from different plant parts of the Fabaceae family or whether this difference is related to taxa.

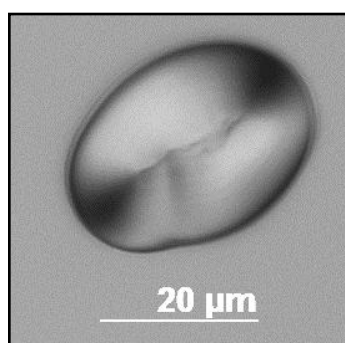
Table 7-11 Fabaceae (Bean) Family Accessions Tested for Starch Grains

Taxa	Common Name	No. Specimens Tested	Starch Present?†	Starch Description
<i>Caragana purdomii</i>	Peashrub	1	Yes	Small round, non-faceted grains not diagnostic.
<i>Glycine max</i> ssp. <i>max</i>	Soybean	4	ND	
<i>Glycine max</i> ssp. <i>soja</i>	Wild soybean	3	ND	
<i>Pisum sativum</i>	Snow pea	2	ND	
<i>Pueraria lobata</i>	Kudzu vine root	4	Yes	Starch detected in roots but not seeds. Compound granules small and very variable; may be round or faceted or a combination of both. Facets typically regular. Tight packing may affect facets.
<i>Sophora davidii</i> var. <i>chuanensis</i>	Unknown	1	?	Uncertain if plastids or starch grains present; if present too small to see clearly. Starch not detected by Lee and colleagues .
<i>Vigna angularis</i>	Adzuki bean	4	Yes	May be very large and irregularly shaped starch grains. Often with wobbly and slightly eccentric fissure; lamellae frequently visible. Large size range and possible alpha and beta granules.
<i>Vigna radiata</i>	Black mung bean	4	Yes	Medium and small-sized bean-type starch with generally round to ovoid shape. Some fissures and lamellae. Some possible alpha and beta granules.

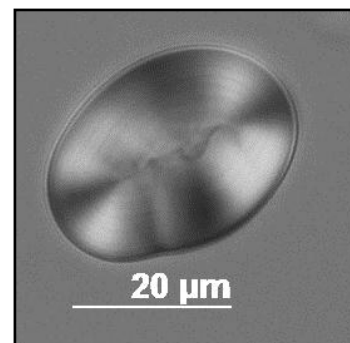
† ND refers to starch not detected.



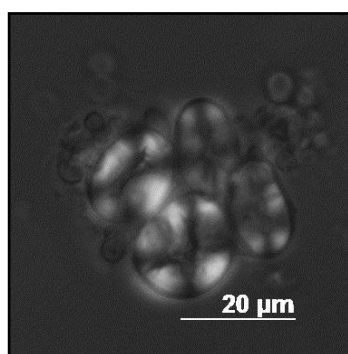
a) *Vigna angularis* (adzuki bean REF312–08) starch under a cross-polarising filter



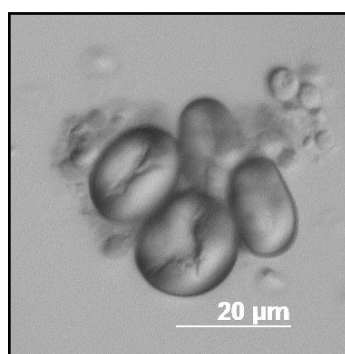
b) *Vigna angularis* (adzuki bean REF312–08) starch under a DIC filter



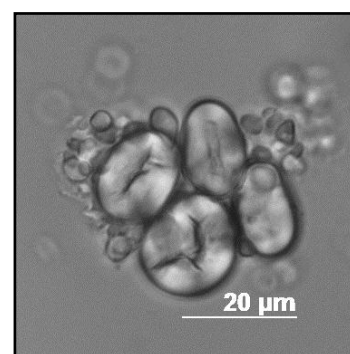
c) *Vigna angularis* (adzuki bean REF312–08) starch under a brightfield filter



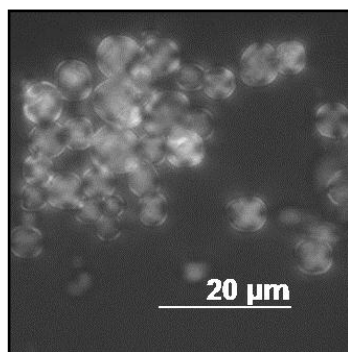
d) *Vigna radiata* (black mung bean REF289–08) starch under a cross-polarising filter



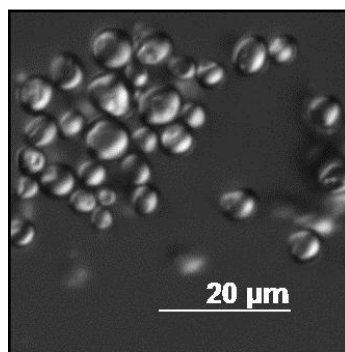
e) *Vigna radiata* (black mung bean REF289–08) starch under a DIC filter



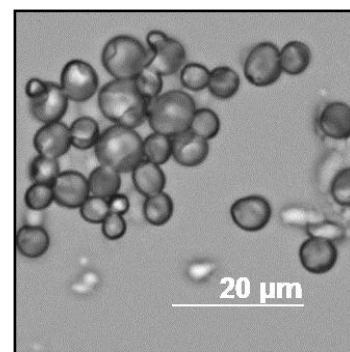
f) *Vigna radiata* (black mung bean REF289–08) starch under a brightfield filter



g) *Caragana purdomii* (REF939–09) bean starch under a cross-polarising filter

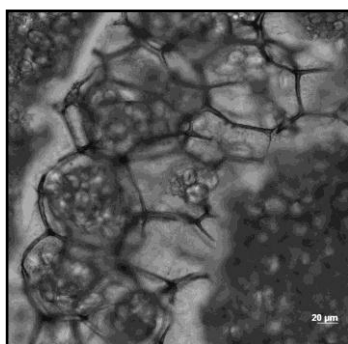


h) *Caragana purdomii* (REF939–09) bean starch under a DIC filter

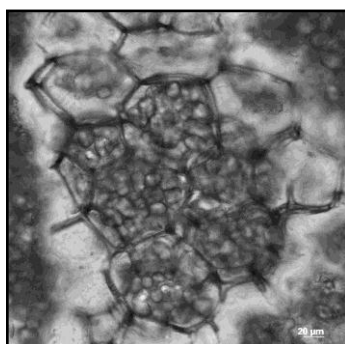


i) *Caragana purdomii* (REF939–09) bean starch under a brightfield filter

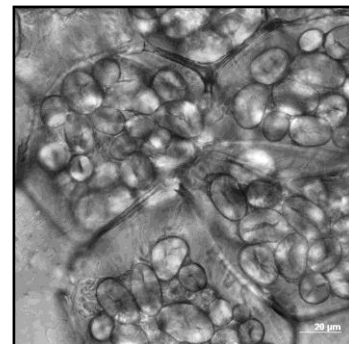
Figure 7-17 Size ranges of various Fabaceae bean starch grains. Granules a–c are adzuki bean (*Vigna angularis* REF312–08) starch grains taken under polarizing, DIC and brightfield filters respectively. Granules d–f are black mung bean (*Vigna radiata* REF289–08) starch grains taken under polarizing, DIC and brightfield filters respectively. Granules g–i are peashrub (*Caragana purdomii* REF939–09) with tiny starch grains taken under polarizing, DIC and brightfield filters respectively.



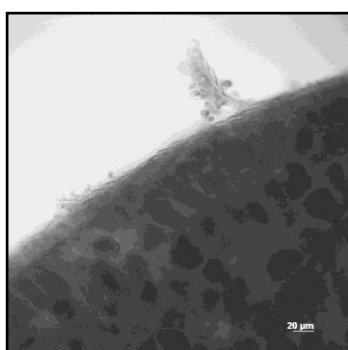
a) *Vigna radiata* (black mung bean REF289-08) starch showing starch packing arrangement in cells



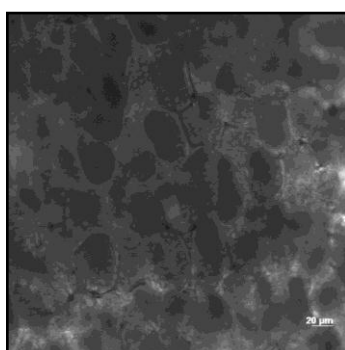
b) *Vigna radiata* (black mung bean REF289-08) starch showing starch packing arrangement in cells



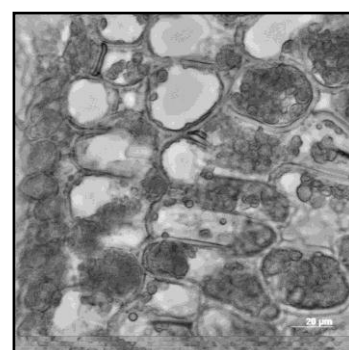
c) *Vigna radiata* (black mung bean REF289-08) starch showing starch packing arrangement in cells



d) *Sophora davidii* var *chuanensis* (REF938-09) bean showing packing arrangement of starch in cells



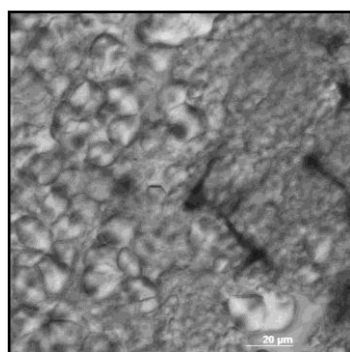
e) *Sophora davidii* var *chuanensis* (REF938-09) bean showing packing arrangement of starch in cells



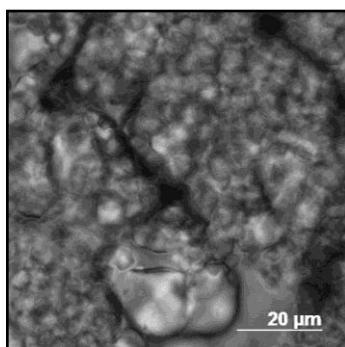
f) *Sophora davidii* var *chuanensis* (REF938-09) bean showing packing arrangement of starch in cells

Figure 7-18a-f Packing arrangement of starch showing storage cells in a–c) black mung bean (*Vigna radiata* REF289-08) and d–f) *Sophora davidii* var. *chuanensis* (REF938-09). All images taken in brightfield.

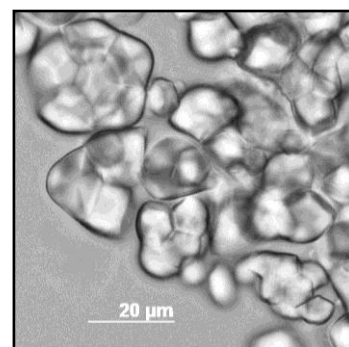
The tubers of wild kudzu vine (*Pueraria lobata*) may be beaten together or ground into thin yet strong fibrous clusters and have a long history of use in China for clothing and textiles (Wong, et al., 2011). An early suggestion by K. C. Chang (1986: 197-201) that Caoxieshan textiles were possibly made from kudzu vine requires further research.



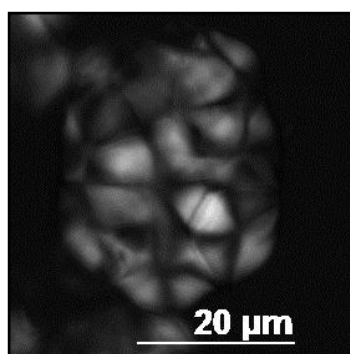
a) *Pueraria lobata* (Kudzu vine root REF177–08) showing cellular packing arrangement under cross-polarising filters



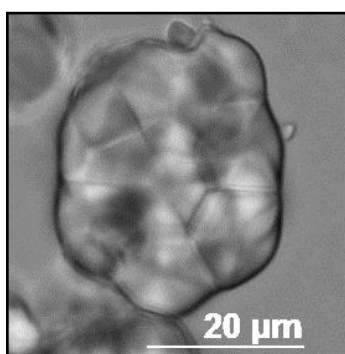
b) *Pueraria lobata* (Kudzu vine root REF177–08) showing cellular packing arrangement under DIC filters



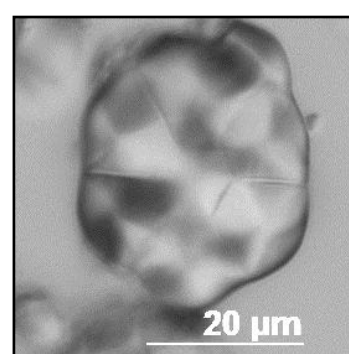
c) *Pueraria lobata* (Kudzu vine root REF177–08) showing cellular packing arrangement under brightfield filters



d) *Pueraria lobata* (Kudzu vine root REF177–08) showing compound starch granules under a cross-polarising filter



e) *Pueraria lobata* (Kudzu vine root REF177–08) showing compound starch granules under a DIC filter



f) *Pueraria lobata* (Kudzu vine root REF177–08) showing compound starch granules under a brightfield filter

Figure 7-19a-f Packing arrangement of starch in root cells of kudzu vine (*Pueraria lobata* REF177–08). (a-c) shows starch within cells while (d-f) shows facettet starch in a tightly packed cluster.

7.3.3 Nuts and Starch

A range of nuts are assumed to have been used by Palaeolithic people. The earliest grinding implements known were used to process nuts at the Gesher Benot Ya`aqov site in Israel and date to the early-middle Pleistocene (Goren-Inbar, et al., 2002). In China macroscopic evidence for nut remains at archaeology sites comes from places such as Donghulin, where hackberry nuts (*Celtis* sp.) were located during excavation (Hao, et al., 2008). However, starch grains were not detected in the hackberry nuts examined.

Walnuts (*Juglans* sp.) and hazlenuts (*Corylus* sp.) are also thought to have been collected by prehistoric people in Asia as a food source including by the Japanese Jomon (Akazawa, 1986: 81). However, some walnuts produce less than 3 percent starch (Savage, G. P., 2001: table 1) and starch was not detected in the various *Juglans* or *Corylus* sp. tested.

7.3.3.1 FAGACEAE FAMILY NUTS—CHESTNUTS

Chestnuts (*Castanea* sp. and *Castanopsis* sp.) and acorns (*Cyclobalanopsis* sp., *Lithocarpus* sp. and *Quercus* sp.) are all members of the Fagaceae family. Chestnuts were used by the Jomon of Japan (Crawford, 2011; Sato, et al., 2003) and were in fact domesticated or cultivated by them as shown by genetic evidence (Sato, et al., 2003). There is also extensive ethnographic evidence for nut gathering and grinding in Japan (Matsuyama, 1981). Chestnut starch grains were examined from modern references (Table 7-12) but were quite small and were not detected in the study area.

Table 7-12 Chestnuts (*Castanea* and *Castanopsis* spp.) in the Reference Collection

Taxa	No. Specimens	Common Name
<i>Castanea</i> sp.	5	Chestnut
<i>Castanea</i> cf. <i>mollissima</i>	2	Chinese chestnut
<i>Castanea sativa</i>	2	Sweet chestnut
<i>Castanopsis</i> sp.	1	Chinquapin
<i>Castanopsis carlesii</i>	1	Small red chinquapin
<i>Castanopsis jacunda</i>	1	Dark lintel chinquapin
<i>Castanopsis sclerophylla</i>	1	Bitter evergreen chinquapin
<i>Castanopsis tibetana</i>	1	Tibetan chinquapin

7.3.3.2 FAGACEAE FAMILY NUTS—ACORNS

Acorns have also been used for millennia in various locations around the world including in Jomon Japan (Akazawa, 1986: 81), epipalaeolithic Israel (Weiss, et al., 2004b: 9551) and in indigenous American economies including Californian Mono and Hupa economies (Bettinger, et al., 1997). The bitter tannins in acorns may require processing through leaching or grinding before the calories are digestible by humans (Bettinger, et al., 1997: 894). Numerous acorns of several genera were examined for starch grains as discussed below.

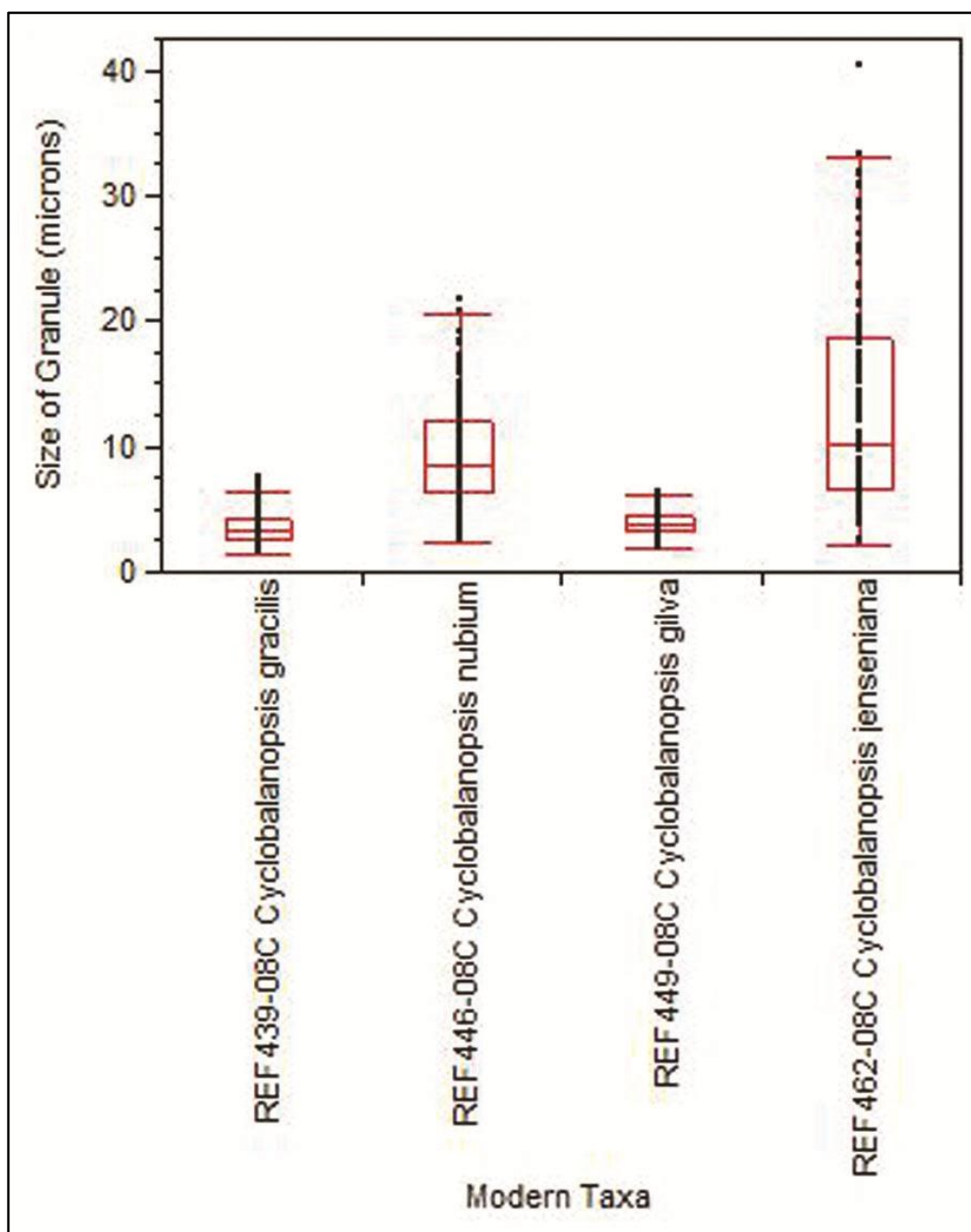
Acorns in the reference collection were taken from four different acorn genera. These include *Cyclobalanopsis* sp., also known as evergreen oaks. These are considered a separate genus by Flora of China taxonomists (Huang, C., et al., 1999) but are typically included as species of *Quercus* by many other researchers (e.g., Menitsky, 2005). The tan oaks or *Lithocarpus* sp. acorns were included; these are a southeast Asian and sub-tropical

genera little known outside of Asia. The single North American tan oak, previously *Lithocarpus densiflorus* but recently renamed *Notholithocarpus densiflorus* (Manos, 2008), was included in the reference collection. It was used as a source of food by Californian Hupa Indians (Bettinger, et al., 1997: 894; George-Moore, 2010). A number of different *Quercus* sp. were also used by American and Californian Indian groups (Bainbridge, November 12-14, 1986; Mason, 1995, 1996; Mason & Nesbitt, 2009; McCorriston, 1994; Ortiz, 1991). *Quercus* is the most widespread and well known genus of acorn bearing trees and numerous examples were included in the reference collection.

In total over 100 accessions in the Fagaceae family form part of the reference collection and 53 of these are listed below (Table 7-13; Table 7-16). References include at least four separate species and eight separate accessions of *Cyclobalanopsis* species (Table 7-13). Nine accessions and at least six different species of *Lithocarpus* were examined (Table 7- 15). Over seventeen species of *Quercus* were examined, with over forty accessions of this genus in the reference collection (Table 7-16). This included a number of *Quercus* cf. *fabri* accessions from the same location but from different trees at Liwu Reservoir in Zhejiang, China. Collection of similar material from different trees may be useful in for future DNA or population studies research.

Table 7-13 Evergreen Oak (*Cyclobalanopsis* sp.) Acorns in the Reference Collection

Taxon	No. Specimens	Common Name
<i>Cyclobalanopsis fleuryi</i>	1	Conical evergreen oak
<i>Cyclobalanopsis gilva</i>	1	Red bark evergreen oak
<i>Cyclobalanopsis gracilis</i>	2	Thin leaved evergreen oak
<i>Cyclobalanopsis jenseniana</i>	1	Large leaved evergreen oak
<i>Cyclobalanopsis nubium</i>	1	Nubile evergreen oak
<i>Cyclobalanopsis</i> sp.	3	Ring cupped oaks

Figure 7-20 *Cyclobalanopsis* sp. size rangesTable 7-14 *Cyclobalanopsis* sp. Size Ranges

Level	No Grains	Minimum	Median	Maximum
REF439–08C <i>Cyclobalanopsis gracilis</i>	118	1.42	3.53	7.55
REF446–08C <i>Cyclobalanopsis nubium</i>	111	2.39	8.54	21.63
REF449–08C <i>Cyclobalanopsis gilva</i>	135	1.77	4	6.14
REF462–08C <i>Cyclobalanopsis jenseniana</i>	108	2.15	10.17	40.29

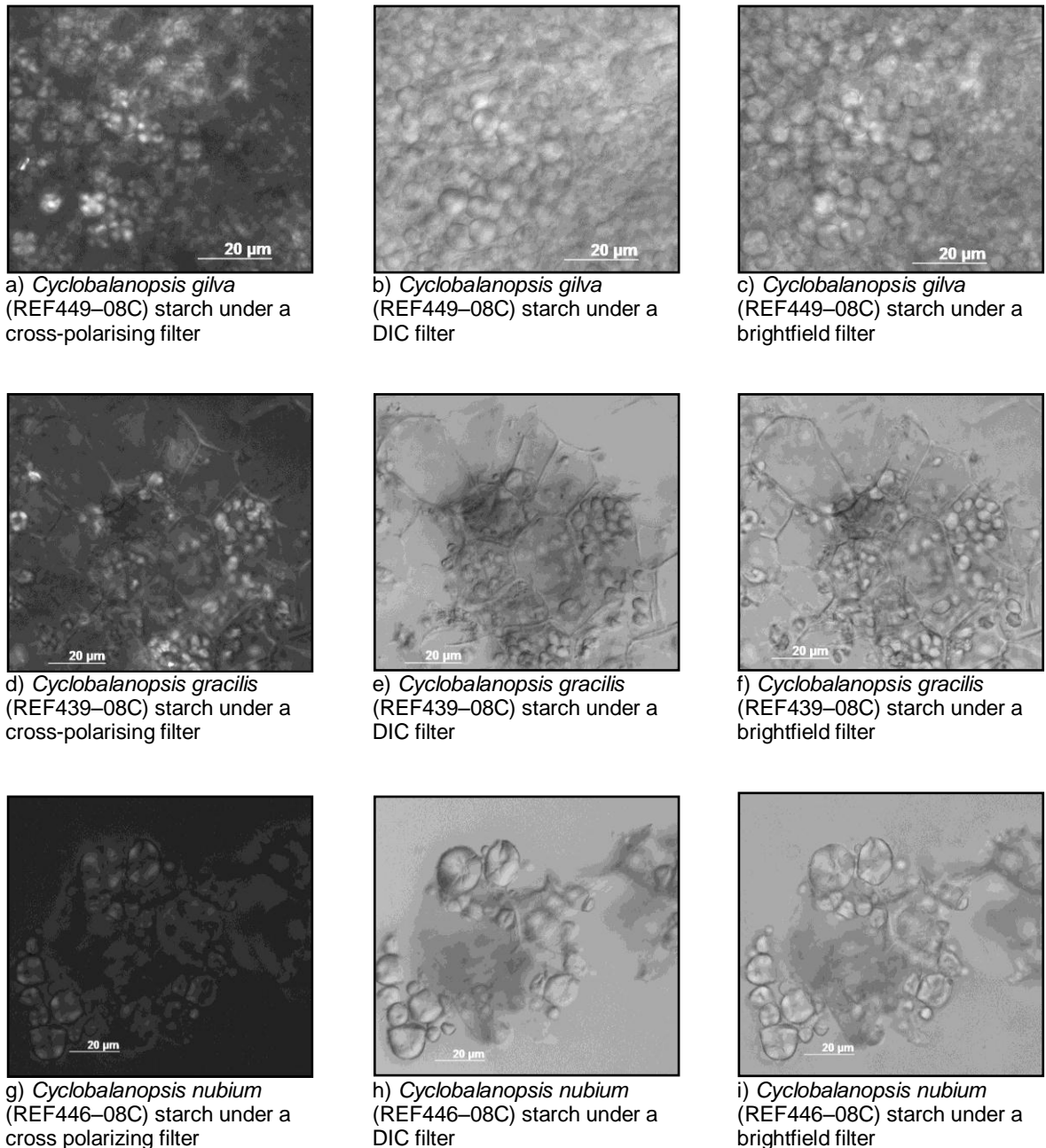


Figure 7-21 *Cyclobalanopsis* sp. starch grains. a–c) *Cyclobalanopsis gilva* (REF449-08C) starch, d–f) *Cyclobalanopsis gracilis* (REF439-08C) showing starch packing arrangement and some cellular shapes, g–i) *Cyclobalanopsis nubium* (REF446-08C) showing different shapes of granules.

Acorn starch may be diagnostic to genus (Liu, Li, et al. 2010c). Diagnostic

Cyclobalanopsis sp. starch is typically oval shaped with an eccentric hilum. Starch grains from *Cyclobalanopsis* sp. exhibited a range of population sizes, with the smallest granule being just over 1 µm in size and the largest around 40 µm (Figure 7-20; Figure 7-21).

However, *Cyclobalanopsis* sp. starch grains were not detected in the study area.

Table 7-15 *Lithocarpus* sp. Acorns in the Reference Collection

Taxon	No. Specimens	Common Name
<i>Lithocarpus brevipaudatus</i>	1	Lingnan oak
<i>Lithocarpus fenestratus</i>	1	Muddy oak
<i>Lithocarpus glaber</i>	3	Japanese oak
<i>Lithocarpus leucodermis</i>	1	White branched oak
<i>Lithocarpus</i> sp (Zhejiang)	1	Lithocarpus
<i>Lithocarpus pachyphylius</i>	1	Thick leaved oak
<i>Lithocarpus craibianus</i>	1	White spiked oak
<i>Notholithocarpus densiflorus</i>	3	Tan oak

Table 7-16 *Quercus* sp. Acorns in Reference Collection

Taxon	No. Specimens	Common Name
<i>Quercus acutissima</i>	2	Hemp oak
<i>Quercus agrifolia</i>	1	Coast live oak
<i>Quercus aliena</i>	2	Stout oak
<i>Quercus canariensis</i>	1	Algerian oak
<i>Quercus cerris</i>	3	Turkish oak
<i>Quercus chenii</i>	2	Small leaved oak
<i>Quercus coccifera</i>	1	Kermes oak
<i>Quercus dentata</i>	2	Dentate oak/ Daimyo oak
<i>Quercus</i> cf. <i>fabri</i>	10	White oak
<i>Quercus ilex</i>	2	Holm oak
<i>Quercus kelloggii</i>	2	Black oak
<i>Quercus mongolica</i>	1	Mongolian oak
<i>Quercus</i> cf. <i>palustris</i>	1	Pin oak
<i>Quercus pubescens</i>	1	Downy oak/ Pubescent oak
<i>Quercus</i> cf. <i>robur</i>	5	English oak
<i>Quercus serrata</i>	2	Serrated leaf oak
<i>Quercus variabilis</i>	2	Cork-bark oak

Lithocarpus sp. starch grains may be round or irregularly round in shape with a slightly eccentric hilum (Figure 7-22; Figure 7-23). Some granules also appear faceted and these granules are not considered very diagnostic. *Lithocarpus* sp. starch grains are typically

small and within the range of 6–20 μm , although some granules may be larger. Acorn starch grains are often packed loosely or sparsely within cells (Figure 7-23; Figure 7-24) and this may be a useful characteristic that distinguishes acorn starch from grass starch. Further research is needed to clarify starch packing in the various taxa.

Starch grains from *Quercus* sp. acorns are typically triangular in shape (Figure 7-24) although other, less diagnostic grains may be irregularly rounded. Sharp facets or pointed corners are rare although some faceting does occur. The hilum may be slightly eccentric and this, along with the shape and loose packing arrangement of the granules are the most diagnostic features.

Acorns including *Quercus* sp. were recovered from pits at Tianluoshan site in South China (Fuller, et al., 2009). *Quercus* sp. acorns are known macrobotanically from sites such as Jiahu (Zhao, Z. & J. Zhang, 2009). *Quercus* sp. acorn starch has been identified as a residue on grinding implements at the 9,220–8,750 BC site of Donghulin (Liu, Li, et al., 2010b) and also at the slightly later 7,500 – 7,000 cal BP site of Shangzhai (Yang, X. Y., et al., 2009a), both located near Beijing. In fact, X. Y. Yang and colleagues (2009a) identified *Quercus dentata*, *Quercus acutissima* and *Quercus mongolica* at this site based on uncertain diagnostic characteristics. Typically and perhaps more accurately, acorn starch is not identified to species level. The c. 10,000 cal BP Shangshan site in Zhejiang Province (Liu, Li, et al., 2010a) and the Peiligang Egou and Shigu sites in Henan Province (Liu, Li, et al., 2010c) also preserved evidence of *Quercus* sp. starch. At an earlier period, the Late Palaeolithic Shizitan site in Shanxi also preserves evidence of *Quercus* sp. acorns as starch residues from grinding (Liu, Li, et al., 2011).

Tanoak (*Lithocarpus* sp.) acorns appear to be less commonly identified in the archaeological record than *Quercus* sp. acorns, although this may be a function of taxonomic knowledge rather than an actual absence of tanoak in prehistoric times. *Lithocarpus* sp. acorns were identified in pits at the Tianluoshan site in Zhejiang, south China (Fuller, et al., 2009). The presence of this tropical or sub-tropical genus as starch grains from Tieshenggou site in North China (Chapter 9) may attest to the Peiligang climate being warmer and wetter than it is today.

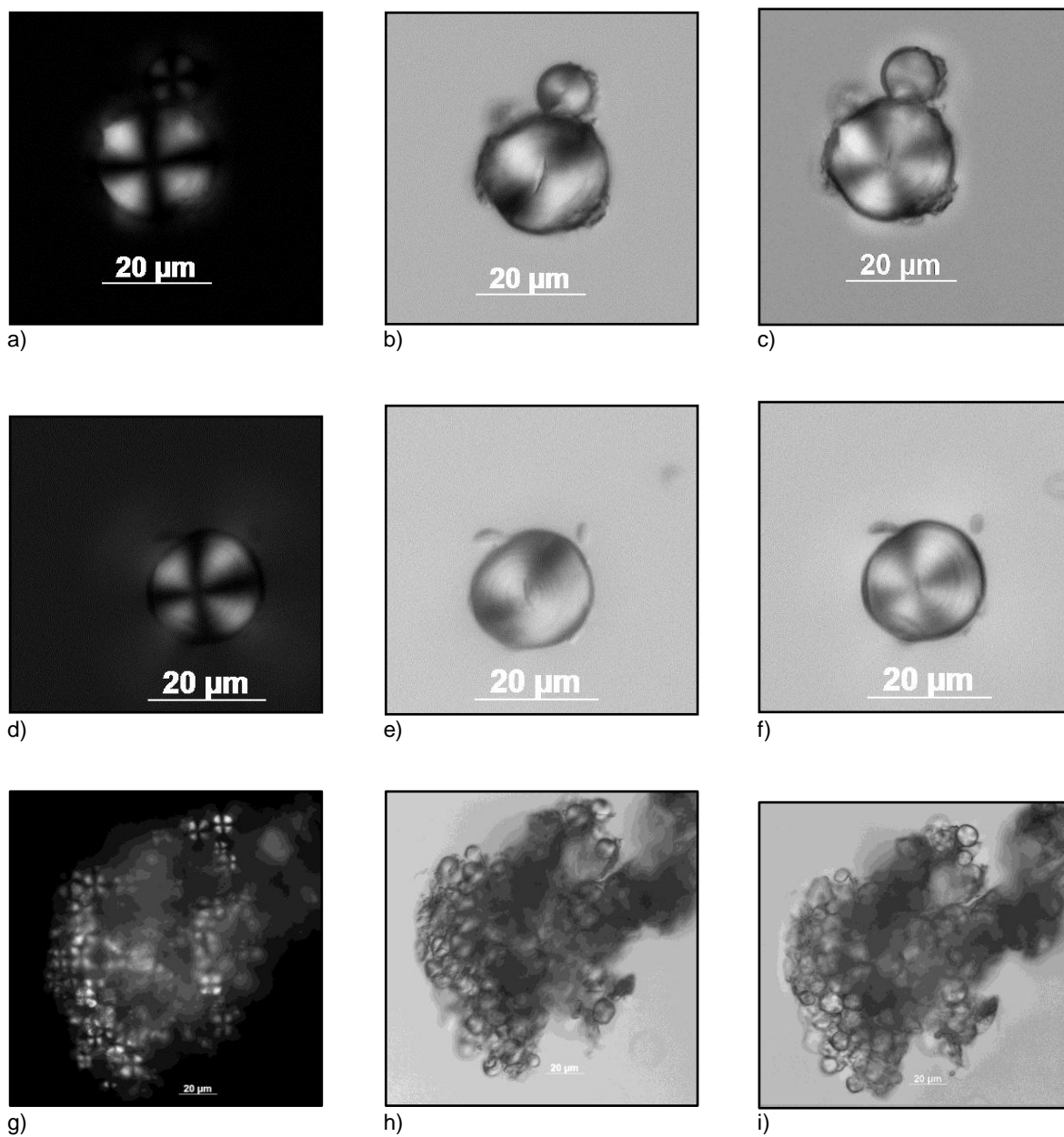
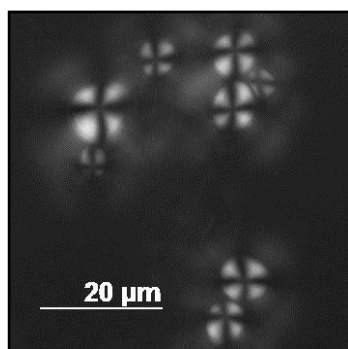
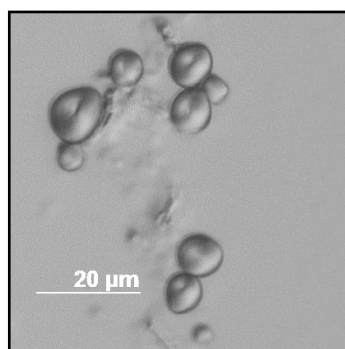


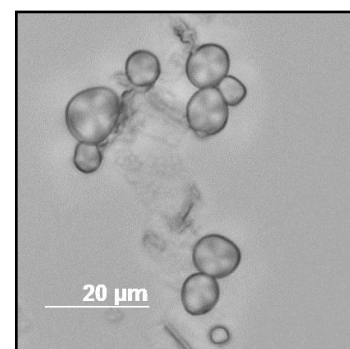
Figure 7-22 *Lithocarpus glaber* (REF561–08C) starch grains exhibiting features typical of *Lithocarpus* sp. granules including rounded granules, a slightly eccentric hilum and lamellae. Images from left to right were taken under a polarizing DIC and brightfield filter respectively.



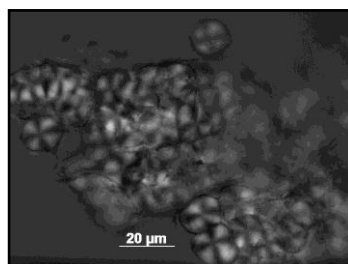
a) *Lithocarpus brevipaudatus* (REF448-08C) under a cross-polarising filter



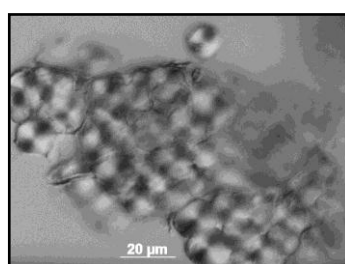
b) *Lithocarpus brevipaudatus* (REF448-08C) under a DIC filter



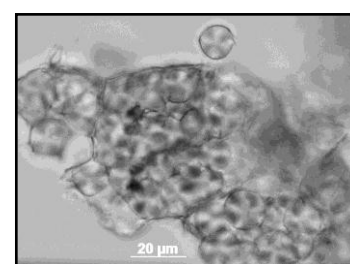
c) *Lithocarpus brevipaudatus* (REF448-08C) under a brightfield filter



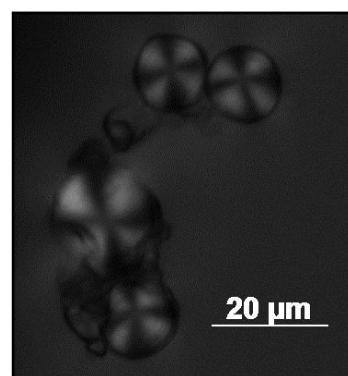
d) *Lithocarpus craibianus* (REF301-08) under a cross-polarising filter



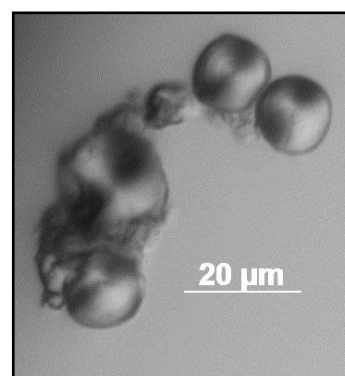
e) *Lithocarpus craibianus* (REF301-08) under a DIC filter



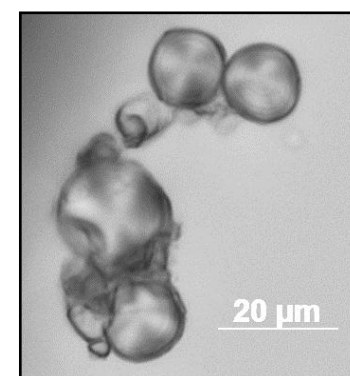
f) *Lithocarpus craibianus* (REF301-08) under a brightfield filter



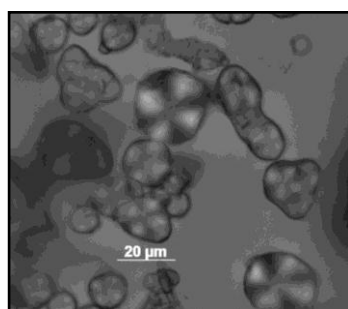
g) *Lithocarpus glaber* (REF561-08C) under a cross-polarising filter



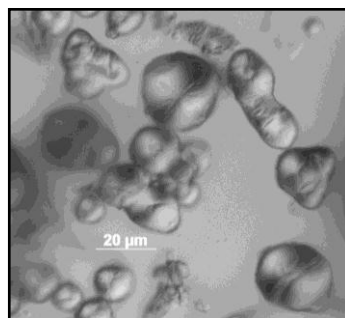
h) *Lithocarpus glaber* (REF561-08C) under a DIC filter



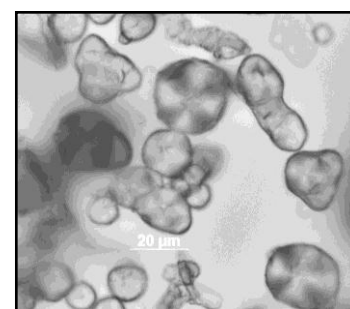
i) *Lithocarpus glaber* (REF561-08C) under a brightfield filter



j) *Lithocarpus pachyphyllus* (REF300-08C) under a cross-polarising filter

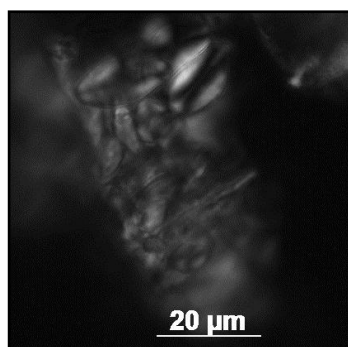


k) *Lithocarpus pachyphyllus* (REF300-08C) under a DIC filter

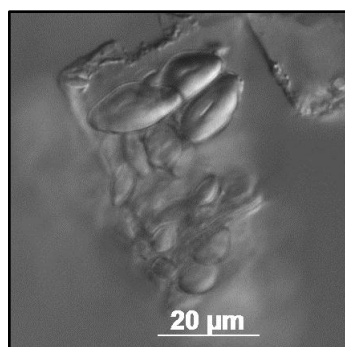


l) *Lithocarpus pachyphyllus* (REF300-08C) under a brightfield filter

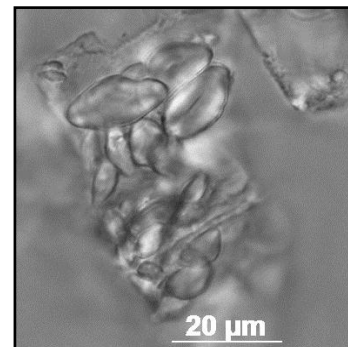
Figure 7-23 Examples of *Lithocarpus* sp. starch grains with a range of morphotypes from acorn starch



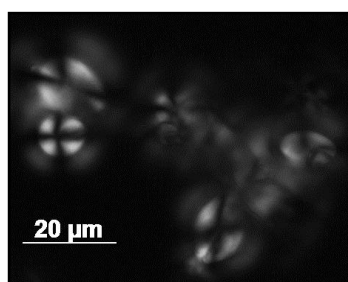
a) *Quercus serrata* (REF286–08) starch under a cross polarising filter



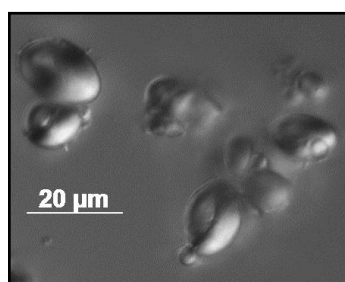
b) *Quercus serrata* (REF286–08) starch under a DIC filter



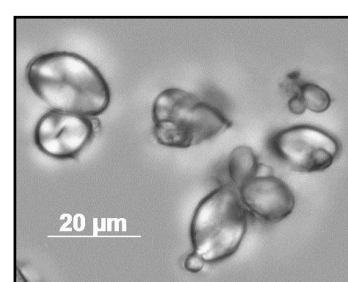
c) *Quercus serrata* (REF286–08) starch under a brightfield filter



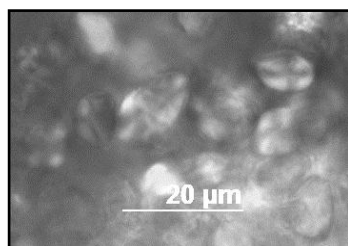
d) *Quercus fabri* (REF441–08C) starch under a cross polarising filter



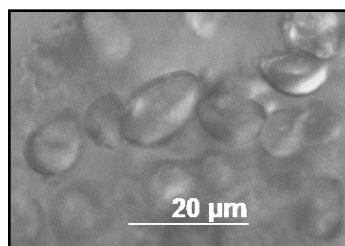
e) *Quercus fabri* (REF441–08C) starch under a DIC filter



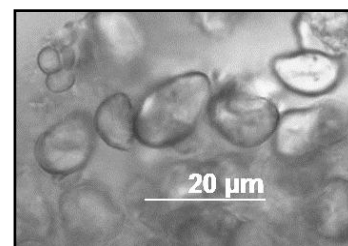
f) *Quercus fabri* (REF441–08C) starch under a brightfield filter



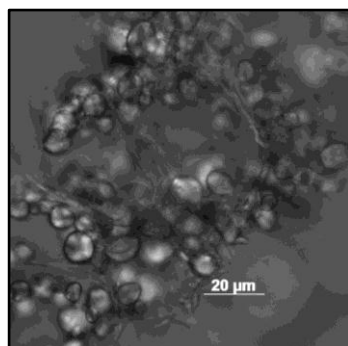
g) *Quercus chenii* (REF444–08C) starch under a cross polarising filter



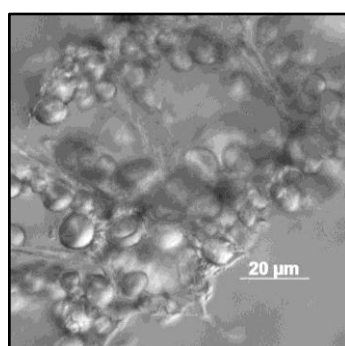
h) *Quercus chenii* (REF444–08C) starch under a DIC filter



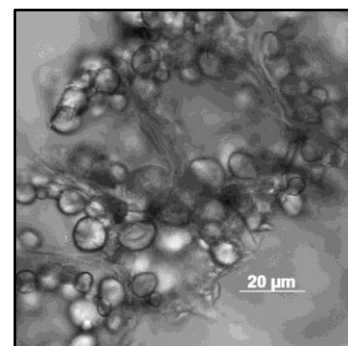
i) *Quercus chenii* (REF444–08C) starch under a brightfield filter



j) *Quercus variabilis* (REF513–08C) starch under a cross-polarizing filter



k) *Quercus variabilis* (REF513–08C) starch under a DIC filter



l) *Quercus variabilis* (REF513–08C) starch under a brightfield filter

Figure 7-24 Triangular *Quercus* sp. starch grains from four different North China species of *Quercus* sp. starch

7.3.4 Poaceae (Grass) Starch

There are approximately ten thousand different grasses (Judd, et al., 2008: 297) and so the more economically important grasses in ancient North China were sampled to test for diagnostic attributes of starch (Table 7-17). However, not all grasses examined had the seed part of the plant tested. In some cases the part of the plant thought most likely to have been economically useful was examined, as with bamboo which may have been used for woodworking and the shoots possibly used for food.

Many Paniceae or millet tribe grass seeds were tested for starch remains. This is partly due to the often cited hypothesis that Peiligang aged grinding artefacts were used to grind foxtail millet (Chang, K. C., 1986:92–93; see also Liu, Li, et al., 2002-2004: 82). It is also partly due to the numerous grass seed remains recovered from flotation of North Chinese Neolithic and early state period sites (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007). Other starch taxa extensively tested include cf Andropogoneae and Triticeae tribe grasses. This is because starch taxa similar to these occurred in populations of starch from North China.

Starch from the grass family has been identified to a range of taxonomic levels including species level (Gong, et al., 2011; Piperno, et al., 2004; Yang, X.Y., et al., 2009b). However, untested and sometimes unspoken assumptions frequently lend support to such models, including assumptions that current plant distributions are similar or identical to past taxon distributions. If differences have occurred in environmental conditions since archaeobotanical plant deposition, such assumptions may not be entirely reliable. Modern taxa growing in a research area may be substantially different to taxa present at the site several thousand years previously. Where thousands or tens of thousands of years have elapsed, or where environmental conditions are known to have changed substantially since plant deposition, it is more reasonable to identify taxa to genus level and state explicitly the assumptions that allow an identification to be made on the basis of fragmentary microfossils.

Starch grains have been identified as domesticates (Perry, et al., 2007; Piperno, 1984; Piperno, et al., 2009; Yang, X. Y., et al., 2009a; 2012). In the central Balsas River Valley of Mexico Piperno and colleagues (2009) categorized domesticated maize starch as larger and more angular than wild teosinte starch. Domesticated broomcorn millet starch was identified by default at the Subeixi site, Xinjiang Province, China (Gong, et al., 2011)

where grains were identified as broomcorn millet based mainly on the presence of broomcorn millet seeds at the site. Other starch reference grains were not examined nor were similar taxa ruled out prior to this identification being made. To make an accurate starch identification it is preferable that similar or related taxa are ruled out or excluded. The range of variation in related modern references should also be examined to strengthen the identification.

X. Y. Yang and colleagues (2012) have examined the potential for domesticated starch to be identified in North Chinese archaeological sites. They suggested that populations of domesticated broomcorn millet were distinguishable from foxtail millet based partly on the presence of fissures as well as on size. However, this is unlikely to be useful archaeologically as the presence of more than one distinct population of similar looking starch grains is rarely identifiable in ancient samples.

Table 7-17 Grass Reference Material in Starch Reference Collection

Grass Sub-family †	Grass Tribe	Grass Genus and Species	No. Specimens	Common Name
Arundinoideae	Arundineae	<i>Phragmites karka</i>	1	Tall reed
Arundinoideae	Arundineae	<i>Phragmites</i> sp.	2	Common reeds
Bambusoideae	Bambuseae	<i>Phyllostachys</i> sp.	3	Bamboos
Chloridoideae	Eragrostideae	<i>Eleusine indica</i>	3	Goosegrass
	Eragrostideae	<i>Eleusine coracana</i>	2	Finger millet
	Eragrostideae	<i>Eragrostis minor</i>	1	Small love grass
	Eragrostideae	<i>Eragrostis</i> sp.	1	Love grass
Ehrhartoideae	Oryzeae	<i>Oryza sativa</i> var <i>indica</i>	7	Indica rice
	Oryzeae	<i>Oryza japonica</i> ssp. <i>indica</i>	5	Japonica rice
	Oryzeae	<i>Oryza nivara</i>	2	Wild rice
	Oryzeae	<i>Oryza rufipogon</i>	2	Brownbeard rice
	Oryzeae	<i>Oryza</i> sp.	10	Rice
	Oryzeae	<i>Zizania</i> sp.	2	Wild American rice

† Panicoideae and Pooideae subfamily grasses tested for starch in Table 7-18 and Table 7-29 respectively.

7.3.4.1 ARUNDINOIDEAE STARCH

Arundinoideae grasses may form reed-like stands along waterways. There are three genera of the Arundinoid subfamily that occur in China (Liu, Liang & Philips, 2006) but these

plants are not known for their cereal seeds. In fact, *Phragmites* sp. reeds occur at Cishan during the Peiligang and related periods leading H. Lu and colleagues (2009a) to suggest that mats of reeds were placed in ash pits. While phytoliths of *Phragmites* sp. were not recovered from the study region the presence of these plants at Cishan site led to tubers being examined for starch grains (Figure 7-25). Tuber starch from *Phragmites* sp. is typically small (<10 μm on average) with a combination of faceted and rounded grains. Diagnostic *Phragmites* sp. starch may have two facets in combination with a rounded edge to granules but this feature occurs in many other taxa including grasses. It is not clear at this stage whether reed tubers have diagnostic starch grains. When individual or single ancient granules are recovered it may be difficult to distinguish individual starch grains from other small grass starch.

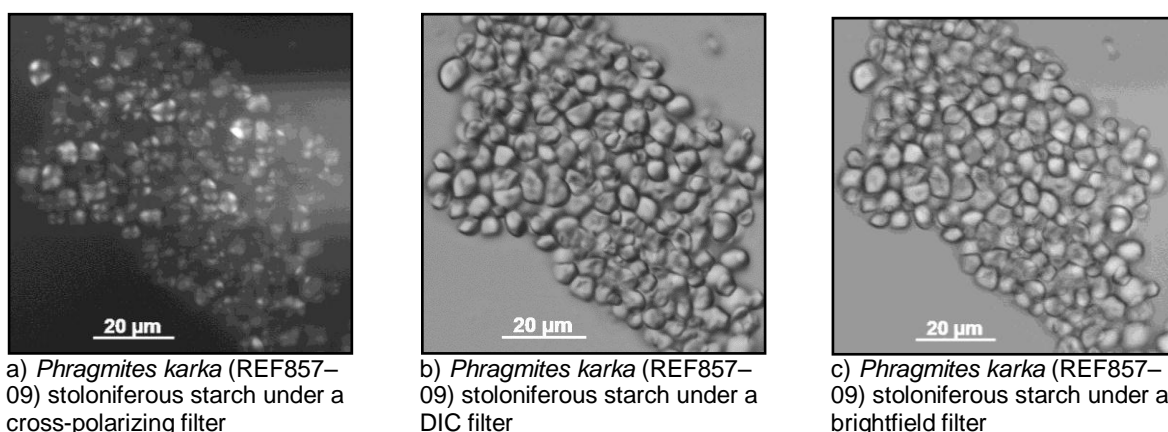


Figure 7-25 *Phragmites karka* (REF857–09) stoloniferous starch (REF857–09) showing small grain size and irregularly rounded starch granules.

7.3.4.2 BAMBUSOIDEAE STARCH

Most bamboos have mass flowering episodes occurring infrequently, with the majority of bamboo taxa only flowering every 60–100 years (Soderstrom & Calderon, 1979: 165). For this reason the seeds of bamboo are unlikely to have been a staple food source and bamboo seeds were not examined for starch. However, bamboo shoots are known to have been eaten in many cultures (Soderstrom & Calderon, 1979: 166) and the wood of bamboo is used for furniture and tools (West & Louys, 2007) so bamboo leaves and stems were tested for transient starch grains (Figure 7-26). Bamboo starch from leaves and stems appeared small and round, as is typical of transient starch grains which move throughout the plant. Such starch is typically non-diagnostic so it is unlikely that bamboo may be identified in the archaeological record on the basis of starch grains.

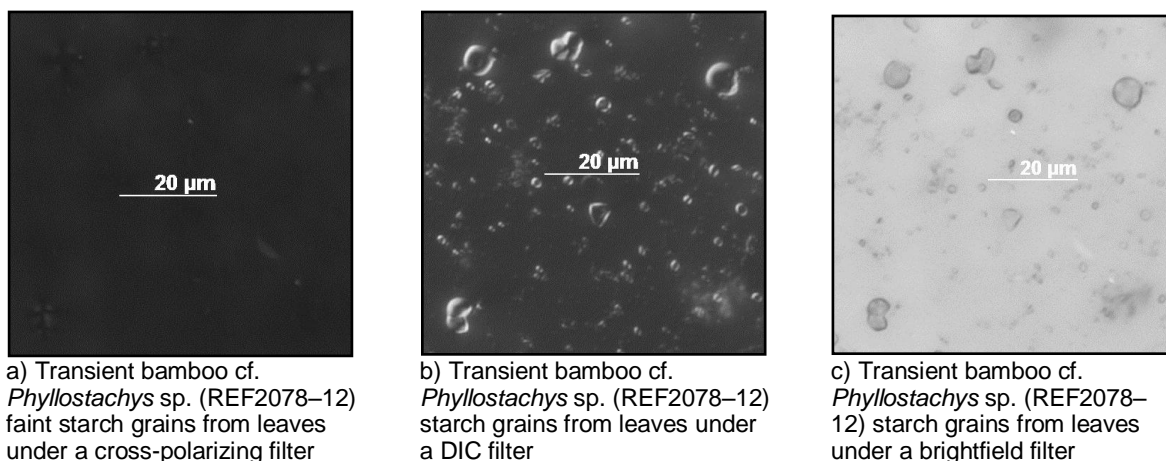


Figure 7-26 Transient bamboo cf. *Phyllostachys* sp. (REF2078-12) starch grains from leaves are quite small and non-diagnostic

7.3.4.3 CHLORIDOIDEAE STARCH

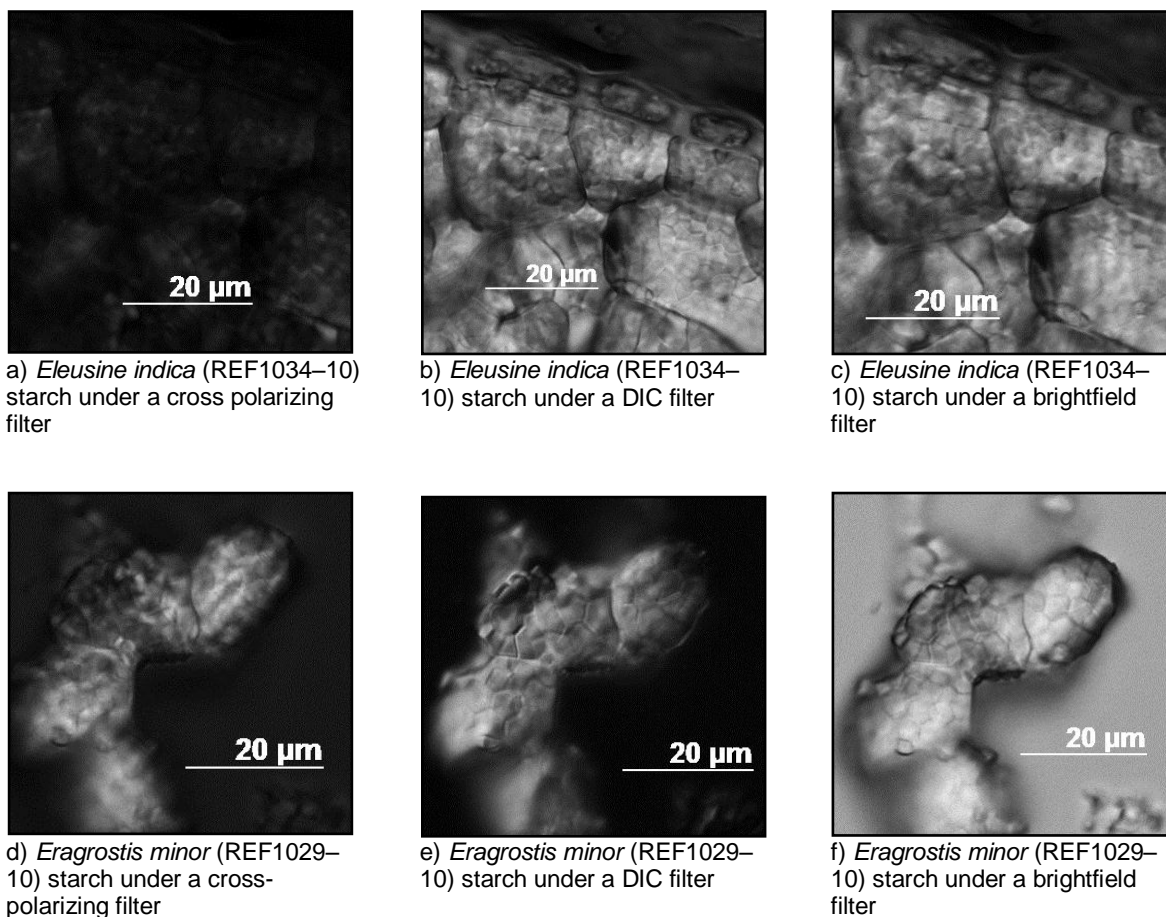


Figure 7-27 Chloridoideae subfamily grass starch including *Eleusine indica* (REF1034-10) and *Eragrostis minor* (REF1029-10) showing typical tightly clustered packing arrangement of various small grained grasses

The chloridoid grass starch examined was small with granules exhibiting a combination of faceted, semi-faceted and rounded grains (Figure 7-27). Chloridoideae subfamily grass starch is not easily distinguishable from small Panicoideae or Ehrhartoideae small grass

starch grains although the populations of Chloridoideae starch examined were relatively small. It is not clear whether this is related to the seeds tested or whether this is a trait that occurs in all species of chloridoid starch. Further research is needed to clarify the size issue and also whether it is possible to distinguish between this and other subfamilies of grasses.

7.3.4.4 EHRHARTOIDEAE STARCH

Henry and colleagues (2009:917) characterize several types of starch grains in their report on cooked starch, including rice (*Oryza sativa*). The grains of rice are said to be compound and between 3–10 μm in size with a centric hilum. This research concurs with this general description except that some granules examined were approximately 14 μm in size. Examination of reference specimens (Figure 7-28) showed that single grains or small clusters of rice starch are difficult to distinguish from other small grass starch grains such as Chloridoideae and Panicoideae sub-family starch. More research is needed to distinguish between these small grains.

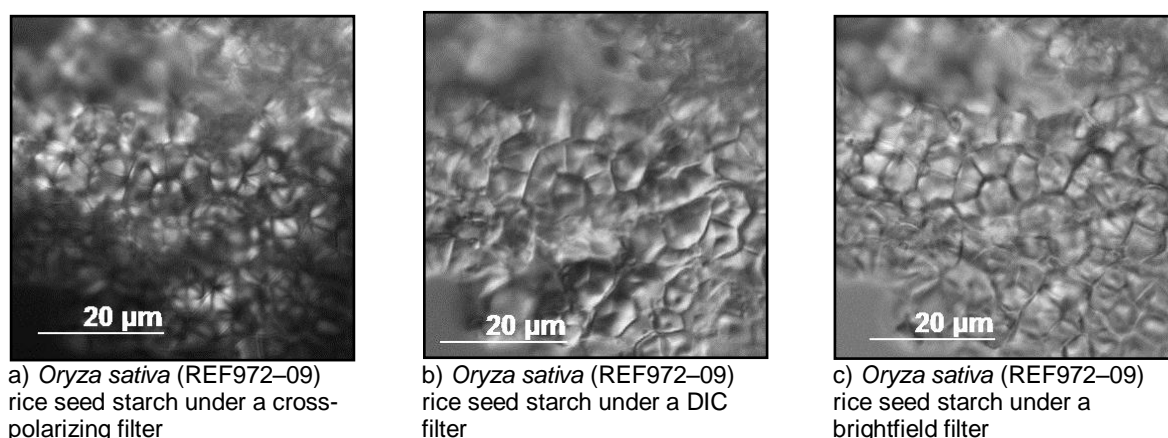


Figure 7-28 Starch from *Oryza sativa* (REF972–09) rice seed starch is typically faceted and tightly packed

7.3.4.5 PANICOIDEAE STARCH

The millet subfamily includes numerous economically important genera and species of grasses. Several taxa relevant to the North Chinese Neolithic were examined (Table 7-18), including taxa from both the Andropogoneae and the Paniceae tribes. In the Andropogoneae tribe starch grains examined tended to be larger than in the Paniceae tribe. This may be because the seeds examined from Andropogoneae were larger. More research is needed to confirm whether there is a link between seed size and starch size.

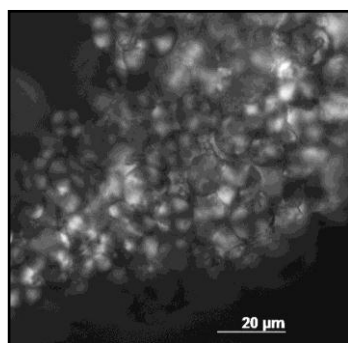
Table 7-18 Panicoideae Subfamily Grass Taxa Examined for Starch

Grass Tribe	Taxon	No. Specimens	Common Name
Andropogoneae	<i>Coix lacryma-jobi</i>	2	Job's tears seed
Andropogoneae	<i>Coix chinensis</i>	1	Chinese job's tears
Andropogoneae	<i>Sorghum bicolor</i>	4	Sorghum/ Durra
Andropogoneae	<i>Sorghum</i> sp.	2	Sorghum
Andropogoneae	<i>Themeda</i> sp.	1	Themeda
Andropogoneae	<i>Zea mays</i>	3	Corn/ Maize
Paniceae	<i>Cenchrus pennisetiformis</i>	1	Bufflegrass/ Sandspur
Paniceae	<i>Echinochloa colona</i>	1	Jungle rice/ a type of barnyard millet
Paniceae	<i>Echinochloa crus-galli</i>	4	Barnyard millet
Paniceae	<i>Setaria italica</i> ssp. <i>italica</i>	30+	Foxtail millet seed
Paniceae	<i>Setaria italica</i> ssp. <i>viridis</i>	20+	Green foxtail grass seed type 1
Paniceae	<i>Setaria faberi</i>	2	Giant foxtail grass
Paniceae	<i>Setaria glauca</i>	1	One of the pigeon grasses
Paniceae	<i>Setaria palmifolia</i>	3	Buddha Grass
Paniceae	<i>Setaria pumila</i>	2	Yellow foxtail grass
Paniceae	<i>Setaria verticillata</i>	1	Bristly foxtail grass
Paniceae	<i>Panicum bisulcatum</i>	3	One of the panic grasses
Paniceae	<i>Panicum maxima</i>	1	Guinea grass
Paniceae	<i>Panicum miliaceum</i>	30+	Broomcorn millet
Paniceae	<i>Panicum virgatum</i>	1	Switchgrass
Paniceae	<i>Paspalum</i> sp.	3	Caterpillar grass
Paniceae	<i>Pennisetum clandestinum</i>	2	Kikuyu grass
Paniceae	<i>Pennisetum glaucum</i>	1	Pearl millet

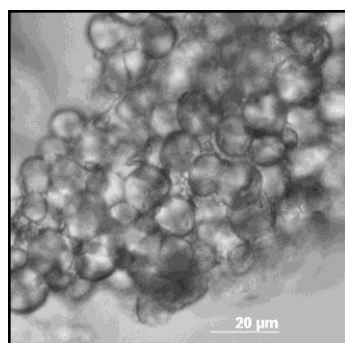
Andropogoneae tribe seeds examined seeds included sorghum, maize⁹ and Job's tears as well as other taxa (Table 7-18). Andropogoneae seeds such as Job's tears have been described from sites in ancient China including in Xinjiang (Jiang, H.-E., et al., 2008). A single reference to Neolithic sorghum in China at the Dahecunsite (Zhengzhoushi, 2001:

⁹ Both sorghum and maize are thought to be historic period introductions to China. They were examined to rule out modern contamination.

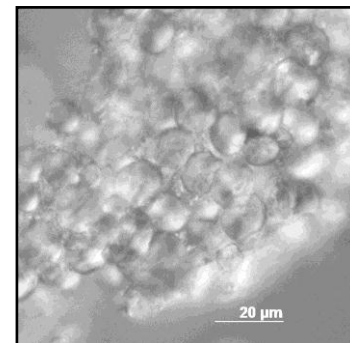
169, 170) was recently found by L. Liu et al. (2012) to be false. Maize is an historic period introduction to China but is a common crop in the study region hence was investigated to exclude modern contamination of samples.



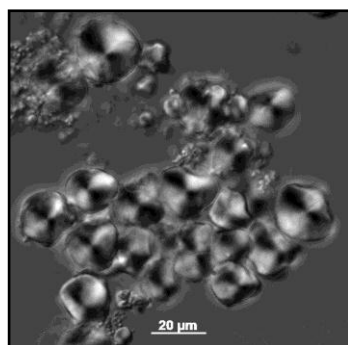
a) *Coix lacryma-jobi* seed starch (REF620-09) under a cross-polarizing filter



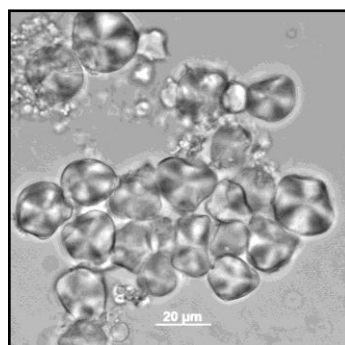
b) *Coix lacryma-jobi* seed starch (REF620-09) under a DIC filter



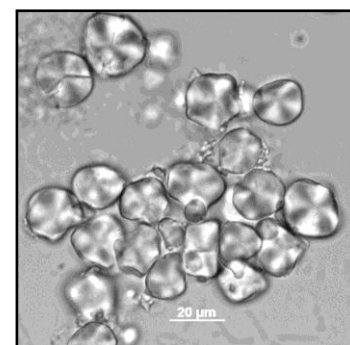
c) *Coix lacryma-jobi* seed starch (REF620-09) under a brightfield filter



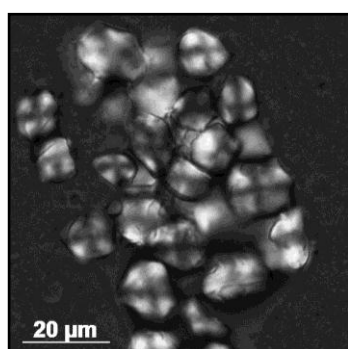
d) *Sorghum bicolor* seed starch (REF506-08C) under a cross-polarizing filter



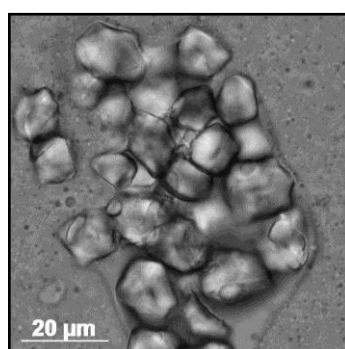
e) *Sorghum bicolor* seed starch (REF506-08C) under a DIC filter



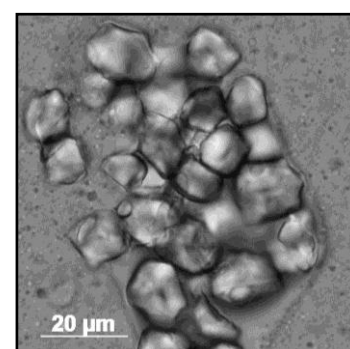
f) *Sorghum bicolor* seed starch (REF506-08C) under a brightfield filter



g) *Zea mays* corn seed starch (REF2074-11) under a cross-polarizing filter



h) *Zea mays* corn seed starch (REF2074-11) under a DIC filter



i) *Zea mays* corn seed starch (REF2074-11) under a brightfield filter

Figure 7-29 Andropogoneae tribe panicoid grass starch showing a combination of rounded and faceted grains. Granules a–c) *Coix lacryma-jobi* seed starch (REF620-09) under a) polarizing, b) DIC and c) brightfield filters; d–e) *Sorghum bicolor* seed starch (REF506-08C) under d) polarizing, e) DIC and f) brightfield filters; and g–i) *Zea mays* corn seed starch (REF2074-11) under g) polarizing, h) DIC and i) brightfield filters

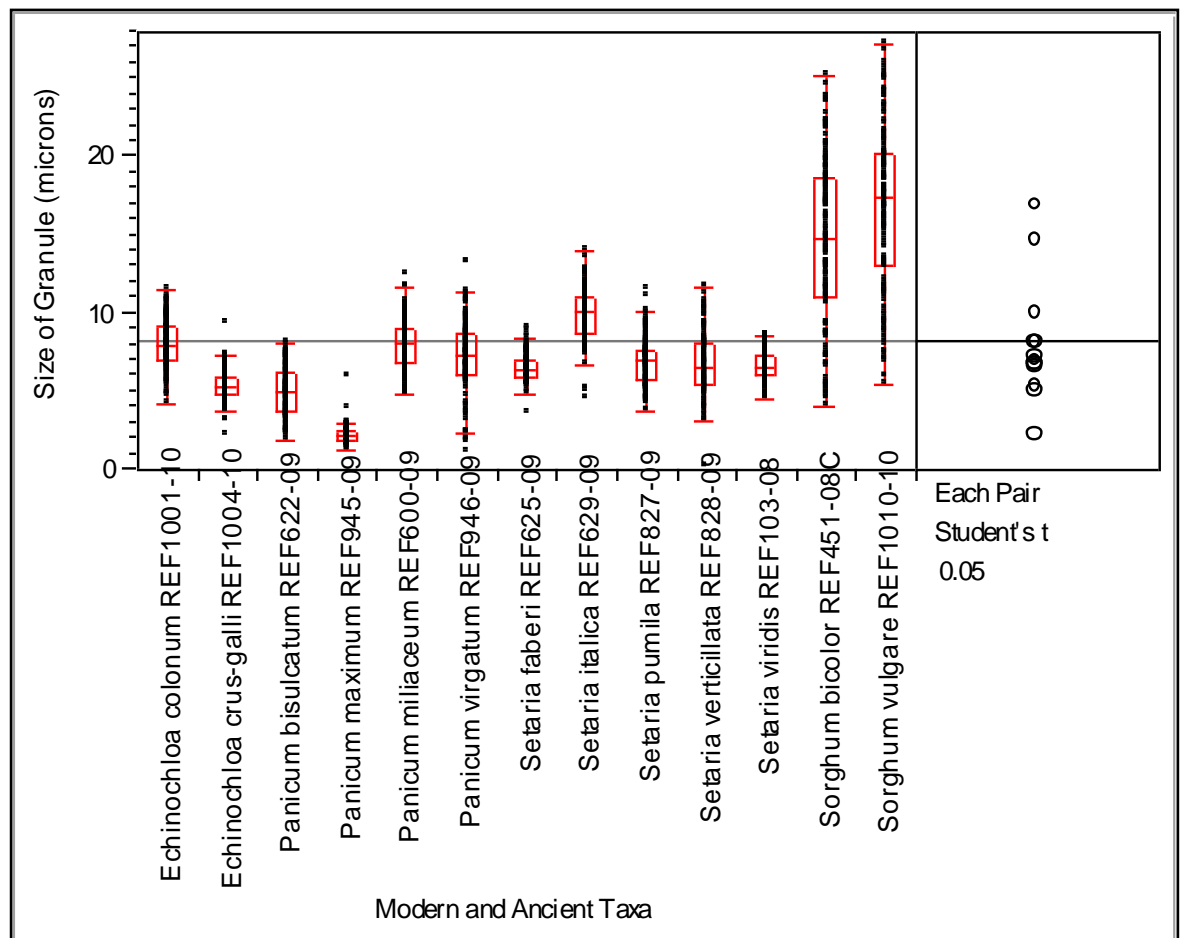


Figure 7-30 Graphic Comparison of Paniceae and Andropogoneae taxa

Andropogoneae tribe starch grains have also been identified by Henry and colleagues (2011: 489) as starch from Neanderthal teeth calculus. The granules were described as round to subangular grains with similarities to *Sorghum* sp. starch granules (Henry, et al., 2011: 489). Following this publication, granules similar to *Sorghum* sp. starch but occurring in a context where sorghum is unknown, are identified as cf. Andropogoneae (see chapter 9).

Features of typical Andropogoneae tribe starch include a population with a combination of rounded and faceted grains and large size (Figure 7-29). Facets are typically irregular and not evenly spaced and this may be a diagnostic trait of this taxonomic group, although more research is required to establish the veracity of this hypothesis. Job's tears seeds may exhibit larger and rounded starch grains (Figure 7-29) as opposed to angular granules. Variation in starches among these types of grasses is not uncommon.

The size of Andropogoneae taxa tends to be larger than Paniceae taxa although this may be a feature of the reference collection, given that several of the Andropogoneae taxa

examined were domesticated (Figure 7-30; Table 7-19; Table 7-20). Piperno (1984) and Holst and colleagues (2007) have argued for a larger size of domesticated maize taxa when compared to wild teosinte starch. It is possible that Andropogoneae tribe taxa exhibit larger starch grains than Paniceae or millet tribe taxa because Andropogoneae seed sizes are typically larger. The size of Andropogoneae and Paniceae tribe starch populations were significantly different, with a student's t-test exhibiting positive values for the comparisons graphed at $df=1$, $p<0.05$. (Table 7-20).

Table 7-19 Comparison Size of Starch Grains in Paniceae and Andropogoneae taxa

Level	No. Granules	Minimum	Median	Maximum
<i>Echinochloa colona</i> REF1001–10	118	4.27	8.06	11.54
<i>Echinochloa crus-galli</i> REF1004–10	120	2.23	5.44	9.46
<i>Panicum bisulcatum</i> REF622–09	107	1.89	5.07	8.19
<i>Panicum maximum</i> REF945–09	102	1.27	2.23	6.06
<i>Panicum miliaceum</i> REF600–09	100	4.86	8.17	12.48
<i>Panicum virgatum</i> REF946–09	111	1.2	7.37	13.26
<i>Setaria faberi</i> REF625–09	111	3.65	6.48	9.17
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	101	4.52	10.18	14.1
<i>Setaria pumila</i> REF827–09	140	3.82	7.12	11.59
<i>Setaria verticillata</i> REF828–09	109	0.16	6.65	11.74
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	103	4.55	6.67	8.71
<i>Sorghum bicolor</i> REF451–08C	129	4.11	14.91	25.27
<i>Sorghum vulgare</i> REF1010–10	122	5.49	17.48	27.3

In the Paniceae tribe several species that occur in later Neolithic periods were examined for starch grains. These include *Echinochloa* sp., *Setaria* sp. and *Panicum* sp. as well as other taxa. Domesticates include *Setaria italica* ssp. *italica*, which is the domesticated form of *Setaria italica* ssp. *viridis*. *Panicum miliaceum* is also domesticated but the wild ancestor is unknown, although *Panicum bisulcatum* has been postulated (Zhao, Z., 2005a). Although some of the taxa examined exhibited size distinctions (Figure 7-31; Table 7-21; Table 7-22) it is difficult to differentiate between the various genera and species of the millet tribe taxa based on their starch grains. This is partly because there are numerous taxa in the millet tribe that have not been tested and partly because the size and shape of those tested taxa appear relatively similar, despite minor differences. However, future research may

find statistically significant methods of differentiating between these similar taxa when they occur within archaeological sites.

Table 7-20a Student's t-test Values Comparing Size of Paniceae and Andropogoneae Taxa

Abs(Dif)- LSD	<i>S.</i> <i>vulgare</i>	<i>S.</i> <i>bicolor</i>	<i>S.</i> <i>italica</i> ssp. <i>italica</i>	<i>E.</i> <i>colona</i>	<i>P.</i> <i>miliaceum</i>	<i>P.</i> <i>virgatum</i>	<i>S.</i> <i>pumila</i>	<i>S.</i> <i>verticillata</i>	<i>S. italica</i> ssp. <i>viridis</i>	<i>S. faberi</i>	<i>E. crus-</i> <i>galli</i>	<i>P.</i> <i>bisulcatum</i>	<i>P.</i> <i>maximum</i>
<i>Sorghum</i> <i>vulgare</i>	-0.6358	1.6317	6.339 0	8.2006	8.2109	9.0556	9.3560	9.4750	9.5402	9.7200	10.9061	11.2416	13.9881
<i>Sorghum</i> <i>bicolor</i>	1.6317	-0.6210	4.086 3	5.9476	5.9579	6.8026	7.1034	7.2219	7.2870	7.4670	8.6532	8.9884	11.7349
<i>Setaria</i> <i>italica</i> ssp. <i>italica</i>	6.3390	4.0863	- 0.611 7	1.2495	1.2598	2.1044	2.4055	2.5237	2.5887	2.7688	3.9551	4.2902	7.0366
<i>Echinochloa</i> <i>colona</i>	8.2006	5.9476	1.249 5	-0.6518	-0.6414	0.2034	0.5033	0.6228	0.6881	0.8678	2.0537	2.3894	5.1361
<i>Panicum</i> <i>miliaceum</i>	8.2109	5.9579	1.259 8	-0.6414	-0.6603	0.1846	0.4843	0.6040	0.6694	0.8490	2.0348	2.3706	5.1173
<i>Panicum</i> <i>virgatum</i>	9.0556	6.8026	2.104 4	0.2034	0.1846	-0.6720	-0.3727	-0.2526	-0.1871	-0.0076	1.1781	1.5141	4.2609
<i>Setaria</i> <i>pumila</i>	9.3560	7.1034	2.405 5	0.5033	0.4843	-0.3727	-0.5984	-0.4806	-0.4157	-0.2355	0.9509	1.2858	4.0322
<i>Setaria</i> <i>verticillata</i>	9.4750	7.2219	2.523 7	0.6228	0.6040	-0.2526	-0.4806	-0.6782	-0.6127	-0.4333	0.7524	1.0885	3.8353
<i>Setaria</i> <i>italica</i> ssp. <i>viridis</i>	9.5402	7.2870	2.588 7	0.6881	0.6694	-0.1871	-0.4157	-0.6127	-0.6977	-0.5184	0.6670	1.0035	3.7504
<i>Setaria</i> <i>faberi</i>	9.7200	7.4670	2.768 8	0.8678	0.8490	-0.0076	-0.2355	-0.4333	-0.5184	-0.6720	0.5137	0.8497	3.5964
<i>Echinochloa</i> <i>crus-galli</i>	10.9061	8.6532	3.955 1	2.0537	2.0348	1.1781	0.9509	0.7524	0.6670	0.5137	-0.6464	-0.3107	2.4359
<i>Panicum</i> <i>bisulcatum</i>	11.2416	8.9884	4.290 2	2.3894	2.3706	1.5141	1.2858	1.0885	1.0035	0.8497	-0.3107	-0.6877	2.0591
<i>Panicum</i> <i>maximum</i>	13.9881	11.7349	7.036 6	5.1361	5.1173	4.2609	4.0322	3.8353	3.7504	3.5964	2.4359	2.0591	-0.7011

Positive values show pairs of means that are significantly different.

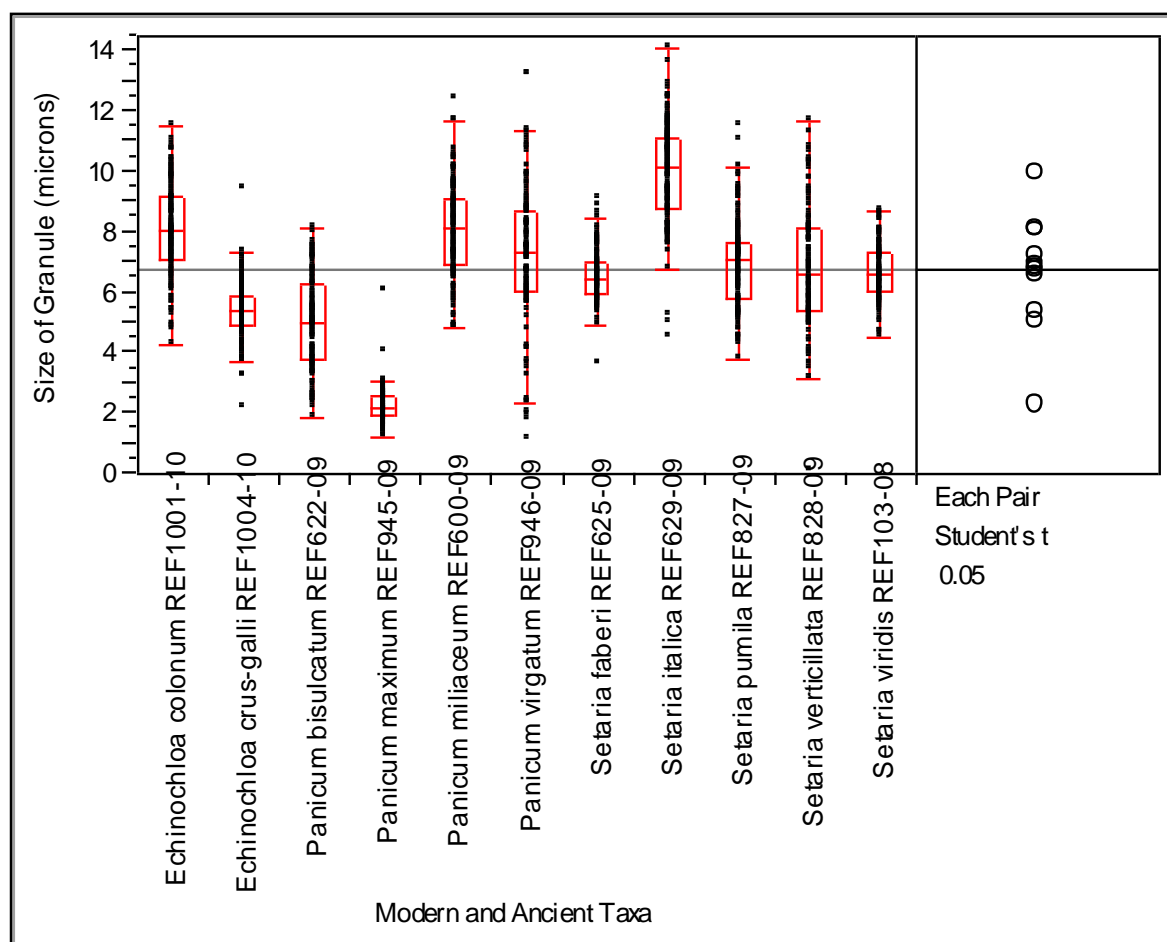


Figure 7-31 Sizes of millet (Paniceae) tribe taxa starch grains

Table 7-21 Comparison of Millet (Paniceae) Tribe Taxa Starch Grains

Level	No. Grains	Minimum	Median	Maximum
<i>Echinochloa colona</i> REF1001–10	118	4.27	8.06	11.54
<i>Echinochloa crus-galli</i> REF1004–10	120	2.23	5.44	9.46
<i>Panicum bisulcatum</i> REF622–09	107	1.89	5.07	8.19
<i>Panicum maxima</i> REF945–09	102	1.27	2.23	6.06
<i>Panicum miliaceum</i> REF600–09	100	4.86	8.17	12.48
<i>Panicum virgatum</i> REF946–09	111	1.2	7.37	13.26
<i>Setaria faberi</i> REF625–09	111	3.65	6.48	9.17
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	101	4.52	10.18	14.1
<i>Setaria pumila</i> REF827–09	140	3.82	7.12	11.59
<i>Setaria verticillata</i> REF828–09	109	0.16	6.65	11.74
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	103	4.55	6.67	8.71

Table 7-22 Student's t-test Values for Comparison of Millet (Paniceae) Tribe Taxa Starch Grains

Abs(Dif)-LSD	<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	<i>Echinochloa colona</i> REF1001–10	<i>Panicum miliaceum</i> REF600–09	<i>Panicum virgatum</i> REF946–09	<i>Setaria pumila</i> REF827–09	<i>Setaria verticillata</i> REF828–09	<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	<i>Setaria faberi</i> REF625–09	<i>Echinochloa crus-galli</i> REF1004–10	<i>Panicum bisulcatum</i> REF622–09	<i>Panicum maximum</i> REF945–09
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	-0.35697	1.51270	1.52480	2.37195	2.65745	2.79262	2.86192	3.03637	4.21712	4.56119	7.31058
<i>Echinochloa colona</i> REF1001–10	1.51270	-0.38040	-0.36823	0.47903	0.76384	0.89975	0.96923	1.14344	2.32396	2.66840	5.41792
<i>Panicum miliaceum</i> REF600–09	1.52480	-0.36823	-0.38533	0.46194	0.74662	0.88268	0.95219	1.12636	2.30683	2.65134	5.40088
<i>Panicum virgatum</i> REF946–09	2.37195	0.47903	0.46194	-0.39222	-0.10774	0.02853	0.09809	0.27220	1.45261	1.79722	4.54680
<i>Setaria pumila</i> REF827–09	2.65745	0.76384	0.74662	-0.10774	-0.34924	-0.21431	-0.14507	0.02945	1.21029	1.55422	4.30358
<i>Setaria verticillata</i> REF828–09	2.79262	0.89975	0.88268	0.02853	-0.21431	-0.39580	-0.32621	-0.15214	1.02823	1.37291	4.12250
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	2.86192	0.96923	0.95219	0.09809	-0.14507	-0.32621	-0.40716	-0.23320	0.94707	1.29191	4.04156
<i>Setaria faberi</i> REF625–09	3.03637	1.14344	1.12636	0.27220	0.02945	-0.15214	-0.23320	-0.39222	0.78819	1.13281	3.88238
<i>Echinochloa crus-galli</i> REF1004–10	4.21712	2.32396	2.30683	1.45261	1.21029	1.02823	0.94707	0.78819	-0.37722	-0.03284	2.71667
<i>Panicum bisulcatum</i> REF622–09	4.56119	2.66840	2.65134	1.79722	1.55422	1.37291	1.29191	1.13281	-0.03284	-0.40136	2.34826
<i>Panicum maximum</i> REF945–09	7.31058	5.41792	5.40088	4.54680	4.30358	4.12250	4.04156	3.88238	2.71667	2.34826	-0.40915

Positive values show pairs of means that are significantly different.

X. Y. Yang and colleagues are pioneers in the field of ancient starch research in China. They were the first to apply the modern research technique of ancient starch analysis to such important sites as Lajia (Lu, H., et al., 2005) and Cishan (Yang, X. Y., et al., 2012). Given their ground-breaking role in ancient starch research, it is natural that errors should have been made (see Ge, et al., 2010 on identification of starch at Lajia). Following

researchers may build on the early work of these pioneers to adjust and clarify initial findings.

X. Y. Yang and colleagues (2012) recently examined starch recovered from an ancient sediment sample from the Cishan site. They claimed that 99.6 percent of phytoliths from this sample were diagnostic to broomcorn millet (Yang, X. Y., et al., 2012: 248). However, phytolith samples typically preserve numerous undiagnostic taxa. Even if the entire depositional plant population had consisted solely of broomcorn millet many of the phytoliths recovered from this plant should still have been non-diagnostic. Numerous parts of the husk surrounding the seed are difficult to identify to genus, let alone species, and many of the phytoliths from broomcorn millet leaves and stems are also not diagnostic. So it is unclear exactly how X. Y. Yang and colleagues managed to get such an exemplary sample. For further discussion of the phytolith study by H. Lu and colleagues (2009b) from Cishan site, see discussion in chapter 3.

X. Y. Yang and colleagues examined nine modern broomcorn millet samples (starch grains $n=923$), and determined the mean size of the starch grains was 6.5–7.5 μm (Yang, X. Y., et al., 2012: 252). Only three of the 923 broomcorn millet grains examined were over 10 μm (Yang, X.Y., et al., 2012: 253). Similarly, Henry and colleagues (2009: Table 2) characterize modern broomcorn millet starch as being between 3–10 μm . This thesis also characterized broomcorn millet starch as being between 4.86–12.48 μm (Table 7-25). However, the ancient grains from Cishan that X. Y. Yang and colleagues identified as broomcorn millet averaged a much larger size with 16 of 26 grains being over 10 μm (Yang, X.Y., et al., 2012: 252-254). X. Y. Yang and colleagues could not explain this size discrepancy with their modern references, but concluded the grains were broomcorn millet nevertheless (Yang, X.Y., et al., 2012: 254). This contradicts their previous summary of research on millet and its wild relatives in China (Yang, X.Y., et al., 2010) where they stated that ‘starch grains more than 12 μm in size are generally not of broomcorn millet’ and ‘starch grains more than 14 μm in size are generally of foxtail millet.’ It is difficult to understand why ancient grains that were substantially larger than modern broomcorn millet references were identified as broomcorn millet. Further research is required to clarify this issue.

From the following examination of modern Paniceae and other grass starch grains, it can be suggested that the starch grains from Cishan that X. Y. Yang and colleagues (2012)

identified as broomcorn millet require further explanation. They may be an as-yet unidentified taxon. They are also similar to the grains identified in this thesis and in papers by Li, Liu and colleagues (2011) as cf. *Andropogoneae* grass starch. Starch grains of cf. *Andropogoneae* have been identified in other places around the world including on the teeth of Neanderthals from the Spy 1 and II sites in Belgium (Henry, et al., 2011: figure 6).

It seems that X. Y. Yang and colleagues are building on their own reference sample research through time. For example, their determination of diagnostic sizes of modern millets appears to be steadily decreasing over time. In their 2005 publication X. Y. Yang and colleagues described modern foxtail millet starch grains as being between 12–38 μm . A later publication from 2010 describes the same type of starches having an average of $9.9 \pm 2.3 \mu\text{m}$ with the largest grain being 19.5 μm (Yang, X. Y., et al., 2010). Most recently in her 2012 publication the size range of modern foxtail millet appears to have decreased again, with X. Y. Yang and colleagues stating that the “mean maximum length measurements of 9 samples are 9–12 μm ” with fewer than 2 percent of grains being larger than 15 μm (2012: 252).

X. Y. Yang and colleagues have also revised the size of their modern broomcorn millet reference material starch grains over time. In an initial publication broomcorn millet grains were described as being between 10–25 μm (Yang, X.Y., et al., 2005), but later decreased to an average of $7.3 \mu\text{m} \pm 1.4 \mu\text{m}$ with the largest grain being 11.9 μm (Yang, X.Y., et al., 2010). Most recently they were described as exhibiting a mean maximum length of 6.5–7.5 μm with the largest being 11.9 μm (2012: 252). Only 3 grains out of 923 broomcorn millet reference samples measured were over 10 μm in size (X. Y. Yang, 2012: 252). This is certainly a very good sample size for broomcorn millet grains and X. Y. Yang and colleagues are to be commended on their large sample size of domesticated millets. However, in the small sample size of ancient Cishan starch grains, over half the grains are larger than the maximum for modern domesticated references. This is problematic and may indicate that the grains are not from broomcorn millet. They may be from a taxon that does not produce many diagnostic phytoliths, such as acorns, which rarely produce phytoliths, or they may represent a different grass specimen. It is hoped that future research by X. Y. Yang and her colleagues will resolve this interesting issue she has reported on.

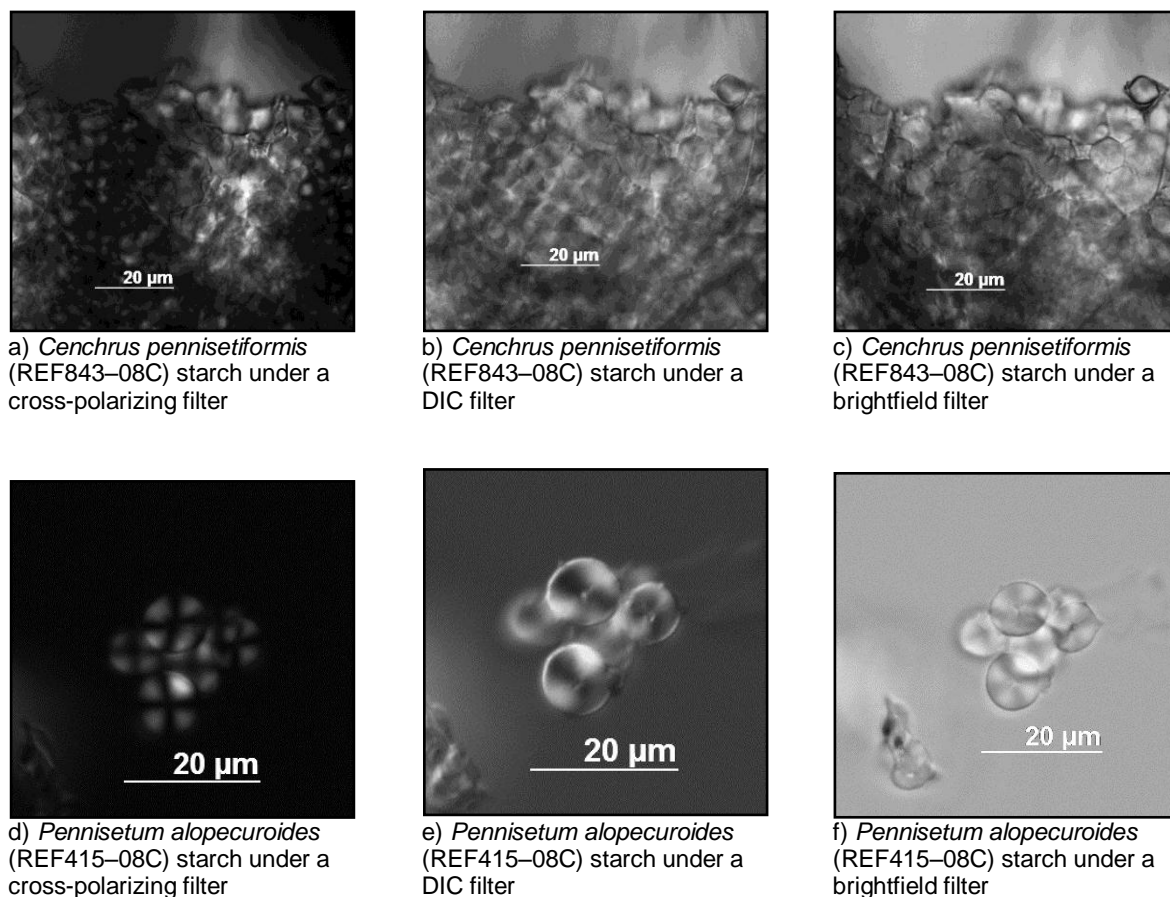


Figure 7-32 Wild Paniceae tribe grass starch

The similarities between the starch grains in some of the Paniceae tribe taxa examined, including both wild and domesticated taxa, are pictured in the following figures (Figure 7-36; Figure 7-39). The Paniceae tribe taxa examined were all typically compound starches although individual granules tended to break apart and separate. It is likely that this also occurs with archaeological starch, meaning that this is probably not a useful diagnostic characteristic. The average size of Paniceae tribe granules is <10 µm (Figure 7-31) although some granules were larger and many were smaller. Granules may exhibit rounded or faceted shapes or a combination of both. The hila are typically centric and fissures may sometimes be present over the hilum. Lamellae are usually not visible.

Starch granule features from the Paniceae tribe are not immediately different from other sub-families of grass starch including Ehrhartoideae granules such as *Oryza* sp. rice (Figure 7-28) or Chloridoideae sub-family taxa including *Eleusine* sp. and *Eragrostis* sp. (Figure 7-27). Further research is needed to clarify differences between small grained grass starch taxa and whether differences visible in modern reference populations are useful archaeologically.

Several species of barnyard grass (*Echinochloa* sp.) were examined for starch grains (Figure 7-33). Starch recovered was typically small (less than 13µm) (Table 7-21) and granules exhibited the typical Paniceae tribe combination of some rounded and some faceted grains (Figure 7-33). The size of a type of barnyard millet (*Echinochloa colona*) was significantly similar to broomcorn millet, with a student's t-test negative value of -0.36 (Table 7-22). This may make it difficult to distinguish between broomcorn millet and barnyard millet starch grains in archaeological samples.

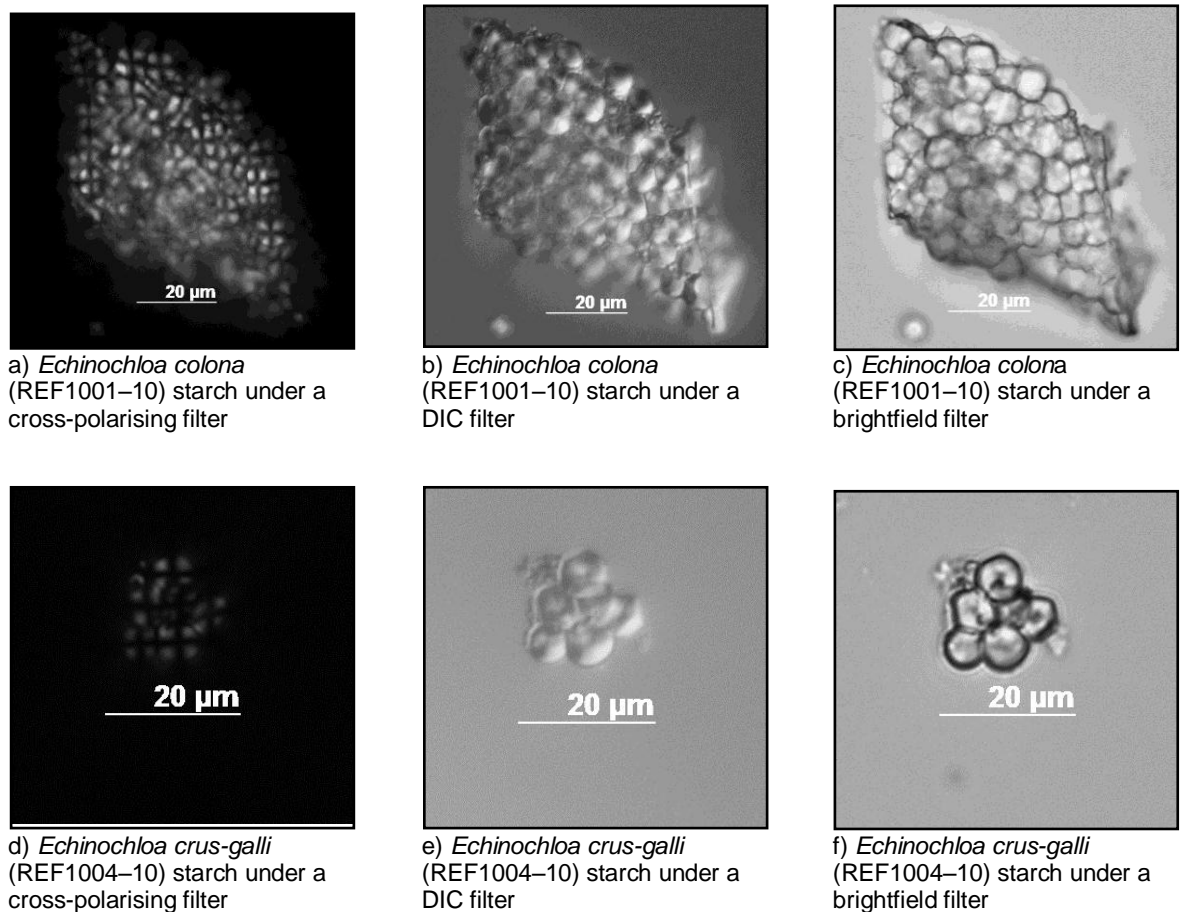
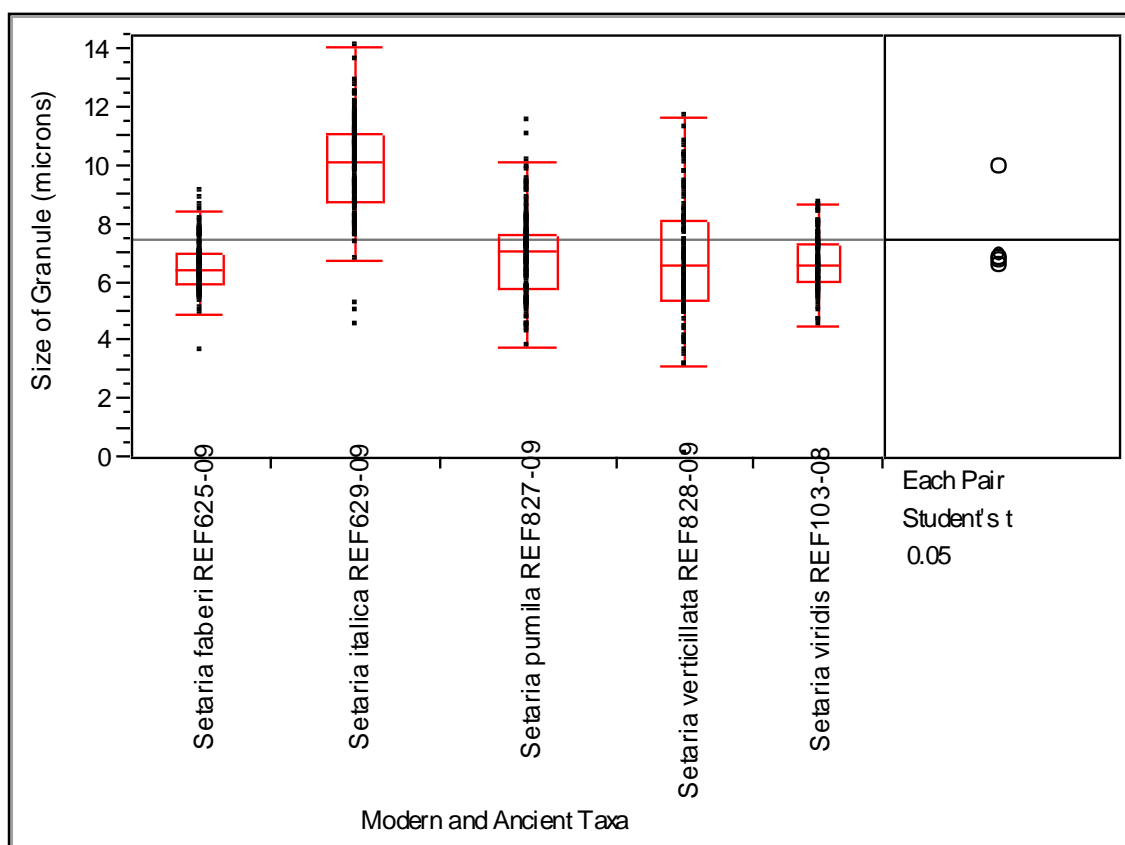


Figure 7-33 *Echinochloa* sp. starch grains

The wild *Setaria* sp. taxa tested for starch included *Setaria faberi*, *Setaria pumila* and *Setaria verticillata* (Figure 7-34; Figure 7-35). Based on size ranges and shape categories these taxa appeared virtually indistinguishable from each other (Figure 7-35; Table 2-23; Table 7-24) although there is a small but statistically significant difference between *Setaria faberi* and *Setaria pumila* with a student's t-test significance level of 0.04, df=1, $p < 0.05$. There is a much greater statistically significant difference between foxtail millet and wild *Setaria* sp. grains with a t-test value of between 2.6 to 3, where df=1, $p < 0.05$. (Figure 7-35; Figure 7-36).

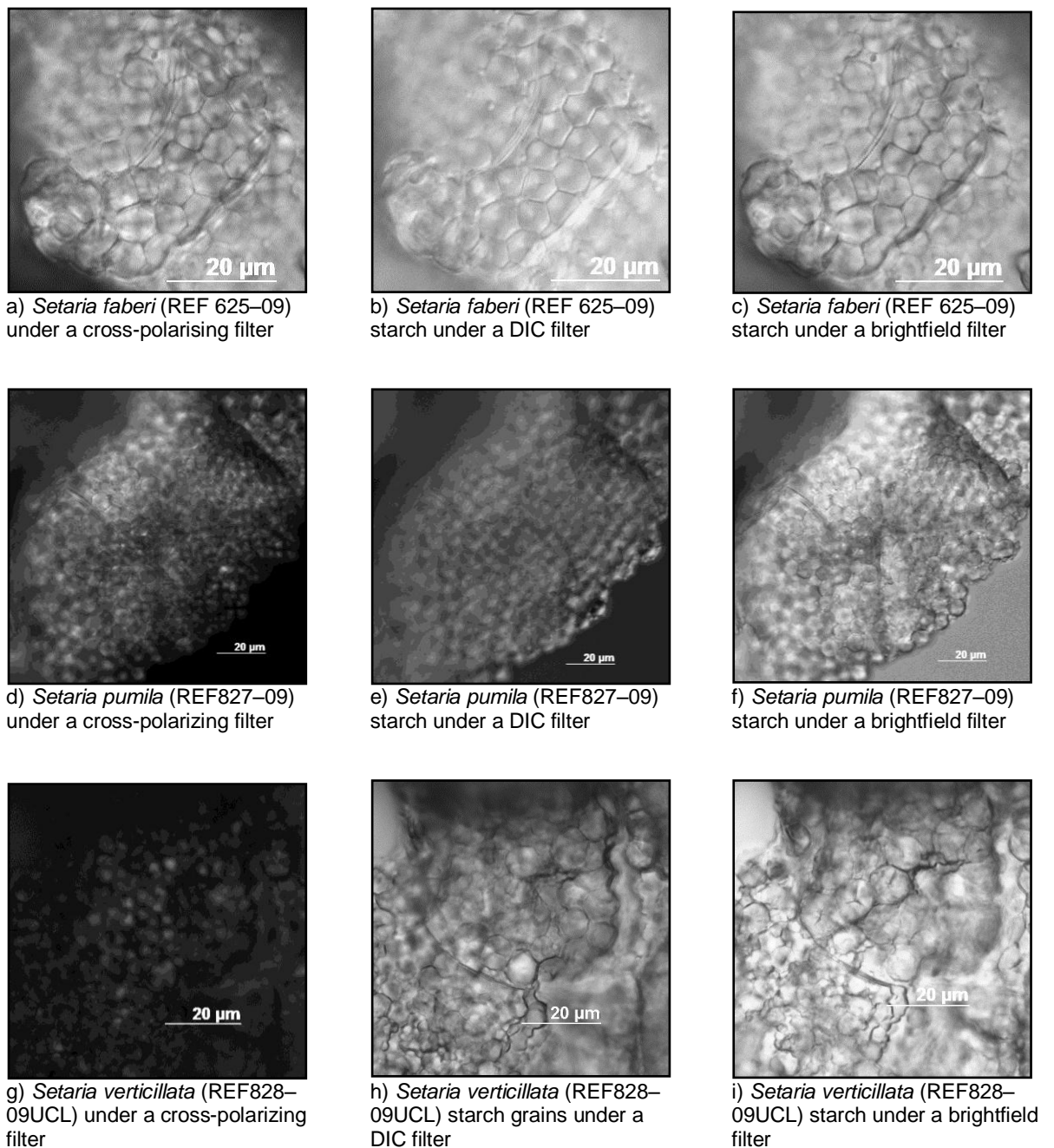
Figure 7-34 Size of *Setaria* sp. starch taxaTable 7-23 Comparison of Sizes of *Setaria* sp. Starch Taxa

Level	No. Grains	Minimum	Median	Maximum
<i>Setaria faberi</i> REF625–09	111	3.65	6.48	9.17
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	101	4.52	10.18	14.1
<i>Setaria pumila</i> REF827–09	140	3.82	7.12	11.59
<i>Setaria verticillata</i> REF828–09	109	0.16	6.65	11.74
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	103	4.55	6.67	8.71

Table 7-24 Student's t-test Values for Comparison of Sizes of *Setaria* sp. Starch Taxa

Abs(Dif)-LSD	<i>Setaria italica</i> ssp. <i>italica</i>	<i>Setaria pumila</i>	<i>Setaria verticillata</i>	<i>Setaria italica</i> ssp. <i>viridis</i>	<i>Setaria faberi</i>
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	-0.34817	2.66615	2.80191	2.87136	3.04561
<i>Setaria pumila</i> REF827–09	2.66615	-0.34063	-0.20511	-0.13571	0.03861
<i>Setaria verticillata</i> REF828–09	2.80191	-0.20511	-0.38604	-0.31631	-0.14243
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	2.87136	-0.13571	-0.31631	-0.39712	-0.22334
<i>Setaria faberi</i> REF625–09	3.04561	0.03861	-0.14243	-0.22334	-0.38255

Positive values show pairs of means that are significantly different.

Figure 7-35 Wild *Setaria* sp. starch grains

Modern references of *Setaria* sp. starch taxa typically show tightly packed clusters of starch grains (Figure 7-35; Figure 7-36). These granules are typically faceted however some granules may be rounded or partly rounded with facets also present. Facets are typically evenly sized and variations on this are rare. Fissures are small and difficult to see in wild *Setaria* sp. starch grains. However some populations do have fissures present. Lamellae were not observed but this may be due to the small size of the granules being examined. Fifty percent of granules were typically within one to three microns of each other in maximum length when measured through the hilum, meaning that size graphs of

Setaria sp. starch show small box plots with a 50 percent variation of less than 3 microns in size range (Figure 7-34).

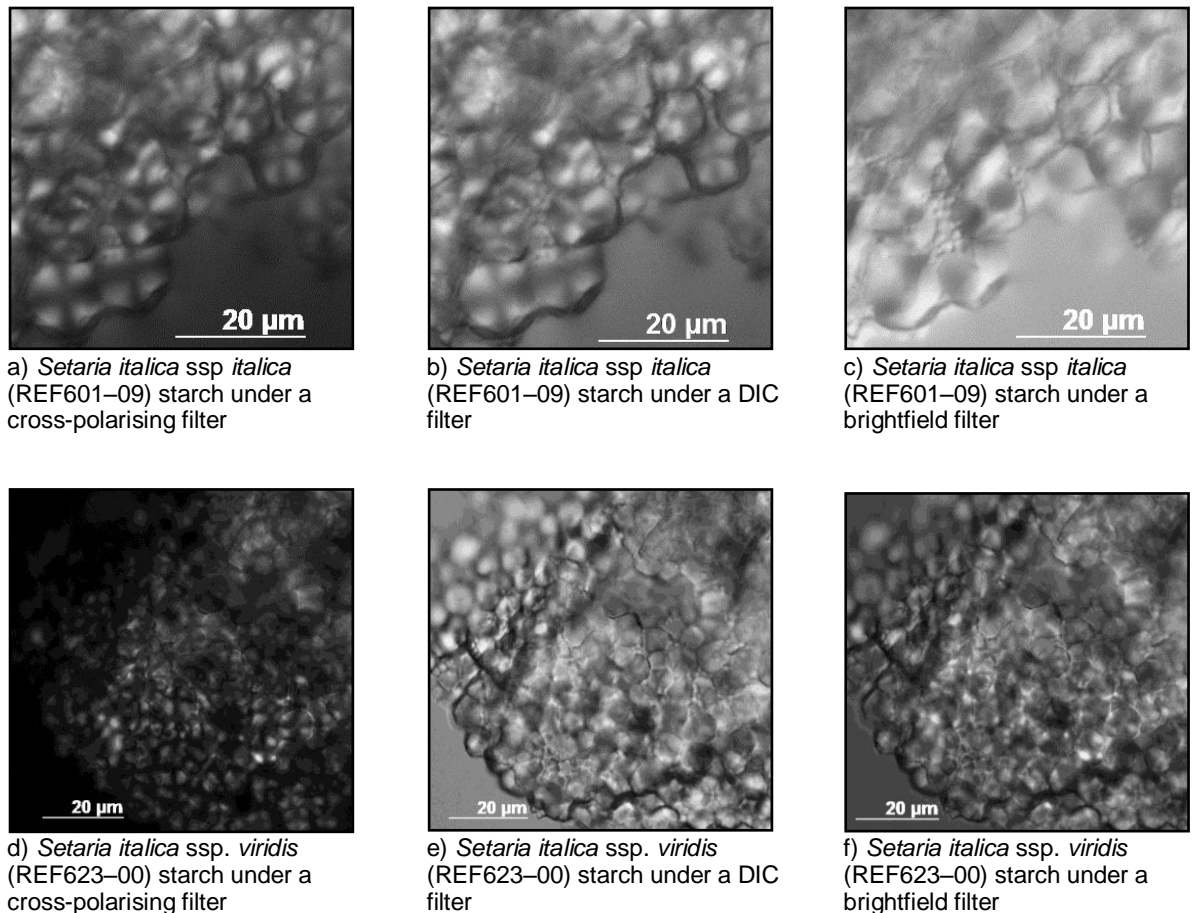


Figure 7-36 Domesticated foxtail millet (*Setaria italica* ssp. *italica*) and wild green foxtail grass (*Setaria italica* ssp. *viridis*) showing larger sized grains of domesticated foxtail millet.

However, given that ancient starch granules typically present as individual grains or sometimes as limited number clusters of less than 5 grains, it is not clear whether population based starch research could separate out ancient *Setaria* sp. taxa if they were recovered from archaeological sites.

In their description of broomcorn millet starch Henry and colleagues (2009: 917) suggest that *Panicum miliaceum* grains are compound starch granules. However, in reference samples it is common for grains to separate from the cluster and become single meaning this characteristic is unlikely to be archaeologically useful. Henry and colleagues (2009: 917) also suggest that grains are ‘subrounded and faceted’ with a centric hilum. My research concurs with this (Figure 7-38). The size range they give is between 3–10 µm

(Henry, et al., 2009: 917) although from my research it appears that some granules may be slightly larger with a maximum of 12.48 μm (Table 7-25).

The taxa of *Panicum* sp. examined also appear to show a larger size of domesticated than wild starch grains (Table 7-26), although *Panicum miliaceum* starch was only slightly larger than *Panicum virgatum* starch with a t-test significance value of 0.4, $df=1$, $p<0.05$. In fact, all the *Panicum* sp. taxa tested were significantly different from each other, based on student's t-test results (Figure 7-39; Table 7-25; Table 7-26).

Broomcorn millet starch was larger than *Panicum bisulcatum* starch with a t-test significance value of 2.6, $df=1$, $p<0.05$. Broomcorn millet starch was substantially larger than *Panicum maximum* starch with a positive t-test significance value of 5.4, $df=1$, $p<0.05$.

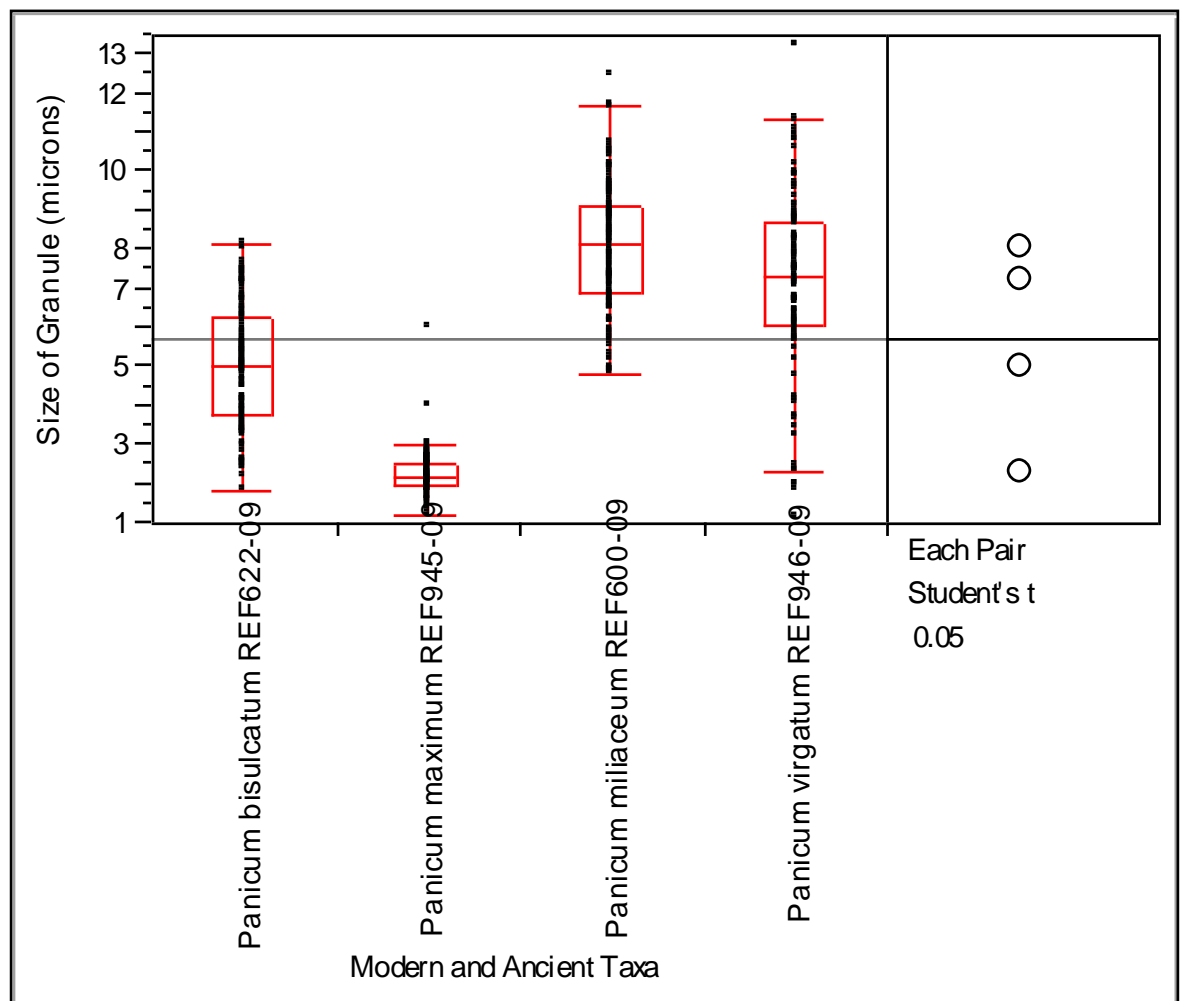


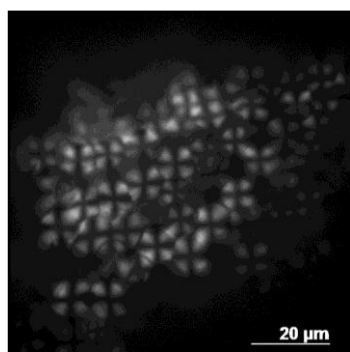
Figure 7-37 Size of *Panicum* sp. starch taxa

Table 7-25 Comparison of Sizes of *Panicum* sp. Starch Taxa

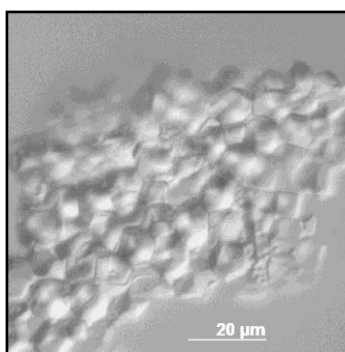
Level	No. Grains	Minimum	Median	Maximum
<i>Panicum bisulcatum</i> REF622–09	107	1.89	5.07	8.19
<i>Panicum maxima</i> REF945–09	102	1.27	2.23	6.06
<i>Panicum miliaceum</i> REF600–09	100	4.86	8.17	12.48
<i>Panicum virgatum</i> REF946–09	111	1.2	7.37	13.26

Table 7-26 Student's t-test Values for Comparison of Sizes of *Panicum* sp. Starch Taxa

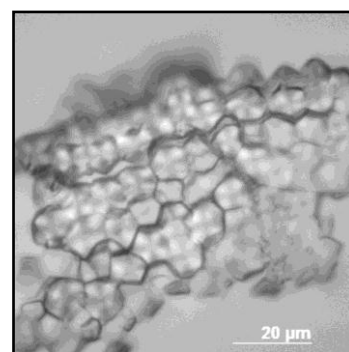
Abs(Dif)-LSD	<i>Panicum miliaceum</i> REF600–09	<i>Panicum virgatum</i> REF946–09	<i>Panicum bisulcatum</i> REF622–09	<i>Panicum maximum</i> REF945–09
<i>Panicum miliaceum</i> REF600–09	-0.42482	0.42211	2.61103	5.36016
<i>Panicum virgatum</i> REF946–09	0.42211	-0.43240	1.75656	4.50573
<i>Panicum bisulcatum</i> REF622–09	2.61103	1.75656	-0.44248	2.30673
<i>Panicum maximum</i> REF945–09	5.36016	4.50573	2.30673	-0.45108



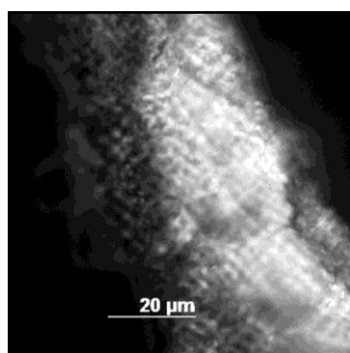
a) *Panicum miliaceum* (REF600–09) starch under a cross-polarizing filter



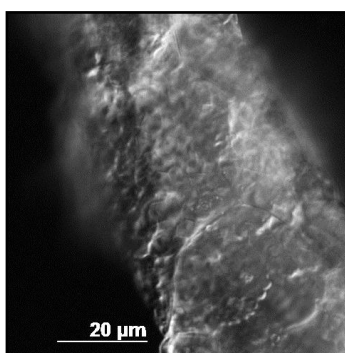
b) *Panicum miliaceum* (REF600–09) starch under a DIC filter



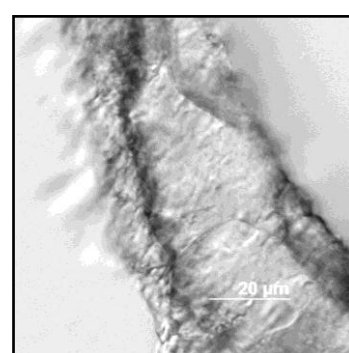
c) *Panicum miliaceum* (REF600–09) starch under a brightfield filter



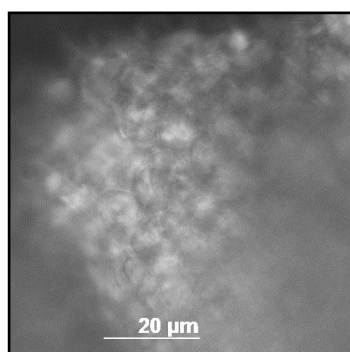
d) *Panicum bisulcatum* (REF619–09) starch under a cross-polarizing filter



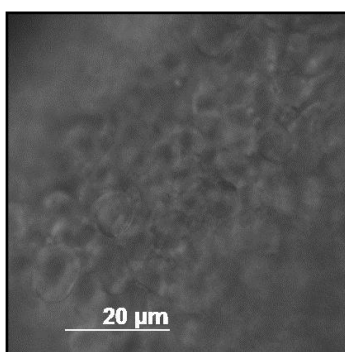
e) *Panicum bisulcatum* (REF619–09) starch under a DIC filter



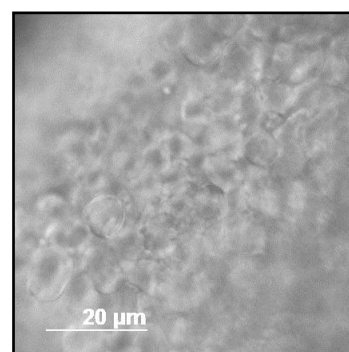
f) *Panicum bisulcatum* (REF619–09) starch under a brightfield filter



g) *Panicum virgatum* (REF946–09) starch under a cross-polarizing filter



h) *Panicum virgatum* (REF946–09) starch under a DIC filter



i) *Panicum virgatum* (REF946–09) starch under a brightfield filter

Figure 7-38 Wild and domesticated *Panicum* sp. starch grains showing large broomcorn millet grains when compared to some, but not all, wild *Panicum* sp. taxa

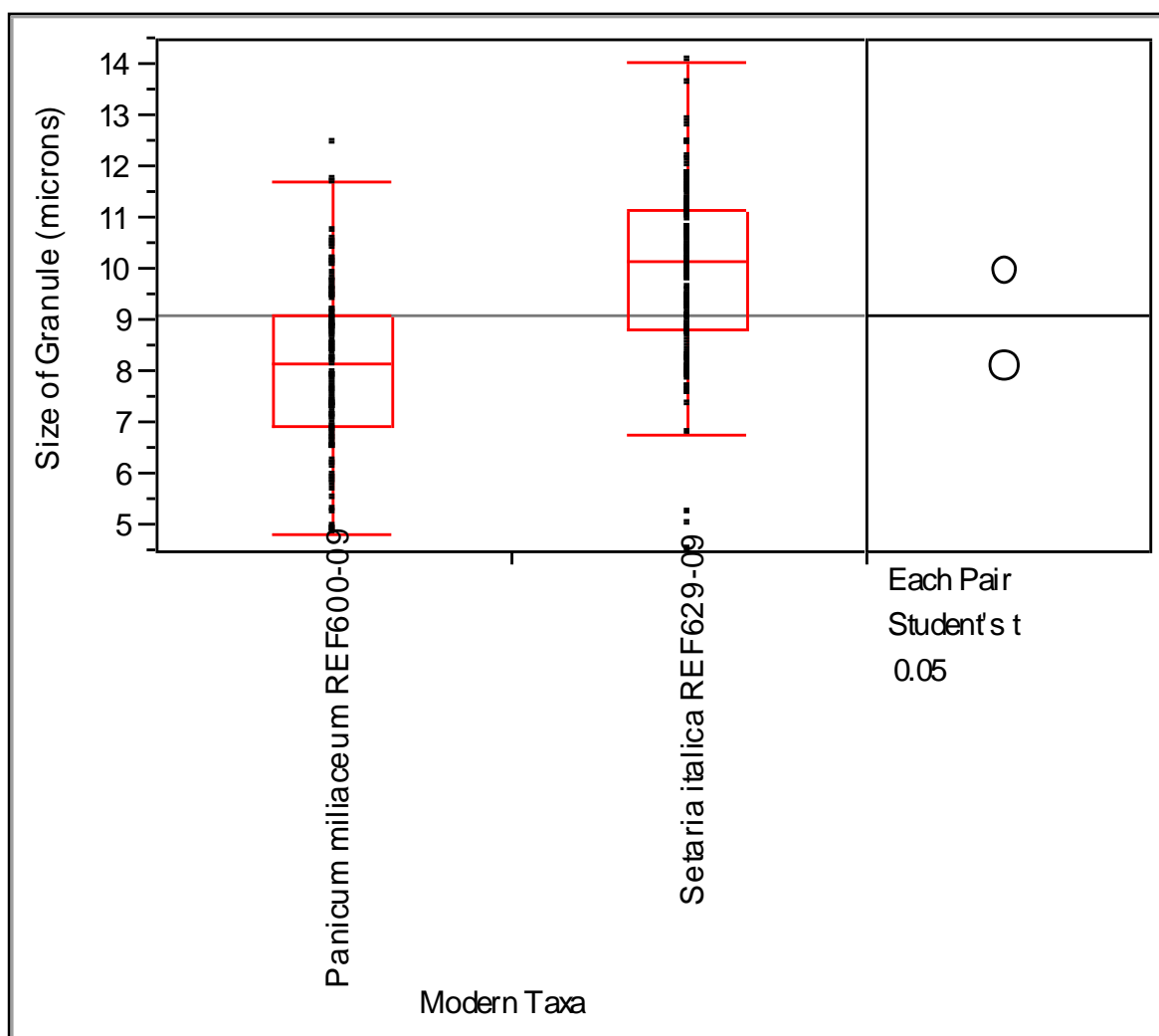


Figure 7-39 Difference in starch grain sizes between Foxtail and Broomcorn millet

Table 7-27 Comparison of Difference in Starch Sizes Between Foxtail and Broomcorn Millet

Level	No. Grains	Minimum	Median	Maximum
<i>Panicum miliaceum</i> REF600-09	100	4.86	8.17	12.48
<i>Setaria italica</i> ssp. <i>italica</i> REF629-09	101	4.52	10.18	14.1

Table 7-28 Student's t-test of Difference in Starch Sizes Between Foxtail and Broomcorn Millet

Abs(Dif)-LSD	<i>Setaria italica</i> ssp. <i>italica</i> REF629-09	<i>Panicum miliaceum</i> REF600-09
<i>Setaria italica</i> ssp. <i>italica</i> REF629-09	-0.38839	1.49211
<i>Panicum miliaceum</i> REF600-09	1.49211	-0.41925

Positive values show pairs of means that are significantly different.

7.3.4.6 POOIDEAE STARCH

A number of pooid grasses occur in China, including those from the Bromeae, Pooeae and Triticeae tribes (Table 7-29). Starches in the pooid grass sub-family are thought to have unusual starch grains which may be round and large, unlike other grass starches (Renvoize and Clayton 1986: 144). Starch from the Triticeae tribe in particular may exhibit distinct populations of alpha and beta granules (Lindeboom, et al., 2004). Lindeboom and colleagues (2004) have characterized this bimodal size distribution in wheat as 70 percent of granules by weight having a diameter between 10–35 μm and the remaining 30 percent of starch granules by weight having a diameter less than 10 μm .

Table 7-29 Pooideae Subfamily Taxa Tested for Starch

Tribe	Taxon	No. Specimens	Common Name
Aveneae	<i>Avena</i> sp.	3	Wild oats
Aveneae	<i>Avena sativa</i>	2	Sterile oat
Bromeae	<i>Bromus</i> cf. <i>japonicus</i>	1	Japanese brome grass
Bromeae	<i>Bromus</i> sp.	2	Brome grass
Pooeae	<i>Poa annua</i>	2	Wintersweet
Pooeae	<i>Poa</i> sp.	1	Poas
Triticeae	<i>Aegilops</i> sp.	1	Goatgrass
Triticeae	<i>Aegilops squarrosa</i>	1	Tausch's goat grass
Triticeae	<i>Agropyron cristatum</i>	1	Crested wheatgrass
Triticeae	<i>Agropyron desertorum</i>	1	Desert goatgrass
Triticeae	<i>Agropyron mongolicum</i>	1	Mongolian goatgrass
Triticeae	<i>Agropyron</i> sp.	6	Wheat grass
Triticeae	<i>Elymus ciliaris</i>	1	Wildrye
Triticeae	<i>Elymus</i> cf. <i>myebraana</i>	1	(unknown)
Triticeae	<i>Hordeum bulbosum</i>	1	Bulbous barley
Triticeae	<i>Hordeum vulgare</i>	1	Common barley
Triticeae	<i>Triticum aestivum</i>	2	Bread wheat
Triticeae	<i>Triticum aestivum</i> ssp. <i>sphaerococcoides</i>	1	Bread wheat subspecies
Triticeae	<i>Triticum dicocoides</i>	1	Wild emmer wheat
Triticeae	<i>Triticum monococcum</i>	1	Einkorn wheat
Triticeae	<i>Triticum turgidum</i>	2	Durum wheat

There are statistically significant differences between Bromeae and Triticeae tribe starch taxa (Table 7-29; Table 7-30; Table 7-31; Table 7-32). Some small *Bromus* sp. grains did exhibit rounded starch but it was substantially smaller than that recovered from larger seeded Triticeae taxa (Figure 7-40; Figure 7-41). *Bromus japonicus* starch grains examined tended to be rounded but elongate in shape, meaning that the taxa so far examined can be distinguished from Triticeae tribe taxa based on shape as well as size categories (Figure 7-42; Figure 7-43; Figure 7-44).

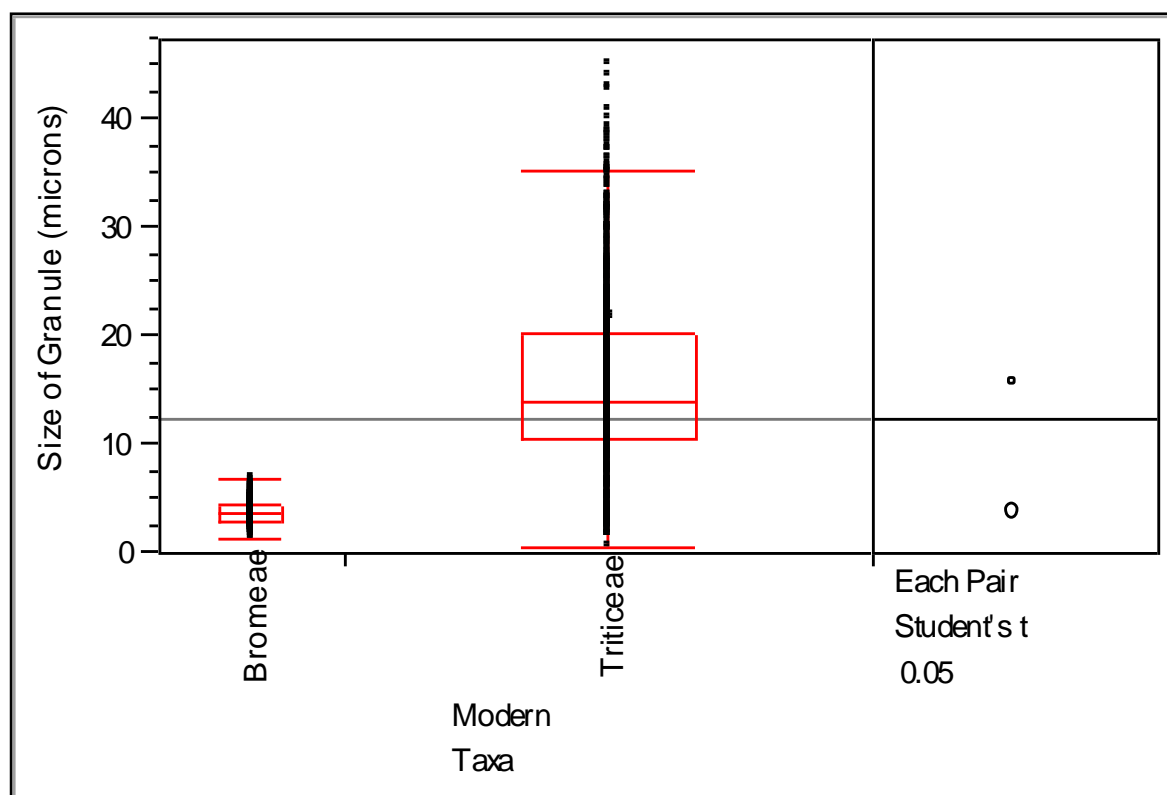


Figure 7-40 Comparison of Pooid subfamily grass tribes: Bromeae and Triticeae

Table 7-30 Pooid subfamily grass tribes: Bromeae and Triticeae

Level	No. Granules	Minimum	Median	Maximum
Bromeae	318	1.46	3.73	6.87
Triticeae	894	0.79	14.17	45.19

Table 7-31 Student's t-test of Pooid subfamily grass tribes: Bromeae and Triticeae

Abs(Dif)-LSD	Triticeae	Bromeae
Triticeae	-0.6594	11.0544
Bromeae	11.0544	-1.1056

Positive values show pairs of means that are significantly different

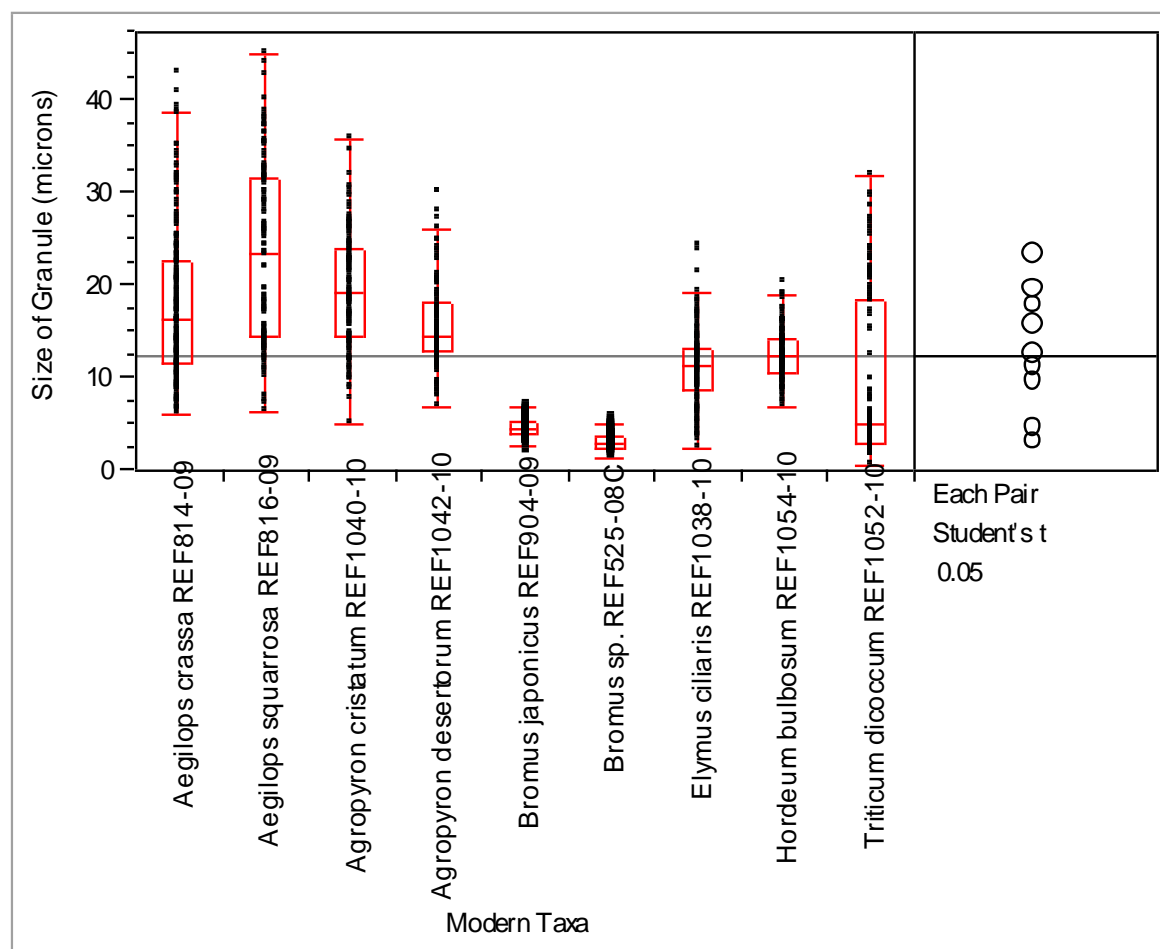


Figure 7-41 Pooid grasses in tribes Bromeae and Triticeae compared

Table 7-32 Comparison of Pooid Grasses in Tribes Bromeae and Triticeae

Level	No. Grains	Minimum	Median	Maximum
<i>Aegilops crassa</i> REF814-09	196	6.18	16.37	43.16
<i>Aegilops squarrosa</i> REF816-09	112	6.34	23.51	45.19
<i>Agropyron cristatum</i> REF1040-10	113	5.02	19.47	35.96
<i>Agropyron desertorum</i> REF1042-10	104	7.01	14.77	30.31
<i>Bromus japonicus</i> REF904-09	132	2.11	4.66	6.87
<i>Bromus</i> sp. REF525-08C	186	1.46	3.06	5.66
<i>Elymus ciliaris</i> REF1038-10	124	2.53	11.54	24.32
<i>Hordeum bulbosum</i> REF1054-10	112	6.92	12.64	20.47
<i>Triticum dicoccum</i> REF1052-10	113	0.79	5.17	31.94

Table 7-33 Student's t-test of Pooid Grasses in Tribes Bromeae and Triticeae

Abs(Dif)-LSD	<i>Aegilops squarrosa</i> REF816-09	<i>Agropyron cristatum</i> REF1040-10	<i>Aegilops crassa</i> REF814-09	<i>Agropyron desertorum</i> REF1042-10	<i>Hordeum bulbosum</i> REF1054-10	<i>Elymus ciliaris</i> REF1038-10	<i>Triticum dicoccum</i> REF1052-10	<i>Bromus japonicus</i> REF904-09	<i>Bromus sp.</i> REF525-08C
<i>Aegilops squarrosa</i> REF816-09	-1.5645	2.3597	4.1907	6.0317	9.2658	10.7539	12.4804	17.3296	18.9322
<i>Agropyron cristatum</i> REF1040-10	2.3597	-1.5576	0.2739	2.1143	5.3485	6.8368	8.5633	13.4125	15.0154
<i>Aegilops crassa</i> REF814-09	4.1907	0.2739	-1.1827	0.6282	3.8660	5.3592	7.0892	11.9379	13.5566
<i>Agropyron desertorum</i> REF1042-10	6.0317	2.1143	0.6282	-1.6236	1.6100	3.0974	4.8234	9.6726	11.2730
<i>Hordeum bulbosum</i> REF1054-10	9.2658	5.3485	3.8660	1.6100	-1.5645	-0.0763	1.6502	6.4993	8.1020
<i>Elymus ciliaris</i> REF1038-10	10.7539	6.8368	5.3592	3.0974	-0.0763	-1.4869	0.2403	5.0894	6.6951
<i>Triticum dicoccum</i> REF1052-10	12.4804	8.5633	7.0892	4.8234	1.6502	0.2403	-1.4357	3.4133	5.0211
<i>Bromus japonicus</i> REF904-09	17.3296	13.4125	11.9379	9.6726	6.4993	5.0894	3.4133	-1.4411	0.1664
<i>Bromus sp.</i> REF525-08C	18.9322	15.0154	13.5566	11.2730	8.1020	6.6951	5.0211	0.1664	-1.2140

Positive values show pairs of means that are significantly different.

The Bromeae tribe starch taxa tested did exhibit rounded granules (Figure 7-42) as predicted in *Genera Graminum* (Clayton & Renvoize, 1986: 144). Alpha and beta populations of granules were not detected in the reference samples examined. However, future research is required to completely rule this out. T-tests of significance between the Bromeae (n=318) and Triticeae (n=894) tribes suggested that there are significant size differences with a positive t-test value of 11.964, df=1, $p < 0.05$ (Table 7-32; Table 7-33; Figure 7-40).

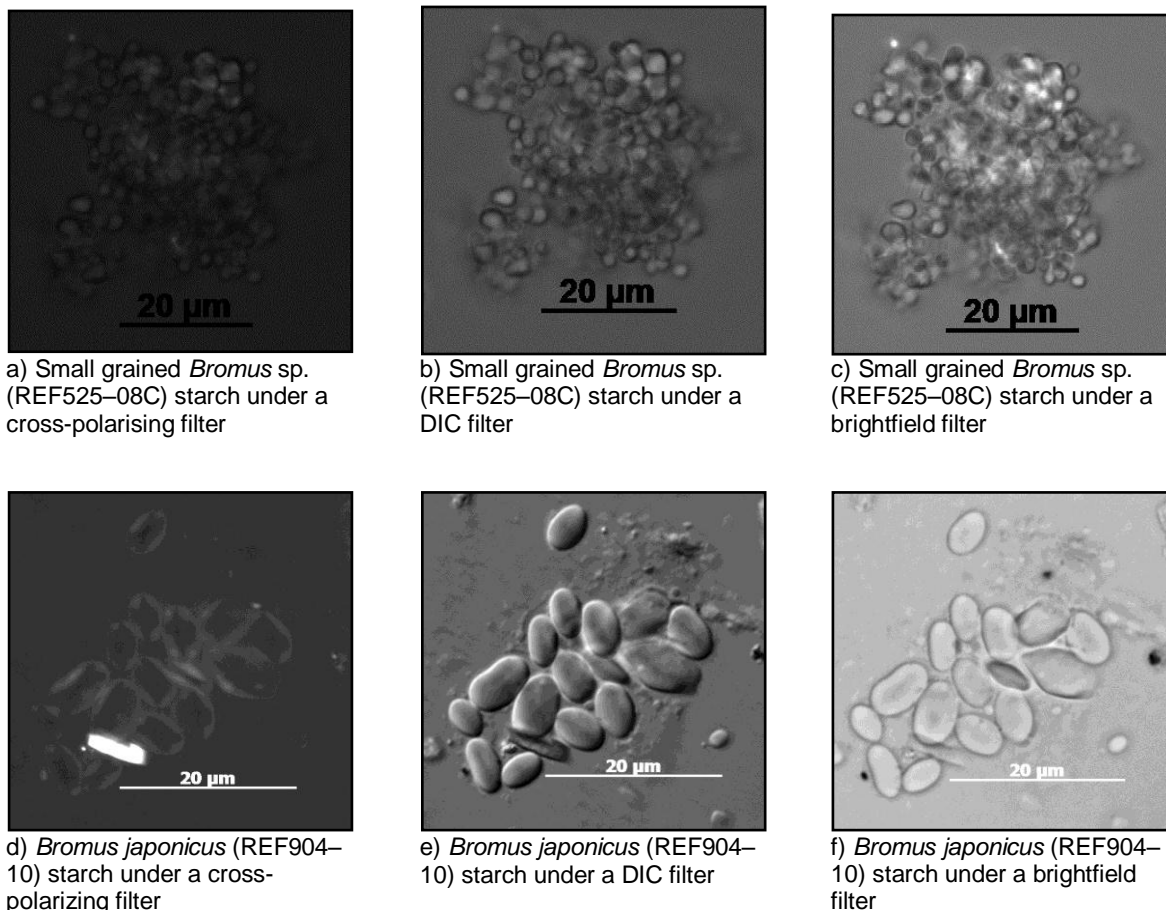


Figure 7-42 Bromeae tribe starch grains from Asia, including (a-c) small grained *Bromus* sp. and (d-f) *Bromus japonicus* starch grains. The Bromeae tribe taxa tested exhibited smaller starch grains than did Triticeae tribe taxa. Pictures and slide of *Bromus japonicus* by Professor Liu.

Triticeae tribe grass starch may be categorized as having rounded or oval shaped granules that may appear lenticular in cross section (Figure 7-43; Figure 7-44; Figure 7-45).

Lamellae may be present or absent. The hilum is typically centric and the arms of the extinction cross are usually straight but may be curved. Damage or heating appears to alter the arms of the cross so that a large dark blur is the main evidence for the damaged granule's extinction cross (Figure 7-45). Some granules may appear to be contained within a rounded, membrane-like structure, with large alpha and beta granules contained within (Figure 7-43).

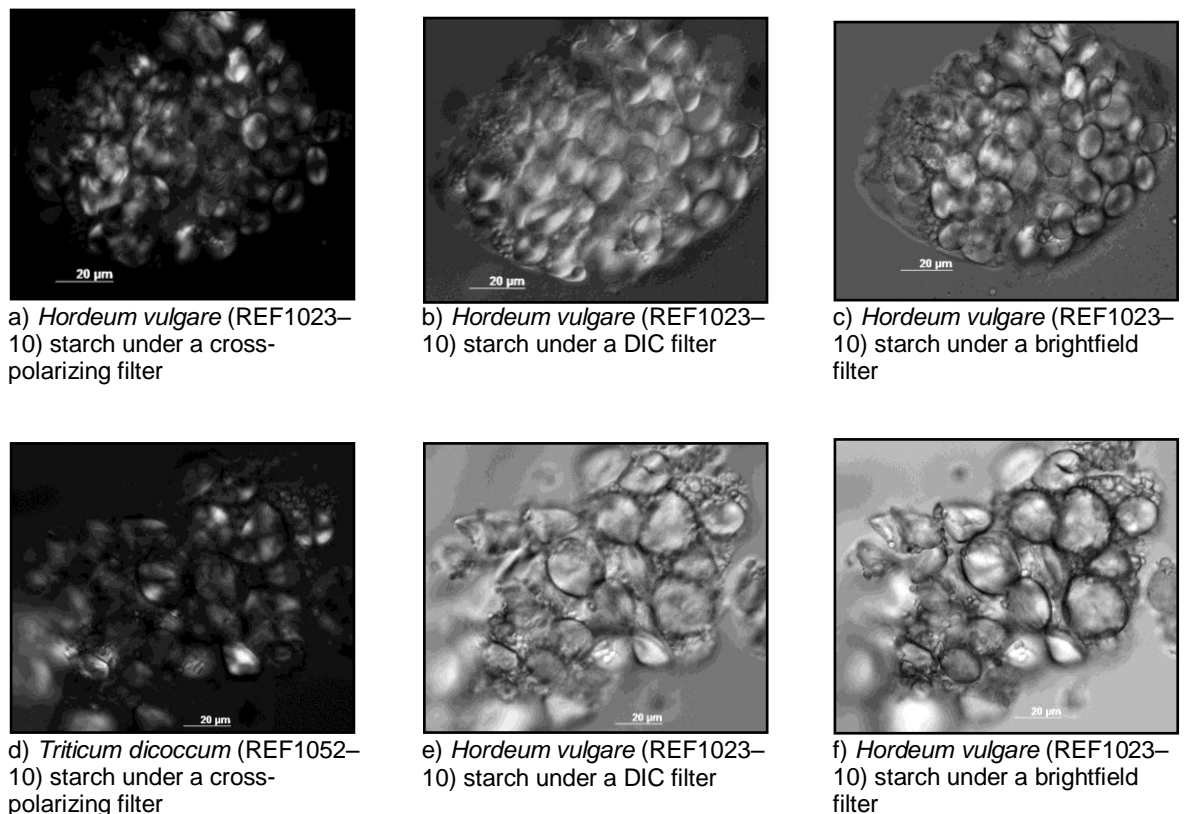
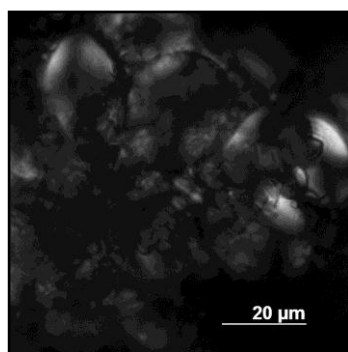


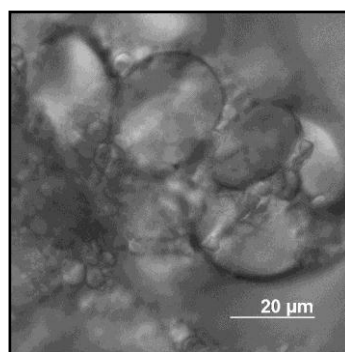
Figure 7-43 Near Eastern Triticeae tribe starch grains

Given the absence of wheat and barley in ancient China (discussed previously in section 7.2), Triticeae taxa from the Near East such as *Triticum* sp. and *Hordeum vulgare* (Figure 7-43) may be eliminated from Peiligang and Late Palaeolithic starch samples. However, the wild and non-wheat taxa occurring in ancient China should not be ruled out. Wild pooid grass taxa occurred in the Peiligang period at sites such as Jiahu (Zhao, Z. & J. Zhang, 2009). During the Longshan period in the later Neolithic, wild *Hordeae* (barley) seed taxa were recorded at the Liangchengzhen site (Crawford, et al., 2005: Table 2). Triticeae tribe taxa similar to *Agropyron* sp. and *Elymus* sp. were present at the Jomon Yagi site on the Kameda Peninsula, Japan (Crawford, 1983: 35).

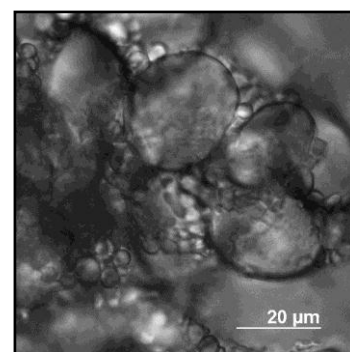
Ancient starch grains from the genera *Agropyron* sp. and *Elymus* sp. (Figure 7-44) exhibited similar starch grains to those present in ancient taxa. The pooid grass known in China as *Roegneria* (Liu, Li, et al., 2011: 3530) is assigned in FOC to the genus *Elymus*. More research is needed to accurately identify these ancient starch grains.



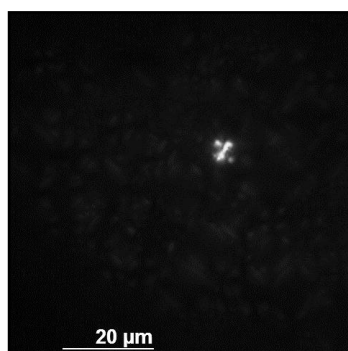
a) *Triticum aestivum* (REF2079–12) starch under a cross-polarizing filter



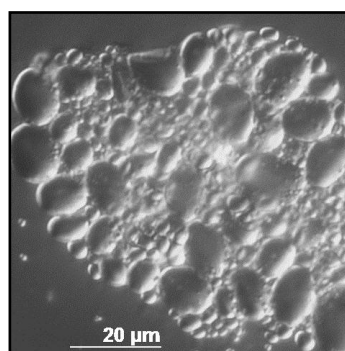
b) *Triticum aestivum* (REF2079–12) starch under a DIC filter



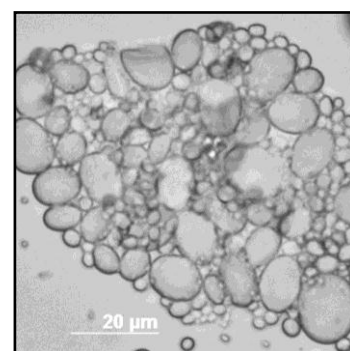
c) *Triticum aestivum* (REF2079–12) starch under a brightfield filter



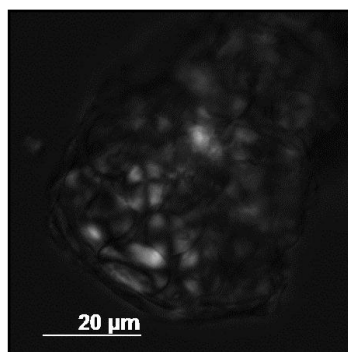
d) *Elymus* cf. *myebraana* (REF903–09) starch under a cross-polarizing filter



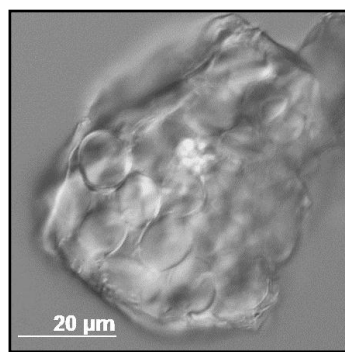
e) *Elymus* cf. *myebraana* (REF903–09) starch under a DIC filter



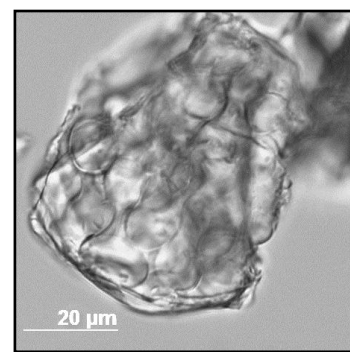
f) *Elymus* cf. *myebraana* (REF903–09) starch under a brightfield filter



g) *Agropyron desertorum* (REF1042–10) starch under a cross-polarizing filter



h) *Agropyron desertorum* (REF1042–10) starch under a DIC filter



i) *Agropyron desertorum* (REF1042–10) starch under a brightfield filter

Figure 7-44 Triticeae tribe starch grains from Chinese modern reference samples. (a-c) Breadwheat (*Triticum aestivum*) is thought to have been introduced to China in approximately 4,500 BP. (d-f) *Elymus* sp. taxa and (g-i) *Agropyron* sp. taxa are indigenous to North China. Their starch grains have similarities to ancient Triticeae tribe starch grains from Tieshenggou and other Neolithic sites.

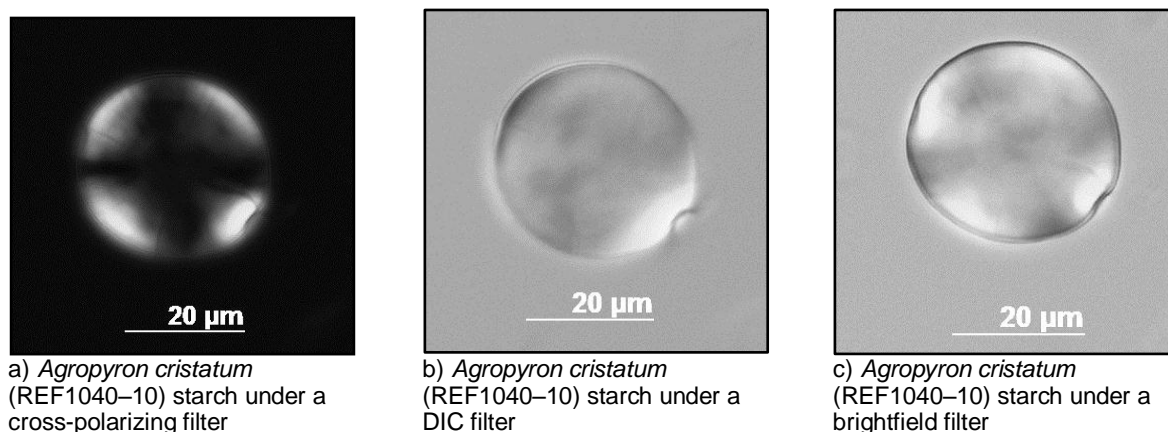


Figure 7-45 Example of Triticeae tribe starch grain with large, rounded morphology, slightly damaged cross, centric hilum and very faint lamellae

7.4 Conclusion

Macrobotanical plant remains tend to be relatively reliable diagnostic indicators of ancient plant taxa. These were identified with the use of published manuals as well as a reference collection of over 150 seed taxa including over twenty genera and fifty species of grass seeds. Plant remains including tuberous parenchyma were also included in the collection as were wood charcoal, nutshell and other vegetative plant remains. While many seeds may be diagnostic to species or even subspecies level not all seeds recovered from ancient flotation samples are able to be identified in detail based on seed morphology alone. Many of the seed remains recovered in the flotation samples examined for this thesis were grasses in the Paniceae or millet tribe (see Chapter 8).

Microfossil plant remains include both phytoliths and starch. Many of the plant specimens used for macrobotanical references were also able to be used for microfossil identification and research as well. Plants used in the reference collection for phytoliths included mainly grasses and other monocots such as sedges but also eudicots including daisies and cucurbits. Over 150 specimens were used for phytoliths or cellular references, including over fifty genera in over twenty families. This included grass subfamilies. Seven out of the twelve grass subfamilies are represented in the reference collection. These subfamilies covered all five of the largest grass subfamilies including Bambusoideae, Chloridoideae, Ehrhartoideae, Panicoideae and Pooideae. Fourteen of the twenty-eight grass tribes that occur in China are also represented in the reference collection. Taxa included in the grass reference collection may be used for comparative purposes in both macrobotanical and microfossil research. After extensive research on grinding implement and sickle residues

only broad taxonomic groups of plants were identified using phytoliths, including monocots (see Chapter 9) and eudicots and grasses (see Chapter 10).

The relatively recent study of archaeological starch has added to the information we have regarding Palaeolithic and Peiligang plant food dietary intake. Several starchy plants are thought to have been used in North China by ancient people during the time covered by this thesis, including yams (cf. Dioscoreaceae), beans (cf. Phaseoleae tribe) and nuts including *Quercus* type acorns (Liu, Li, et al., 2010c; 2011). Several tribes or types of grasses may also be represented in residues including Andropogoneae or Paniceae tribe panicoid grasses and Triticeae tribe pooid grasses (Liu, Li, et al., 2010c; 2011). Research elsewhere in the world bears this out. For instance Piperno and other colleagues (Dickau, et al., 2007; Piperno, 1984; Piperno, et al., 2009; Piperno & Dillehay, 2008) frequently distinguish maize from other grass taxa including related wild taxa. Piperno and colleagues have also identified Triticeae tribe starch at the Ohalo II site in Israel (2004) although the identification of the *Aegilops/Hordeum/Triticum* (AHT) taxa that is recognized is not relevant to China prior to the introduction of many of the species from this group sometime after c. 4,500 cal BP.

Much of the research pertaining to the identification of ancient Chinese starches relates to data collected during the course of this thesis and with colleagues (Professor Li Liu) however it is presented here in detail for the first time. This is the reason for such a detailed presentation of information regarding ancient starch in contrast to the information presented for macrobotanical and phytoliths remains. However, all slides, starch counts, photographs and details of research presented in this chapter are my own work unless stated otherwise.

To date plant references from the collection have been used in several microfossil related publications (Bestel, et al., 2011; Bestel & Liu, 2008; Liu, Li., et al., 2010a; 2010b; 2010c; 2011). Yams, beans, acorns and grasses appear to be the main diagnostic types of starch to occur as residues in Peiligang and other North Chinese sites (Liu, Li, et al., 2010b; 2010c; Tao, et al., 2011; Yang, X. Y., et al., 2009a). However, many other taxa not discussed here were examined for starch grains and ruled out or excluded on the basis of starch presence or absence, starch granule size and starch morphology. Research on further refining the identity of ancient starch taxa is ongoing.

Chapter 8: Macrobotanical Remains From Flotation Samples

Prior to the 1960s archaeologists typically collected macrobotanical seeds and other plant remains by hand or based on naked eye visibility. Both Struever and colleagues (1968) and Jarman and Legge (1972) pioneered the use of bulk sediment flotation to systematically recover both macroscopically and microscopically visible charred plant remains. This allowed structured sampling and collection of both small and large seeds and other charred plant remains. Flotation did not become routine in China until the 1990s and the first manual describing how to carry out flotation was not published in China until 2001 (Zhao, Z., 2001).

The identification of macrobotanical seed and plant remains pre-dates flotation especially at sites such as waterlogged lake dwellings where macrobotanical identification of plant remains has occurred for well over 100 years (Heer, 1886). It is considered a reliable technique (Pearsall, 2000: 4-5) especially when compared with newer archaeobotanical identification techniques such as phytolith and starch research. The plant remains recovered from flotation samples taken from Late Palaeolithic, Peiligang and Yangshao period sites in North China were sorted by myself. I am extremely grateful for the assistance of Professor Gary Crawford and Dr. Gyoung-Ah Lee in identifying ancient charred seed and other macrobotanical remains. The results of the sorting and identification of taxa recovered from these samples are discussed throughout this chapter.

8.1 Seeds Present in Flotation Samples

An extensive macrobotanical reference collection was used to identify the seeds recovered (see chapter 7 section 7.1). The main diagnostic features of seeds in the assemblage included seed shape, size, embryo scar shape and position and seed coat surface texture (Pearsall, 2000: 133). A minimum of seventeen different identifiable seed taxa were present in the samples analysed (Table 8-1). These included *Amaranthaceae*/*Chenopodiaceae*, a minimum of two types of *Fabaceae*, *Lamiaceae* cf. *Perilla* sp., *Solanaceae* and *Rosaceae* taxa. A range of different *Poaceae* taxa were recovered from the *Paniceae* tribe including *Digitaria* sp. (crabgrass), *Echinochloa* sp. (barnyard grass), cf. *Setaria* sp., *Setaria* sp. type, *Setaria* sp. (seeds identified as possible foxtail grass although there is some degree of uncertainty), *Setaria italica* ssp. *italica* (foxtail millet), *Setaria italica* ssp. *viridis* (green foxtail grass), *Panicum* sp. (panic grass), *Panicum miliaceum*

(broomcorn millet), and other Paniceae tribe taxa. Other grass taxa were also present as well as a range of unidentified seeds.

Table 8-1 Identifiable Seeds in Flotation Samples

	Shizitan S14	Shizitan S9	Fudian Dong	Liujianhe Shuiku	Bucun	Didong	Tianpocun	Yulinzhuang
Amaranthaceae / Chenopodiaceae	3	7		1	2	1		
Fabaceae					3			
Lamiaceae cf. <i>Perilla</i> sp.					1			
Poaceae – <i>Digitaria</i> sp.					101			
Poaceae – <i>Echinochloa</i> sp.		1						
Poaceae –cf. <i>Setaria</i> sp.		2	2					
Poaceae – <i>Setaria</i> sp. type		2						
Poaceae – <i>Setaria</i> sp.					4	1		
Poaceae – <i>Setaria</i> <i>italica</i> ssp. <i>italica</i>			2		66	1		23
Poaceae – <i>Setaria</i> <i>italica</i> ssp. <i>viridis</i>					10	68		11
Poaceae – <i>Panicum</i> sp.					4	1		
Poaceae – <i>Panicum</i> <i>miliaceum</i>			3		4			
Poaceae – Other Paniceae		3	1		176	47		29
Other Poaceae		2		3	102	93	2	
<i>Portulaca</i> sp.				1				
Rosaceae						1		1
Solanaceae					1			
Unidentified taxa	2	16	3	2	16	2		8
Total	5	28	11	7	490	215	2	75

As described in Chapter 5, seeds and macroremains were examined under low power using a Nikon DS-5 microscope with attached Nikon DS-5 camera or a Zeiss AxioScop A1 microscope with attached Zeiss AxioCam HRc digital camera. Zeiss AxioVision version 4.8 software was used to photograph and measure seeds presented in this thesis. In addition, the use of a Neoscope JCM 5000 SEM at the University of Toronto was kindly facilitated by Professor Gary Crawford.

A background to the known or postulated uses of the seeds recovered will be presented here along with a discussion of the reasons for the occurrence of these taxa in the samples analysed. This is presented here rather than elsewhere in the thesis for ease of reference when the flotation recovery results are presented.

8.1.1 Amaranthaceae / Chenopodiaceae

Chenopodiaceae seeds may be difficult to distinguish from seeds in the Amaranthaceae family and are classified here together. Modern seeds which occasionally fall into flots are easily distinguished by the uncharred endosperm inside the seed testa. Amaranthaceae/Chenopodiaceae seeds (hereafter amaranth/chenopod) occur at the oldest *c.* 20,000 cal BP Shizitan S14 site (this thesis). They were recovered from the ZL05 site in the Hulu River Region of northwestern China in a pre-Dadiwan context (the Dadiwan period lasted from *c.* 7,800–7,400 B.P.); more precise ‘pre-Dadiwan’ dates were not given in this report (Ji, 2009: 40-42)). They occur in South China at places like Bashidang in Hunan Province around 8,000 BP (Hunansheng, 2006: 518, 523). They have been found throughout the Neolithic in North China (Lee, G.-A., et al., 2007). They continued to occur in early state Erlitou period (Bestel, 2006; Lee, G.-A. & Bestel, 2007).

In the Americas, chenopods or quinoa were domesticated by 5,000 cal BP (Bruno, 2006: 43). Chenopods may have been cultivated for a long period in China (Lee, G.-A., et al., 2007: 1090) although evidence of the antiquity of this is unclear. Chenopod seeds may be eaten while the leaves may be used as a vegetable (Hunansheng, 2006: 523; Lee, G.-A., et al., 2007: 1090). In Taiwan, people apparently mixed chenopod plants in with the millet crop to create a range of starchy foods for consumption (Fogg, 1983) and chenopods are still cultivated in China today. Further research is required to fully understand the domestication of chenopods in China..

8.1.2 Fabaceae

At least two types of beans and legumes from the Fabaceae family were recovered from the Yangshao period flotation samples. These include possible wild soybeans (*Glycine* sp.) as well as another bean with smaller seeds that is yet to be identified. Soybeans were recovered from Jiahu in the Peiligang period (Zhao, Z. & J. Zhang, 2009: 86) however they are typically considered to be wild in the early Neolithic and appear to have been domesticated much later than millets (Lee, G.-A., et al., 2011).

8.1.3 Lamiaceae cf. *Perilla* sp.

Beefsteak plant (*Perilla* sp.) was recovered from the Yiluo region during the Yangshao period (Lee, G.-A., et al., 2007) and at Bashidang in South China sometime around c. 8,000 cal. BP (Hunansheng, 2006: 518, 527). It is used today as a seasoning or flavouring in Japanese food and the leaves may be eaten as a vegetable (Hunansheng, 2006: 527).

8.1.4 Poaceae Grasses

Several different types of grasses were present in the flotation samples analysed. Given that there are over 10,000 species of grasses in the world (Tudge, 2005: 148) it is sometimes difficult for researchers to identify each seed accurately to species although published references such as Nesbitt (2006) may be useful. Some of the domesticated taxa and wild taxa that could be identified, if only to a range of taxonomic levels, are discussed below.

8.1.4.1 POACEAE-PANICEAE - *DIGITARIA* SP.

There are 22 species of crabgrass (*Digitaria* sp.) that occur in China today (Chen, S. L., & Phillips, 2006c). *Digitaria* sp. contributed the largest number of seeds to the assemblage recovered from Jiahu site, with 1247 *Digitaria* sp. seeds recovered in the first phase (only 548 soybean seeds at this time and 324 rice grains). There were 958 *Digitaria* sp. seeds recovered from the second phase (compared with 32 soybeans and 78 rice grains) (Zhao, Z. & J. Zhang, 2009: 86). Crabgrass seeds were also present in large numbers at the Yangshao period Bucun site.

8.1.4.2 POACEAE-PANICEAE - *ECHINOCHLOA* SP.

Wild barnyard grass (*Echinochloa* sp.) was recovered from Jiahu in the Peiligang period (Zhao, Z., and J. Zhang, 2009). It was present in the Early Jomon period at the Nakano B locality at Hakodate Airport by c. 9,000 – 8,700 cal BP (Crawford, 1983: 31).

Domestication based partly on an increased seed size was noted by Crawford (1983: 31-34) in the Late Jomon period by c. 2,000-1,800 BC.

8.1.4.3 POACEAE-PANICEAE – CF. *SETARIA* SP., *SETARIA* SP. TYPE, *SETARIA* SP.

Some seeds cannot be identified with certainty when they are preserved as charred and burnt macroremains. Modern identification of grasses typically uses a range of plant characteristics to make an identification including diagnostic inflorescence details such as seed and bract position which typically do not preserve well as charred remains. For this reason several seed taxa were not able to be identified with certainty. The cf. *Setaria* sp. seeds recovered have a pointed top and high embryo scar. They are most likely wild *Setaria* sp. but because of the significance of their presence at the Late Palaeolithic Shizitan site and the difficulty of accurately identifying small Paniceae tribe grasses they were prefaced with a ‘cf.’ The *Setaria* sp. type seeds have a high embryo scar as do many members of the genus *Setaria* (Figure 7-1) but have rounded tops rather than a pointed top. This characteristic is evident in later Neolithic flotation samples where some wild *Setaria* type seeds exhibit a flattened dorsal and curved top. Seeds identified as *Setaria* sp. exhibit a combination of characteristics described above but always have a high embryo scar. They may be broken or partly damaged so it is not possible to ascribe them to either the foxtail millet or green foxtail grass taxon.

8.1.4.4 *SETARIA ITALICA* SSP. *ITALICA* AND *SETARIA ITALICA* SSP. *VIRIDIS*

Foxtail millet (*Setaria italica* ssp. *italica*) is the domesticated form of green foxtail grass (*Setaria italica* ssp. *viridis*) (Harlan and de Wet, 1971; Prasada Rao, et al., 1987). It was until recently considered the main crop during the Neolithic of North China (Ho, 1975, 1977; Zohary & Hopf, 2000: 86). It was also thought to have been the earliest domesticated millet in North China (Zohary & Hopf, 2000: 83). However, recent finds have suggested that broomcorn millet occurs earlier than foxtail millet at several sites including Dadiwan (Barton, L., et al., 2009), Yuezhuang (Crawford, et al., 2007) and Cishan (Lu, H., et al., 2009a).

The domesticated form of foxtail millet is larger and plumper than the wild green foxtail grass. This equates to greater thickness, height and width measurements. Domesticated foxtail millet typically exhibits a lateral groove and a rounded dorsal surface. Both these features are absent in wild foxtail grass. If fragments of the husk are attached to charred material it may be possible to identify the genus with greater certainty as a *Setaria* sp. husk

exhibits a diagnostic cellular pattern that distinguishes it from similar species such as *Panicum* sp. seeds.

8.1.4.5 POACEAE-PANICEAE - *PANICUM MILIACEUM*

As discussed in Chapter 3, the wild ancestor of broomcorn millet (*Panicum miliaceum*) is unknown although *Panicum bisulcatum* has been suggested as its wild ancestor (Yang, X. Y., et al., 2012: 252). However, *Panicum miliaceum* is a C4 plant (ref) and *Panicum bisulcatum* is a C3 plant, making it highly improbable that it is the ancestor of broomcorn millet. Broomcorn millet is thought to do well in dry conditions (Lu, H., et al., 2009a) and has recently been suggested as either being an earlier domesticate than foxtail millet or as appearing in greater numbers than foxtail millet, at several North Chinese sites, (Barton, L., et al., 2009; Crawford, et al., 2006; Lu, H., et al., 2009a; Zhao, Z., 2005a). At the Xinglonggou site over 1,500 broomcorn millet grains were recovered through flotation but only a few dozen foxtail millet seeds (Zhao, Z., 2005a).

Broomcorn millet grains are typically larger than foxtail millet and have a different shaped embryo scar (Figure 7-1). Broomcorn millet embryos are typically triangular shaped and both shorter and wider at the embryo base than foxtail millet or other *Setaria* sp. The cellular husk pattern is diagnostic, especially when viewed under an SEM.

8.1.4.6 POACEAE-OTHER PANICEAE TRIBE

A range of wild grass seeds are typically present in flotation samples from the Chinese Neolithic (Lee, G.-A., et al., 2007). At this stage it is not clear whether they represent a crop/ weed assemblage or whether they were culturally utilised. While some of these seeds are distinctive and occur in multiple samples, the similarities between millet tribe seeds make it difficult to identify or distinguish between genera and species (King, n.d.). Such taxa are frequently classed together as 'Paniceae' type wild grass seeds. They are often distinguished from other grass seeds by the size of the embryo and the rounded shape of the seed (Figure 7-1).

8.1.4.7 POACEAE - OTHER GRASS SEEDS

Several grass seeds that were not from the Panicoideae sub-family were recovered from the flots. These taxa require further research prior to identification.

8.1.5 Rosaceae

A single nut/pip or stone fruit present at the Yulinzhuang site was possibly from the Rosaceae family (Figure 8-4). A stone-fruit type nut was present at the Yangshao Didong site and was tentatively assigned to this family. The Rosaceae family includes up to 3,500 species in China (Gu, et al., 2003). Many of these are fruit trees including peaches, apricots, plums, apples, and pears (Woodland, 2009: 358). Various berries such as raspberries and blackberries are in this family and may be archaeologically visible.

8.1.6 Solanaceae

The Solanaceae family includes a range of culturally valuable plants such as tobacco and tomatoes. Solanaceae seeds are typically identified from the distinctive cellular patterning on the outside of the seed. A number of nightshade seeds (also in the Solanaceae family) were recovered by Lee and colleagues (2007: Table 1) in the Yangshao and Longshan periods from the Yiluo region. They were also present at Liangchengzhen during the Longshan period (Crawford, et al., 2005). Several small fragments of cf. Solanaceae were recovered from Yangshao period samples with a minimum of one individuals seed present.

8.1.7 Summary of Taxa Present

The small number of identified plant families present in this study is probably not a reflection of a limited diet in ancient times, but rather an artefact of preservation and plant identification. Unidentifiable seed fragments were present in samples from both the Late Palaeolithic and Peiligang periods. Samples from the Yangshao period presented numerous examples of unidentifiable seeds, seed fragments and unknown seeds. Unidentifiable seeds refer to those fragments that have lost their diagnostic or identifying characteristics.

Unknown seeds refer to seeds that may in future be identifiable, as they retain diagnostic features such as the embryo or testa. Large numbers of both are typical of Neolithic North Chinese samples (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007).

Many of the seeds recovered were from secondary or tertiary depositional contexts such as ash pits or cultural layers. They may represent many uses of plants including food, fodder, fuel or household and utensil items. They may not all represent food or subsistence items and some seeds may represent an anthropogenic palaeoenvironment.

8.2 Flotation Sample Results

Flotation samples from Late Palaeolithic, Peiligang and Yangshao contexts were examined. A total of thirty-two flotation samples from thirteen sites were examined for seeds and other identifiable plant remains. These will be examined and discussed below.

A total of 19 samples from the Late Palaeolithic site of Shizitan were examined with 38 seeds recovered (see Appendix 6). This site cluster dates between *c.* 20,700–20,000 cal BP (lab number BAO1158; see Appendix 4) to 8,470–8,210 cal BP (Shizitan kaogudui, 2010:16). Most seeds were recovered from the locality 9 site dating to between 13,800–8,500 cal BP (Xia, Z., et al., 2002).

Ten samples from seven Peiligang aged sites (*c.* 9,000–7,000 cal BP) in the Yiluo region were also examined (see Appendix 7 and Appendix 8) producing a total of eighteen seeds including five domesticated millet seeds. One of these sites, the Fudian Dong site, was Accelerated Mass Spectrometry (AMS) radiocarbon dated using charcoal obtained from an ash pit to between 7,504–7,412 cal BP (lab number NZA 33139; see Appendix 4). This places the sites in the Yiluo region in the late Peiligang period which is consistent with pottery typologies.

Four samples from four Yangshao aged sites (*c.* 7,000–5,000 cal BP) in the Yiluo region were examined and produced substantially higher numbers of identifiable seeds with a total of 882 charred specimens recovered (see Appendix 9). Greater numbers of mainly foxtail millet domesticates were recovered from Yangshao period sites. The minimal numbers of identifiable macroremains recovered means that the potential for microfossil research, including starch and phytolith residue studies, is high (see Chapters 9 and 10). The sites studied are outlined in greater detail in Chapter 4. The flotation remains are discussed below in chronological order.

8.2.1 Palaeolithic Flotation Samples

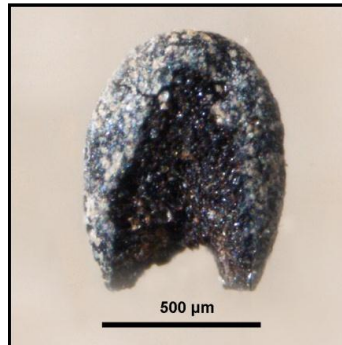
Few archaeobotanical studies have been carried out on Palaeolithic sites in China, and this bias tends to be worldwide. Exceptions are the flotation carried out at Zengpiyan (IACASS, et al., 2003: 286) where rice was expected but not found. Only tubers and charcoal were recovered from this site (IACASS 2003:286). At the site of Yuchanyan, also in South China, flotation was carried out to search for ancient rice remains although the rice recovered (Yuan, Jiarong, 2002: 160, figure 5) appears on the basis of its yellow colour to

be modern. Excavation at Dadiwan (Ji, 2009) included flotation of pre-Dadiwan layers where chenopods were recovered although the dates for these layers were not specified in the report.

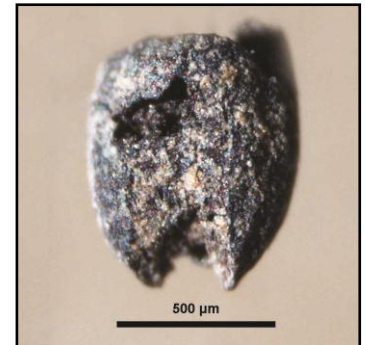
8.2.1.1 SHIZITAN FLOTATION RESULTS



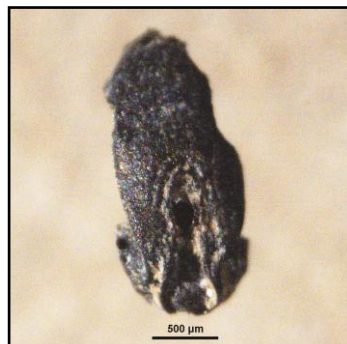
a) cf. *Setaria* seed from Shizitan



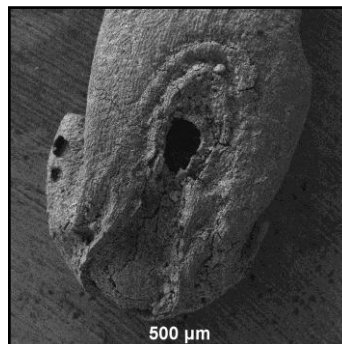
b) *Setaria* type seed with elongate embryo



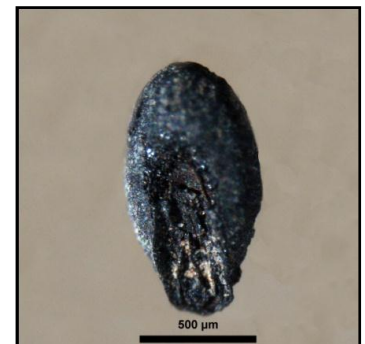
c) *Setaria* type seed with elongate embryo



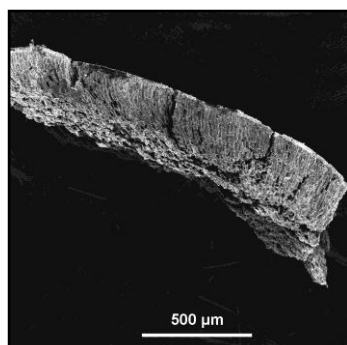
d) *Echinochloa* sp. seed with double-edged embryo from Shizitan



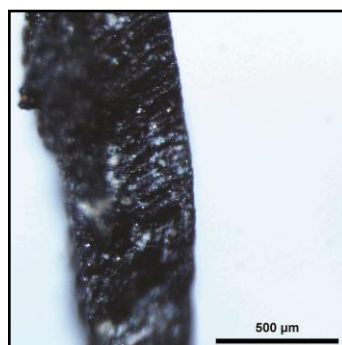
e) SEM image of Shizitan *Echinochloa* sp. keyhole shaped embryo



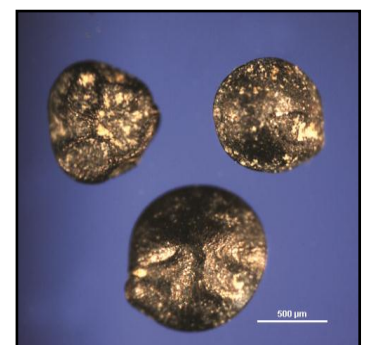
f) Wild grass seed from Shizitan



g) SEM image of rind type fragment from Shizitan



h) Rind type fragment from Shizitan



i) Seeds from Chenopodiaceae or Amaranthaceae family S14 locality

Figure 8-1 Shizitan locality S9 (a-h) and locality S14 (i) plant remains from flotation. a) cf. *Setaria* sp., b and c) *Setaria* type seed – ventral surface, d) *Echinochloa* sp., e) Embryo of (d), f) Other grass seed, g) 'rind' type plant remains, h) 'rind' type plant remains showing cellular structure, i) Chenopodiaceae seed. Scale 1 mm unless stated. Image (a) taken by Sheahan Bestel and Gyoung-Ah Lee. Image (b-i) taken by Sheahan Bestel and Gary Crawford.

This lack of palaeoethnobotany may be partly due to the fact that archaeobotany is a relatively recent field in China (Liu, C., et al., 2008; Zhao, Z., 2004) despite flotation in Heilongjiang province by Crawford in 1986 (Crawford, 2011, Pers. Comm). It may also be due in part to the smaller numbers of plant remains typically expected at older sites. Seeds from the Shizitan site thus represent some of the oldest systematically collected archaeobotanical remains in China. The Peiligang seed remains are among the oldest systematically recovered archaeobotanically identified Neolithic plant remains in North China.

Table 8-2 Plant Taxa Recovered from Shizitan Flots

Taxon/ Locality	Flot 1	Flot 2	Flot 3	Flot 8	Flot 9	Flot 12B	Flot 17	Flot 19	Total
Locality	S9	S9	S9	S9	S9	S14	S9	S9	
Plant remains— rind					pres				
Seeds									
Amaranthaceae /Chenopodiaceae				1		3		3	7
<i>Echinochloa</i> sp.			1						1
Paniceae tribe cf <i>Setaria</i> sp.								2	2
Paniceae tribe <i>Setaria</i> type	2								2
Other Paniceae tribe	1			2					3
Other Poaceae		1					1		2
Unknown	4	3	2			2	2	3	16
Total	7	4	3	3	0	5	3	8	33

Of the nineteen Shizitan flotation samples analysed, three came from the 20,700–20,000 cal BP layer. Of these, only one sample had charcoal or plant remains present, with only five seeds present, including three chenopods and two unidentified seeds (see Table 8-2; Figure 8-1). The other sixteen samples were taken from the Shizitan S9 locality, dated to c.13,800–8,500 cal. BP (Liu, Li, et al., 2011). At this locality, four separate cultural layers were evident and flotation samples included sediment taken from Layer 4, the oldest layer. The upper section of layer four was 234–354 cm below the surface, while the lower section of layer four was 354–450 cm below surface level (see Appendix 5).

Several grinding *mopan* or basal stones with starch residues of grasses, acorns, yams and beans were recovered in association with this layer (Liu, Li, et al., 2011). Similarities and differences between the starch and macrobotanical taxa site will be discussed in Chapter 11.

The 28 seeds from the S9 locality came from a total of 225 litres of sediment floated, although only six of the sixteen floated samples produced any seeds. Identified taxa included seeds from the Amaranthaceae/Chenopodiaceae (amaranth/goosefoot) and Poaceae (grass/ cereal) families (Figure 8-1; Table 8-2). Ten of these 28 seeds were grass seeds including two cf. *Setaria* sp., two *Setaria* sp. type, one *Echinochloa* sp., three cf. Paniceae and two other Poaceae grass seeds. Four chenopods were present in the samples. Other seeds were unidentified.

Of the ten grasses present in the S9 sample, eight were identified as being from the Paniceae grass tribe. Four of these were similar to *Setaria* sp. grasses with two being identified as cf. *Setaria* sp. seeds. Foxtail millet or *Setaria italica* ssp. *italica* was one of the first domesticates in North China (see discussion on broomcorn millet below). Millet in China presumably represents an indigenous domestication process (Chang, K. C., 1986; Ho, 1975; Smith, B. D., 1998) although macrobotanical evidence for the pre-domestication usage of wild millets has until now been absent in the North Chinese archaeological record. This is the earliest evidence for the presence of *Setaria* type seeds in any archaeological site in China so far.

Other Paniceae tribe grass seeds were also present in the S9 samples, including a wild barnyard grass specimen (*Echinochloa* sp.). Barnyard grass is the wild progenitor of *Echinochloa crus-galli* or *E. esculenta* (Japanese millet) (Crawford, 2008: 448) and was domesticated in Late Jomon Japan (Crawford, 1983: 31-34). The presence of these Paniceae tribe seeds at the site suggests that parts of the Neolithic subsistence spectrum were present by Late Palaeolithic times.

Other seeds at the S9 site included possible amaranth/chenopod seeds. It is common to find such seeds in archaeobotanical assemblages in the Neolithic and later periods (Bestel, 2006; Lee, G.-A., et al., 2007).

8.2.2 Peiligang Flotation Samples

Sediment from ash pits and sealed cultural occupation layers from seven Peiligang sites in the Yiluo basin were sampled (see Figure 4-1 and Table 8-3) and flotation was carried out to recover charred macrobotanical remains. The seven sites were all dated on pottery typologies to the Late Peiligang period (*c.* 7,500–7,000 cal BP in this area of China). In addition, the site of Fudian Dong was AMS radiocarbon dated between 7,504–7,412 cal BP, placing it within the late Peiligang. Due to the importance of the small numbers of seeds recovered from the Peiligang, domesticated seeds themselves were not directly dated.

8.2.2.1 RESULTS FROM PEILIGANG FLOTATION SAMPLES

Although sample sizes were small, 90.5 litres of sediment from seven sites (ten samples) were floated. However, only two of the seven sites analysed yielded any seeds (see Table 8-3). A total of 18 seeds were found making an average seed density of approximately one seed per five litres or two seeds per bucket of sediment floated.

Table 8-3 Plant Taxa Recovered from Peiligang Flots

	Beiyang	Fudian Dong	Liujianhe Shuiku	Tieshenggou	Wuluo Xipo	Xishiqiao	Zhuge Shuiku	Total
Nut (g)								
Plant remains					1x tuber/ root			
Seeds								
Amaranthaceae/ Chenopodiaceae			1					
<i>Panicum miliaceum</i>		3						
<i>Setaria italica</i> ssp. <i>italica</i>		2						
Paniceae cf <i>Setaria</i> sp.		2						
Paniceae tribe grasses		1						
Other grass			3					
<i>Portulaca</i> sp.			1					
Unknown Seeds		3	2					
Total Seeds	0	11	7	0	0	0	0	18

Seeds recovered from the Peiligang samples include chenopods (Amaranthaceae/Chenopodiaceae) and grass seeds including millet tribe seeds (Paniceae tribe of Poaceae grass family) (Figure 8-2).

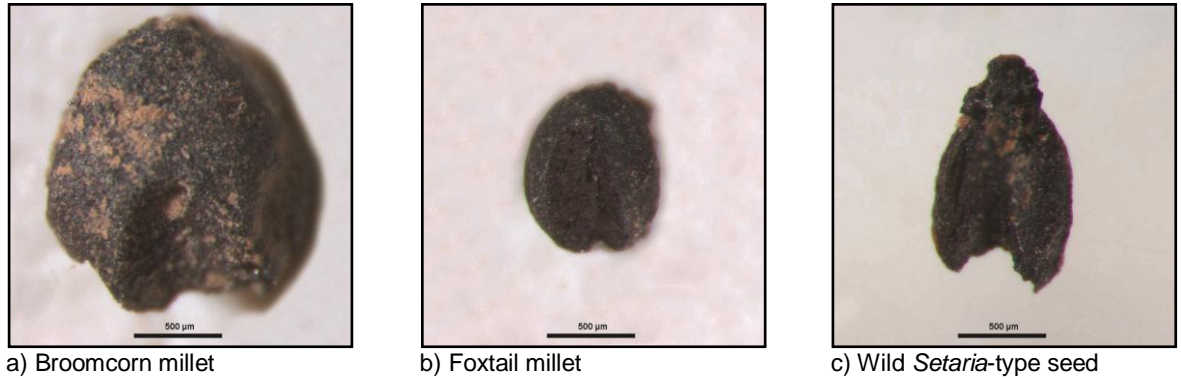


Figure 8-2 Peiligang seeds from the Yiluo region including (a) domesticated broomcorn millet and (b-c) domesticated and wild foxtail millet seeds respectively.

The site of Fudian Dong had both domesticated foxtail and broomcorn millet present (Figure 8-2). The wild form of foxtail millet, *Setaria italica* ssp. *viridis*, was also present at Fudian Dong (Figure 8-2). No other Peiligang site examined produced domesticated or wild Paniceae tribe grasses. Three non-Paniceae tribe grasses as well as a *Portulaca* sp. seed were present at the Liujianhe Shuiku site.

Foxtail millet first occurs as a domesticate during the Peiligang period (Chang, K. C., 1986: 91-92; Zhao, Z., 2005a). However, wild green foxtail grass occurs side by side with foxtail millet throughout much of the Neolithic in North China (Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007). This co-occurrence of wild (*Setaria italica* ssp. *viridis*) and domesticated (*Setaria italica* ssp. *italica*) forms of *S. italica* throughout much of the early Holocene is possibly due to green foxtail grass growing as a weed in crop fields with the cultivated, domestic variety. The modern distinction between millet ‘weed’ and ‘crop’ seeds may not have been recognised in ancient times (Hunt, et al., 2008: S14). However, it is also possible that the more numerous and larger *Setaria* sp. seeds were preferentially selected and this would eventually have led to the domestication of the plant or cultigen. Strong selection pressure, despite potential pollination from wild *Setaria* grasses, would allow for continued plant domestication. Further research is needed to determine why the wild and the domesticated subspecies of *Setaria italica* ssp. *italica* occur together and to examine the effect of this continued gene flow on domestic and wild populations.

Table 8-4 Plant Taxa Recovered from Yangshao Flots

	Bucun	Didong	Tianpocun	Yulinzhuang	Total
Nut				pres	
Plant remains	pres	pres		pres	
Spores		3		2	
Seeds					
Amaranthaceae/ Chenopodiaceae	2	1			3
Fabaceae cf. <i>Glycine</i>	2				2
cf Fabaceae	1				1
Lamiaceae cf. <i>Perilla</i>	1				1
Poaceae					
<i>Digitaria</i> sp.	101				101
<i>Panicum miliaceum</i>	4				4
<i>Panicum</i> sp.	4	1			5
<i>Setaria italica</i> ssp. <i>viridis</i>	10	68		11	89
<i>Setaria italica</i> ssp. <i>italica</i>	66	1		23	90
<i>Setaria</i> -type embryos				4	4
<i>Setaria</i> sp.	4	1			5
<i>Setaria</i> / Paniceae	103	47		9	159
Paniceae	2			20	22
Other Paniceae grasses	71				71
Other grass	102	93	2		197
Rosaceae		1		1	1
Solanaceae	1				1
Unknown Seeds	16	2		8	26
Total Seeds	490	215	2	75	782

Fruits and other vegetative remains were poorly represented in Peiligang samples although fragments of a charred root or tuber were present at the Wuluo Xipo site (Table 8-3). Due to the charred and fragmentary nature of these remains, it was not possible to identify this with any more detail. Peiligang or pre-Peiligang people appear to have collected and used *Setaria italica* ssp. *italica* plants to the extent that they modified the seeds (domestication). However, the lack of seed plant resources recovered from the site suggests that Peiligang

period people may still have been partly reliant on other wild resources. This may have included fruit, nuts and tubers, which do not preserve well as charred specimens. Evidence for the use of starchy nut resources including acorns is discussed in Chapter 11.

8.2.3 Yangshao Flotation Results

The Yangshao period (7,000–5,000 cal BP) is generally considered a secondary period in terms of agricultural origins (Chang, K. C., 1986: 112). That is, agriculture is typically considered to have been well-established by this time, so research questions related to the Yangshao period have focused on the establishment of agriculture rather than its origins.

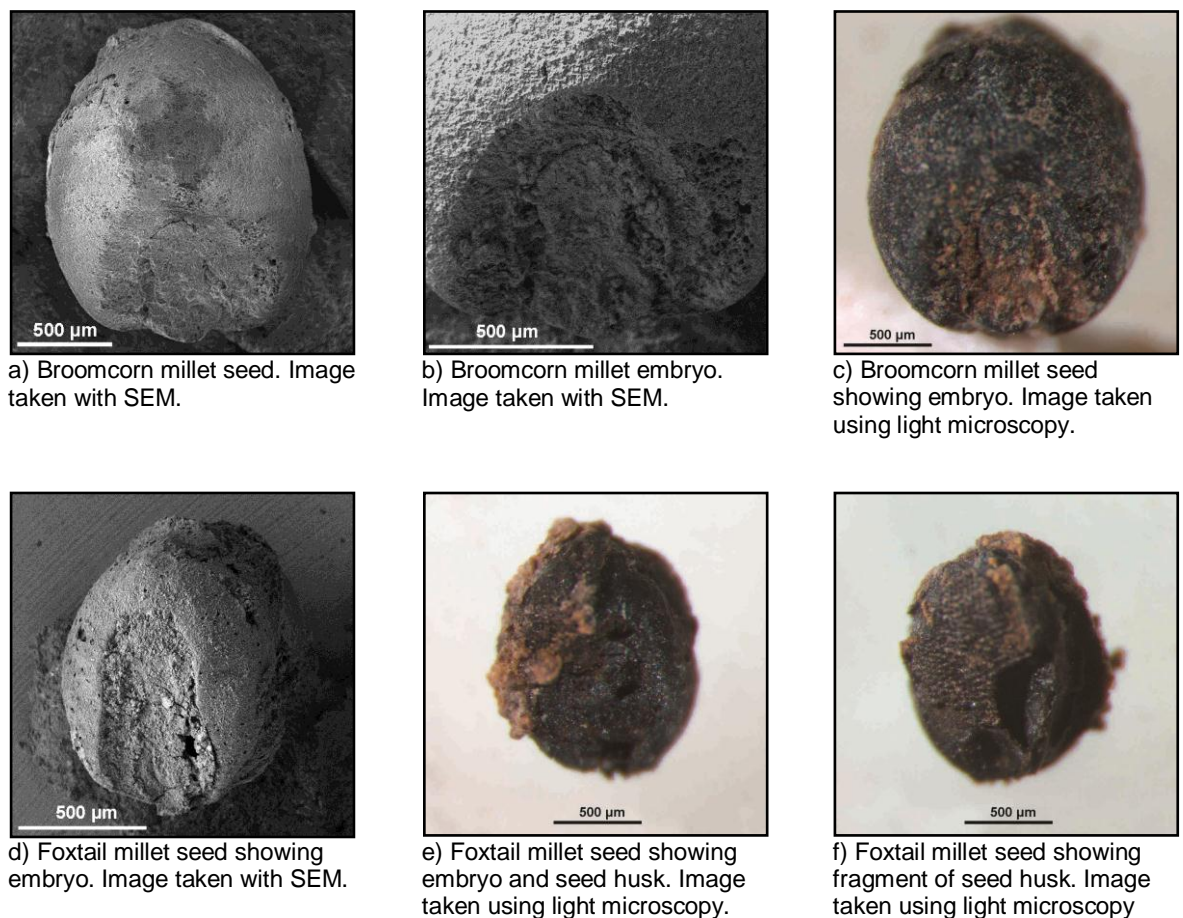


Figure 8-3 Cultivated seeds from Yangshao flots where a–c) is a single broomcorn millet seed and d–f) is a foxtail millet seed. SEM images taken by Sheahan Bestel and Gary Crawford.

Four Yangshao sites were examined as part of this research (Table 8-4). Three sites yielded substantial numbers of seeds while the Tianpocun site only preserved two small wild grass seeds. Numerous domesticates were recovered from the other three Yangshao samples (Figure 8-3) including many foxtail millet seeds. Wild grass seeds of various types were also common. These are difficult to identify to a genus or species taxonomic level and were generally identified as Poaceae grass seeds. Small numbers of non-Poaceae taxa were

also present in Yangshao samples, including Chenopodiaceae/ Amaranthaceae, Solanaceae and Rosaceae family seeds (Figure 8-4). In total over 95 percent of the seeds present in the Yangshao samples were grass seeds.

8.2.3.1 BUCUN SITE

Thirteen litres of sediment from ash pit H2 were floated and sampled from the Bucun site. A total of four hundred and ninety seeds were recovered, including 69 crop seed remains (see Table 8-4). These included mainly foxtail millet but three specimens of broomcorn millet were also present. In addition, a single chenopod, three beans and one Solanaceae seed fragment (Figure 8-4) were also present. A wide range of seeds from this site was represented in the 16 unknown or unidentified seeds present. This is approximately 3 percent of the total number of seeds at the site. Domesticates make up about 14 percent of seeds at the site. Large numbers of small, wild grass seeds were also present.

8.2.3.2 DIDONG SITE

A total of 215 seeds were recovered from the Didong site (see Table 8-4). Over 98 percent of these were grasses including only one foxtail millet seed domesticate. Two seeds were unidentified specimens and one seed each of Chenopodiaceae, Solanaceae and Rosaceae were also present. There were over 70 specimens similar to green foxtail grass, the wild ancestor of foxtail millet. This may suggest that the domesticated *Setaria italica* ssp. *italica* was not yet present in heavy use at this site. It is also possible that the wild seeds were used for food in addition to the domesticated millet as people frequently collect weeds for other purposes. The discarded charred seeds may have been farming by-products that were removed from the sample once the useful domesticated millet had been extracted.

8.2.3.3 TIANPOCUN SITE

In eight litres of sediment only two grass seeds were recovered from the Tianpocun site (see Table 8-4). This may reflect the nature of sampling, where some sites have many, and other sites have few seed remains. It may also reflect the use of plants other than grasses at the site, such as acorns or yams. These may have been present and used as food, fodder or fuel but not preserved in the seed macrobotanical record. It is possible that agriculture, including domesticated cereals, had not been adopted at the Tianpocun site.

8.2.3.4 YULINZHUANG SITE

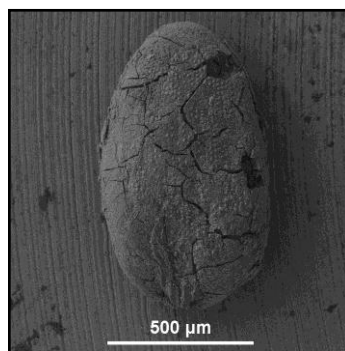
Six litres of sediment from the Yulinzhuang site yielded a total of 75 seeds including 23 foxtail millet grains (Table 8-4). Other Panicoid grasses were also common in the sample, although many cannot be accurately identified at this time. Eight unidentified seeds were found, making up eleven percent of the total seeds at the site. Fruit remains were present in the form of a large ‘pip’ or the inner section of a stone fruit with the seed inside the endocarp (Figure 8-4). Spores were also present, possibly indicating the use or presence of ferns at or near the site.

8.2.3.5 YANGSHAO SITE TAXA

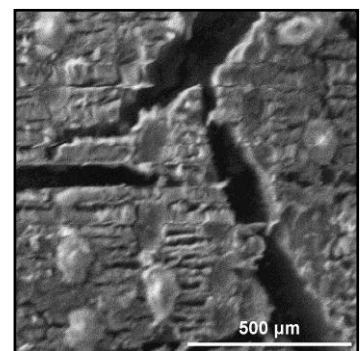
Numerous domesticates were evident in the Yangshao flots. These included mainly foxtail millet but also small amounts of broomcorn millet (Table 8-4; Figure 8-3). This indicates that these seeds may have been a staple food during this time. However, staple foods may make up variable percentages of seed based foods in different communities.



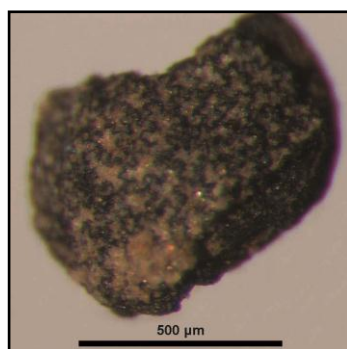
a) Soybean (*Glycine* sp.) seed showing the hypocotyl-radicle.



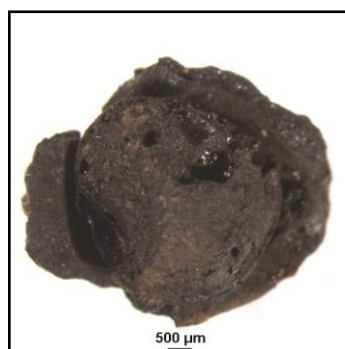
b) Crabgrass (*Digitaria* sp.) seed with seed husk patterning still visible.



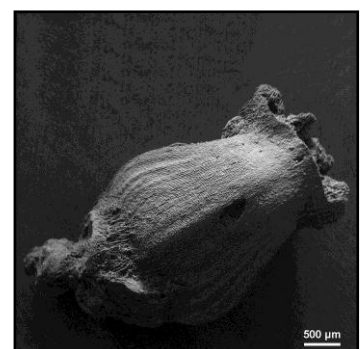
c) Detail of seed coat patterning from crabgrass (*Digitaria* sp.) seed



d) Solanaceae type fragment of seed



e) cf. Rosaceae fruit with the pip or stone still in the fruit



f) Fragment of grass rachis

Figure 8-4 Wild plants and fruits from the Yangshao period in the Yiluo region. Images b, c, and f were taken using an SEM while images a, d, and e were taken with light microscopy. SEM images and Rosaceae fruit image (e) taken by Sheahan Bestel and Gary Crawford.

Aside from domesticates, plants that may have been under cultivation at Yangshao sites include soybean (*Glycine* sp.) and other Panicoid grasses such as *Digitaria* sp. seeds (Figure 8-4). Soybeans were later domesticated in Asia (Lee, G.-A., et al., 2011) and *Digitaria* sp. seeds were utilized as crops in parts of India and in Africa (Singh and Arora, 1972). These potentially cultivated taxa are discussed in more detail in Chapter 11.

8.3 Comparisons Between Palaeolithic, Peiligang, and Yangshao Macroremains

Due to the small number of seeds in the late Palaeolithic and Peiligang samples it was not possible to carry out statistical correlations. However, seed density, size and type from Palaeolithic, Peiligang and Yangshao period sites are compared below to help understand how the subsistence economy changes through time in the research region. The changes in domesticate seed size for the Peiligang and Yangshao periods and variation in types of seeds are also examined.

8.3.1 Seed Density

The density of seeds at a site has been used as a proxy measure of population size (Lee, G.-A. & Bestel, 2007). However, where a population relies on ground acorns or tubers as well as other uncooked foods and does not rely heavily on cooked seeds for subsistence, a measure of seed density is less indicative of changes in diet. Density of seeds in the flotation samples examined may not reflect the entire plant food segment of the diet. Seed density is presented here as a basic indicator relating to ancient seed use only (Figure 8-5; Table 8-5).

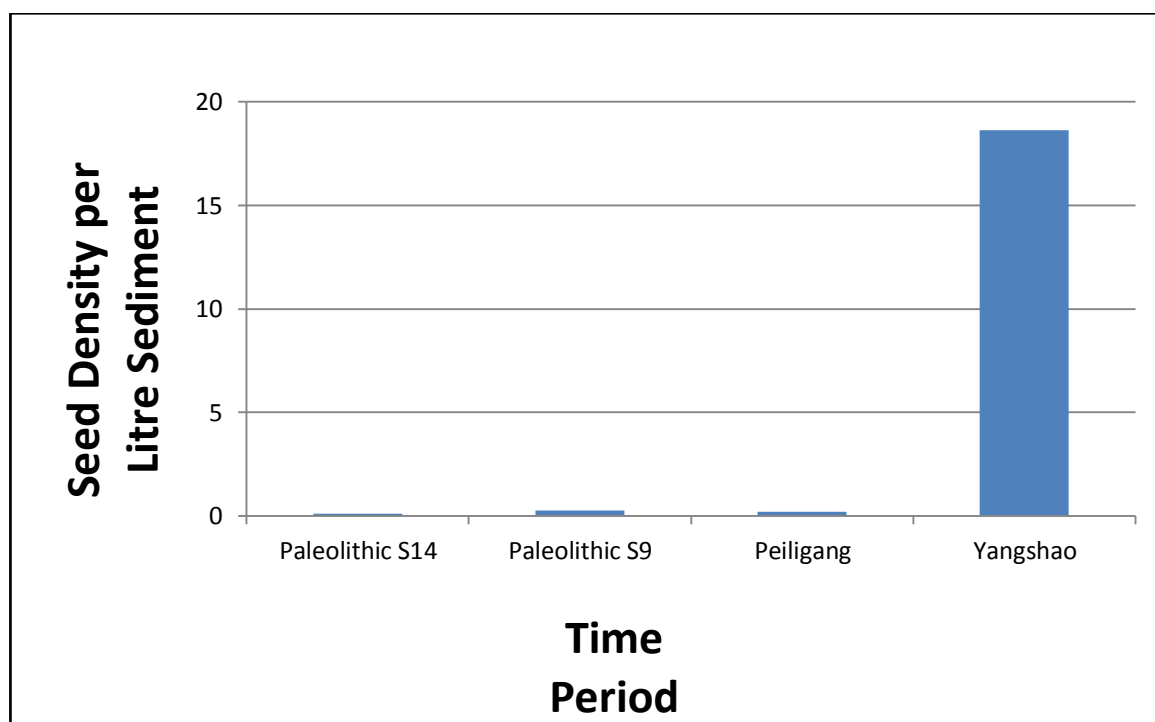


Figure 8-5 Density of seeds per litres of sediment

Table 8-5 Density of Seeds Per Litres of Sediment

Site	Date cal BP	Number of Seeds	Litres of Sediment	Number of Seeds per Litres of Sediment
Shizitan Locality S14	20,000-20,700 cal BP	5	45	0.11
Shizitan Locality S9	13,900–8,500 cal BP	28	225	0.14
Peiligang Period	9,000–7,000 cal BP	18	90.5	0.20
Yangshao Period	7,000–5,000 cal BP	782	42	18.62

Density of seeds within the study region during the Late Palaeolithic around the 20,700–20,000 cal BP period is relatively small with a seed density of 0.11 seeds per litre of sediment. Seed density increased to 0.14 seeds per litre of sediment floated during the later Palaeolithic period at the S9 site dated to between 13,800 – 8,500 cal BP. The seed density increased again in the Peiligang period to 0.2 seeds per litre and increased exponentially during the Yangshao period to over 18 seeds per litre (Figure 8-5). This may reflect a greater use of seed plants and cereal crops as well as a population increase (Liu, Li, et al., 2002-2004: 48; Qiao, 2007).

The low seed densities during the Palaeolithic and Peiligang period may reflect similar subsistence strategies during this time although the Late Palaeolithic did not preserve any

evidence for domesticated cereals. The low numbers of seeds likely reflect the fact that seed crops were not the only major food source (see chapter 9 and 11 for a discussion of acorn usage in the Peiligang and Late Palaeolithic study region).

A total of 28 seeds were recovered from approximately 225 litres of sediment floated at the S9 site locality (Figure 8-1). This makes the average seed density approximately one seed per 7 litres of sediment floated (10 litres is approximately a single bucket of sediment).

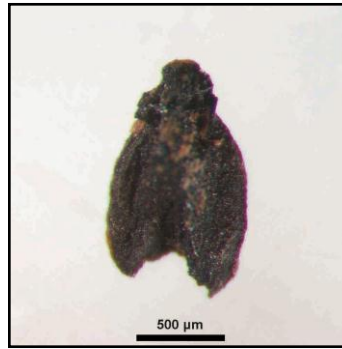
Although there has been no known systematic archaeobotanical research on other Palaeolithic sites in North China, small sample sizes and low seed densities are evident in the first 'agricultural' Peiligang period (7,500–7,000 cal BP) in the Yiluo basin of North China (Lee, G.-A., et al., 2007: 1889-1890). G.-A. Lee and colleagues (2007) found seven seeds in thirteen litres of soil sampled from two Peiligang-aged sites in this region. Therefore in the preceding Palaeolithic period a seed density of *c.*0.14 seeds recovered per litre of sediment floated is not unexpected. This seed density is less than that in Early Jomon period sites such as that at Hamanasuno, on the Kameda peninsula in Japan. At such sites seed density is generally less than one seed per litre of sediment (Crawford, 1983: 94-96, figure 15). Jomon period sites are typically described as hunter-gatherer sites (Matsui & Kanehara, 2006; Pearson, 2006) although Crawford (2008), noting the presence of domesticates, conceptualises them as occupying a 'middle ground' between hunting and agriculture.

The similar seed density between Peiligang period sites in China and Jomon sites in Japan may suggest that plants with domesticated cereal crops in both locations comprised only a minor component of the diet. This may be a typical seed distribution for hunter-gatherer-fisher societies with minor numbers of domesticates. Agricultural societies with staple foods comprised of cereals and seed plants preserve far more numerous traces of weedy and cereal seeds.

8.3.2 Domesticated Seed Size



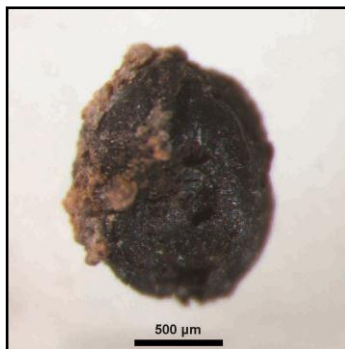
a) cf. *Setaria* seed from the Late Palaeolithic Shizitan site



b) *Setaria* sp. weedy seed from the Peiligang Fudian Dong site, with some charring damage



c) Early domesticated *Setaria italica* ssp. *italica* (Foxtail millet) from Peiligang Fudian Dong site



d) *Setaria italica* ssp. *italica* (Foxtail millet) with husk fragment on upper left, from the Yangshao period Bucun site



e) *Panicum miliaceum* (Broomcorn millet) from Peiligang Fudian Dong site



f) *Panicum miliaceum* (Broomcorn millet) from the Yangshao Bucun site

Figure 8-6 The evolution of foxtail and broomcorn millet: (a-d) cf. *Setaria* sp. seeds from Late Palaeolithic, Peiligang and Yangshao sites exhibit a width increase across the Peiligang and Yangshao period. (e-f) Broomcorn millet (*Panicum miliaceum*) exhibits a width and length increase from the Peiligang to Yangshao.

The increase in seed density during the Yangshao period may be due to increased seed crops in the diet as well as a population increase (Lee, G.-A., et al., 2007). This may correspond with a decrease in dietary acorns, as suggested by the proxy evidence of a decreased number of acorn grinding implements (see Chapter 9 and Chapter 11). The importance of millet seeds in the diet is suggested partly by the increased size of these domesticates in the Yangshao when compared to those in the Peiligang (see Figure 8-6; Table 8-6; Table 8-7).

Table 8-6 Comparison of Foxtail Millet Seed Length at the Late Palaeolithic Shizitan (this thesis), Dadiwan (range size data from Liu, C., 2006: 914–916), Fudian East (this thesis) and Bucun and Yulinzhuang (this thesis).

Site	Time Period	Taxa	Number of Seeds ¹⁰	Length (mm)	Reference
Shizitan S9	13,800–8,500 cal BP	cf. <i>Setaria</i>	1	0.64	Chapter 8
Fudian Dong	7,504–7,412 cal BP	Foxtail millet	1	1.39	Chapter 8
Dadiwan QDH379	6,500–6,000 cal BP	Foxtail millet	10	1.23-1.34	(Liu, C., 2006)
Dadiwan QDH219	5,500–5,000 cal BP	Foxtail millet	700	1.29-1.55	(Liu, C., 2006)
Bucun H2	c. 5,500–5,000 cal BP	Foxtail millet	48	0.92-1.50	Chapter 8
Yulinzhuang H1	c. 5,500–5,000 cal BP	Foxtail millet	10	1-1.4	Chapter 8

While seed thickness is probably a more important indicator of the domesticated status of millet seeds, the length of millet seeds also increases with domestication (Zhao, Z., 2005a: 194). Raw data for domesticate seed size in the Peiligang and Yangshao period sites examined is given in Appendix 7.

Due to differences in data for the sizes of early millet grains published, it was not possible to table an increase in width or thickness for early millets across a range of sizes. Instead, published records of the length of early millet seeds from the sites of Dadiwan, Xinglonggou and sites in the Yiluo Region were presented (Table 8-6; Table 8-7).

¹⁰ Only measurable seeds were included in the table.

Table 8-7 Comparison of Broomcorn Millet Seed Length at Dadiwan (range size data from Liu, C., 2006: 914–916), Xinglonggou (average size data from Z. Zhao, 2005:193), Fudian East (this thesis) and Bucun (this thesis).

Site	Time Period	Taxa	Number of Seeds ¹¹	Length (mm)	Reference
Xinglonggou Phase 1	7,670–7,610 cal BP	Broomcorn millet	1400	1.6 (average)	(Zhao, Z., 2005b, 2011)
Xinglonggou Phase 3	4,000–3,500 cal BP	Broomcorn millet	50+ measured	1.98 (average)	(Zhao, Z., 2005b, 2011)
Fudian Dong	7,504–7,412 cal BP	Broomcorn millet	1	1.6	Chapter 8
Dadiwan QDH398	7,800–7,350 cal BP	Broomcorn millet	8	1.6–2.07	(Liu, C., 2006)
Dadiwan QDT109	6,500–6,000 cal BP	Broomcorn millet	500	1.75–1.93	(Liu, C., 2006)
Dadiwan QDH379	6,500–6,000 cal BP	Broomcorn millet	285 popped	1.78–1.91	(Liu, C., 2006)
Dadiwan QDH379	6,500–6,000 cal BP	Broomcorn millet	135 unpopped	1.32–1.68	(Liu, C., 2006)
Dadiwan QDH219	5,500–5,000 cal BP	Broomcorn millet	5	1.8	(Liu, C., 2006)
Bucun H2	c. 5,500–5,000 cal BP	Broomcorn millet	4	1.41–1.56	Chapter 8

At Dadiwan, the seed size of foxtail millet increased across the middle and late Yangshao period (Table 8-6). Measurements were not published for foxtail millet size at Xinglonggou but an increased length and width was evident in the Yangshao period in the study region at sites such as Bucun and Yulinzhuang (Table 8-6). Although only a single grain of foxtail millet from the Peiligang Fudian Dong site was sufficiently complete to be measured, the photograph of millet seeds all taken at the same scale shows the size increase by the Yangshao period (Figure 8-6). One cf. *Setaria* sp. seed from the late Palaeolithic Shizitan

¹¹ Only measurable seeds were included in the table.

S9 site was also measured. It is substantially thinner (Figure 8-6) and slightly smaller than later Yangshao period *Setaria italica* ssp. *italica* domesticates (Table 8-6).

Broomcorn millet seeds also increased in size over time in the Yiluo Region (Figure 8-6). There is an increase in the average length from Phase 1 (new dates of 7,670–7,610 cal BP given in Z. Zhao (2011: S301)) to Phase 3 (4,000–3,500 cal BP) at the Xinglonggou site. However, at the Dadiwan site broomcorn millet seeds seem to decrease in length from the initial Dadiwan to the late Yangshao period (Table 8-7). This may reflect the fact that millet seed thickness or width is a better measure of domestication than length (Zhao, Z., 2005a; 194). However this data was not published and so was not available for comparison. In addition, by the late Yangshao period at Dadiwan, there were only five grains of broomcorn millet present (Gansusheng, 2006: 915). It is possible that a reduction in the use of broomcorn millet led to a decreased rate of evolution or a plateauing size length trend.

8.3.3 Variation in Types of Seeds

An analysis of the range of seeds present in a diet may allow certain inferences to be made, including inferences about foraging behaviour and nutrition. When unknown seeds are included in the analyses, there are a minimum of three types of seeds (chenopod and two unknowns) in the Palaeolithic Shizitan S14 site. This number increased to include a minimum of four species of seeds present in the late Palaeolithic at Shizitan S9, including at least three species of grasses. Peiligang sites preserved remains of a minimum of eight species of seeds including chenopods/amaranth, portulaca and several different species of grasses. Even greater variation in seed type is present in the Yangshao period, with fourteen species of plant represented by seeds in the flots. When unknown seeds are included in these counts the range of seed taxa increases but still there is a visible increase across time in the types of seeds. Seed numbers from the Palaeolithic and Peiligang periods are probably not large enough to represent a statistically significant sample. Future research should aim to increase the sample size to allow more plant remains including seeds to be recovered.

8.3.4 Carbonisation and Charring Temperature of Seeds

On the basis of charring experiments on broomcorn and foxtail millet, X. Y. Yang and colleagues (2011) have suggested that the charring temperature of broomcorn and foxtail millet may be estimated based on the structure of starch granules retained in charred millet grains. They suggest that at 200° C starch granules retain their structure but at 250° C

starch granules become amorphous and are therefore unidentifiable. At 300° C their experimental starch grains were turned into cavities or holes in the charred grain and thus were not identifiable. From their experimental research they suggest that charred grains from the Beiniu site were ‘formed by baking rather than direct burning’ at approximately 250° C. This is in contrast to the seeds from the Yangshao site they examined, where starch granules were amorphous, suggesting they were baked at over 300° C (Yang, X. Y., et al., 2011: 1499).

Possible starch granules or other small cellular plastids were visible using the SEM in some of the Shizitan grass seeds studies, although there were only a few specimens. This may suggest that these grains were charred at temperatures of less than 250° C and therefore that these seeds were charred by some form of indirect burning. However, it is probably not possible to extrapolate these results directly as micro-environmental differences in burning environments and temperatures may cause uneven charring. Starch grains were not observed under the SEM in the Peiligang or Yangshao seeds examined. This is consistent with research by Yang and colleagues (2011: 1499), whose preliminary research suggests a different, more direct type of charring.

8.4 Discussion

A number of points have been raised in this chapter and will be discussed further here. Although the sample size is small, the data presented raises issues concerning Late Palaeolithic subsistence, subsequent domestication, agriculture and the use of wild resources by crop growing communities.

8.4.1 Seeds from Cultural Layers Rather Than from Ash Pits

The Shizitan flots are from cultural layers, rather than from culturally produced ash pits, as is the case with some of the Peiligang samples. Ash pits were dug for an unknown purpose during the Neolithic. They may have been dug for storage reasons and were then filled with rubbish including pot sherds, animal bones and ash presumably from cooking fires. The ash preserves charred seeds and other plant remains (see Chapter 5, Figure 5-2 for more details on ash pits).

In all archaeobotanical analyses, there are concerns about whether the seeds recovered from ash pits represent a cultural use of plants, or whether they represent accidentally charred seeds from the palaeoenvironment around the site. However, the association of the

charred seeds from the cultural layers with rich artefactual remains suggests that the seeds were connected to human activity. Seeds from later Neolithic sites in China are generally collected from ash pits and are considered to have been deposited in a culturally used and subsequently sealed archaeological context. Despite their secondary or later depositional context, they are typically conceived of as having been deposited through a human, and therefore a cultural, depositional filter. Ash pits have not been recovered from Palaeolithic sites in China, so they are considered indicators of the sedentism evident in early agricultural type villages in North China (Cohen, D. J., 2011).

The Poaceae or grass family is represented by 10 out of 28 seeds in the analysed S9 samples. Despite the small sample size this may attest to the relative importance of grasses in the diet of people during the Late Palaeolithic in this region of North China. The seeds may also represent an anthropogenic environment. It may be difficult to distinguish between a campsite located near certain culturally used seeds and edible seeds growing near a campsite. Crawford (2005: 87) has defined anthropogenesis as the ways in which humans impact their environment. He notes that this impact may be visible archaeologically in a number of ways including archaeobotanically through carbonised seeds (Crawford, 2005: 87). Certain grasses, including some *Setaria* sp. are typical of disturbed environments (Dekker, 2003) including locations where humans may have purposely or incidentally cleared ground to build a house or set-up semi-sedentary dwellings. Such seed remains may therefore represent intentional use of these plants or unintentional deposition of seed remains in a fire through their close association with or proximity to, human living places. It is also possible that ancient humans actively sought out cleared areas for dwelling or preparing food. Issues regarding the anthropogenesis of domesticated plants are complex (Crawford, 2008) and the small numbers of seed remains discussed here make it difficult to evaluate anthropogenesis from the data presented.

8.4.2 Palaeolithic Plant Food Subsistence

Cereal and grass seeds are known from Late Palaeolithic deposits elsewhere in the world including the c. 23,000 B.P Ohalo II site (Piperno, et al., 2004). Weiss and colleagues (2004b) used this site as evidence for Flannery's (1969a) broad spectrum revolution. Grasses were also evident at Kebara Cave in Israel in the Middle Palaeolithic period (Albert, et al., 2000). Given the indigenous domestication of millets in China, the use of grasses in Late Palaeolithic North China is to be expected.

Palaeoenvironmental data from the Shizitan locality 9 shows overwhelming evidence for an environment heavily invested with grasses. Pollen analysis (Xia, Z., et al., 2002) suggests that grasses were predominant from 30,000 cal BP onwards, so it is not surprising that people made use of them. Previous studies on the Palaeolithic period have typically focused on animal hunting rather than plant gathering. Hence this research provides the first quantifiable evidence for gathering behaviours and the earliest evidence for the use of millet tribe grasses in Palaeolithic North China.

Grass seed use in subsistence is generally considered to be a Holocene adaptation in China (e.g. Shizitan Kaogudui, 2010), although this may be due to a lack of archaeobotanical research into the Palaeolithic period. A pre-domestication presence of millet has not been defined until now, despite researchers postulating an indigenous origin for foxtail millet domestication in China (Chang, K. C., 1986; Ho, 1975). However, Li Liu and colleagues (2002-2004: 82) identified four *Setaria* sp. from Wuluo Xipo that, due to their small sizes, were classified as being in an intermediate stage between wild and domesticated. Z. Zhao (2005a) also suggested that the small sized millet seeds at Xinglonggou were transitional between wild and domesticated forms.

8.5 Summary and Conclusion

The first systematic palaeobotanical research into Palaeolithic North China from the site of Shizitan is presented here. The data suggests that Panicoid grasses may have formed part of the subsistence regime of Palaeolithic people for at least 4,000 years prior to the grasses' cultivation and eventual domestication by the Neolithic Peiligang period (c. 9,000–7,000 cal BP). The data presented, however small in absolute sample size (although not necessarily small in terms of the litres of volume of soil examined) thus gives new information concerning ancient subsistence in North China. Future research will help to reveal the length of time that *Setaria* type grasses were in use prior to eventual domestication. This issue parallels debate regarding the length of time that rice was used in South China prior to its domestication (see discussion in Chapter 11).

From a bulk sediment sample of 225 litres taken from the Late Palaeolithic Shizitan S9 site, 28 seeds were recovered. These include the earliest known examples of Paniceae millet tribe grasses such as *Echinochloa* sp. and *Setaria*-type seeds in North China. The sediment sample of 90.5 litres of sediment from ten samples taken from seven Peiligang sites produced 18 seeds, 5 of which were domesticates. The lack of cereal seeds or domesticates

in the samples may suggest that in this region during the Peiligang, domesticated millet seeds were not a staple food. The four Yangshao sites examined produced 782 seeds in 42 litres of sediment including 12 percent (n=93) domesticates. Questions regarding the length of time taken for seeds to become domesticated and whether the Peiligang or Yangshao period may be considered 'agricultural' will be discussed in the concluding chapter.

Grasses were present and formed a part of late Palaeolithic anthropogenic communities and diets long before the Neolithic Holocene period. However, macrobotanical remains only present part of the picture of plant based food or botanical subsistence retained in the archaeological record. For this reason, other archaeobotanical data were collected from artefacts including grinding implements and sickles. These artefacts will be examined using a range of microfossil techniques in the following chapters.

Chapter 9: *Mopan* and *Mobang* Grinders

Grinding technology may pre-date *Homo sapiens* ssp. *sapiens*. Ancient starch has been recovered from grinding slabs on Sai Island, North Africa dating to c. 180,000 BP (Van Peer, et al., 2003) and in the Ngalue Cave site in Mozambique dating to c. 105,000 BP (Mercader, 2009). However, Gremillion (2011: 25) suggests that tools used to process plant foods, including grinding slabs and other grinding implements, typically appear late in prehistory at around 40,000 years BP. This may make them a feature of the Middle/Upper Palaeolithic transition period although more research is required to fully understand the origins of grinding and other plant food processing technology.

In China, Late Palaeolithic grinding slabs have been reported from Shizitan (Shizitan Kaogudui, 2010), Xiachuan (Chung, 2000; Lu, T. L. D., 1999) and Longwangchan (IACASS and Shaanxi Provincial Institute, 2007). It has been suggested that agricultural people in North China may have descended from the Xiachuan culture with its proto-axes and grinding slabs (Fan, 1993: see also Lu, T. L. D., 1999: 134). Despite this, grinding slabs of all shapes and sizes were often considered an agricultural proxy (see Liu, Li, et al., 2002-2004: 81) and dated typologically to Holocene times based on their assumed function in cereal grinding. We now know that grinding implements pre-date cereal agriculture in North China (Liu, Li, et al., 2010b; 2010c; 2011; Shizitan Kaogudui, 2010).

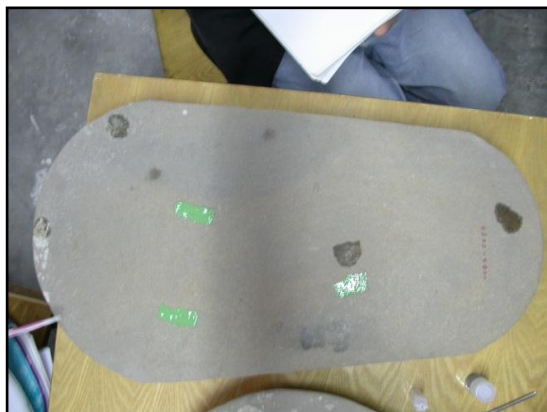
Xiachuan grinding slabs were typically roughly shaped with negative flake scars around the edge of a medium or coarse grained slab (Lu, T. L. D., 1999: fig 4(3) and 4(5)). Shizitan slabs were similar (Liu, Li, et al., 2011; Lu, T. L. D., 1999: fig 4(7)) but Peiligang grinding slabs were much more standardised. Grinding slabs and rollers with a concave surface and four short legs are considered diagnostic of the Peiligang and Cishan cultures in the middle Yellow River valley region (Chang, K. C., 1986: 92-93). These are termed *mopan* and *mobang* slabs and roller-pestles respectively to avoid confusion with terms used elsewhere in the world. Recent residue and use wear analyses (Liu, Li, et al., 2010a; 2010b; 2010c) suggest such implements were multi-functional, with acorn grinding being an important use.

Mopan grinding slabs and *mobang* rollers from three Peiligang sites were examined for starch residues as described in Chapter 5. Few starch grains were recovered from the Egou and Shigu sites so these artefacts were not analysed in detail. However, six artefacts from

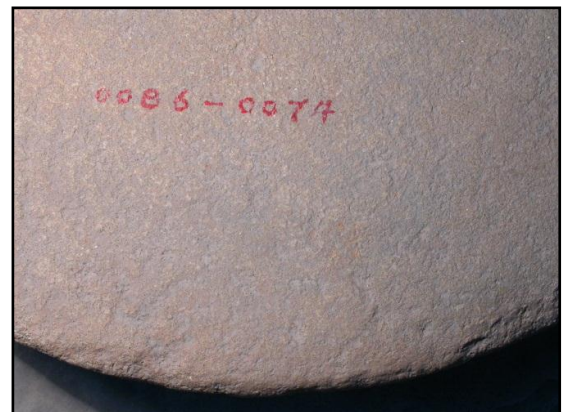
the Tieshenggou site preserved over 50 starch grains each. Ancient starch was identified using the reference collection outlined in Chapter 7. The types and percentages of starch recovered are discussed below.

9.1 Artefact Description

Due to the use of different terms used to describe grinding implements from different geographic locations, throughout this thesis the terms *mopan* and *mobang* will be used to describe grinding slabs or bases and grinding rollers or pestles respectively. Peiligang *mopan* and *mobang* follow a standard description. *Mopan* slabs are typically made of coarse or medium grained sandstone and are relatively flat in plan view (Figure 9-1).



a) Grinding *mopan* showing placement of green PVS use-wear peels (not discussed in this thesis) and wet residue samples (TSG GS2)



b) Close-up of coarse-grained sandstone grinding *mopan* showing roughened grinding surface (TSG GS2)



c) Grinding *mopan* broken into three fragments and lacking stone feet (TSG GS 6_7_10)



d) Grinding *mopan* with *mobang* or roller showing asymmetrical end and feet of slab (TSG GS26)

Figure 9-1 Examples of Peiligang Grinding *Mopan* implements

Mopan may be up to 50 cm long and weigh around 10–20kg (Liu, Li, et al., 2010c: 817). They typically have four short legs (Chang, K. C., 1986: 92-93) with feet approximately two inches high (see fig 9.1). One of these ‘feet’ from a grinding slab from the Egou site retained numerous acorn starch granules when tested by Li Liu and colleagues (2010c).

This is perhaps due to flour probably blowing all around the slab during grinding.

Reflecting the spot nature of sampling, the same slab and the same dry sample yielded only a single starch grain when re-processed a year later.



a) Cross-section of grinding *mobang* showing coarse-grained sandstone material (TSG R1)



b) Cross-section of rounded end of grinding *mobang* (TSG R9)



c) Fragment of coarse-grained grinding *mobang* with visible sediment retained after thirty years in storage (TSG R8)



d) Fragment of coarse-grained grinding *mobang* (TSG R9)



e) Fragments of grinding *mobang* showing length of implement (RSG R2)

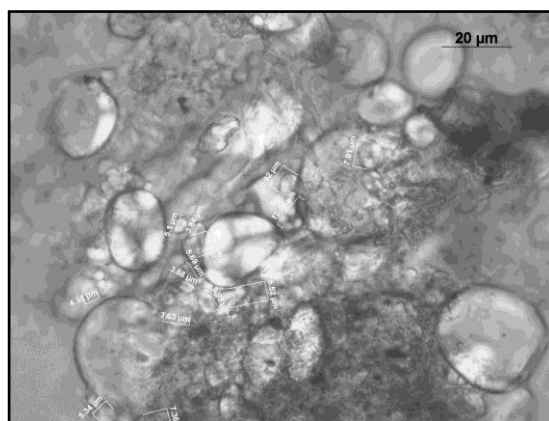
Figure 9-2 Examples of Peiligang Grinding *Mobang* implements

Mobang grinding implements from the Peiligang period are typically made of medium grained sandstone (Liu, Li, et al., 2010c: 817-818). They may be round or oval in cross section (Figure 9-2). The ends of the rollers are also variable with some use wear traces suggesting pounding or crushing pestle usage (Liu, Li, et al., 2010c: 818).

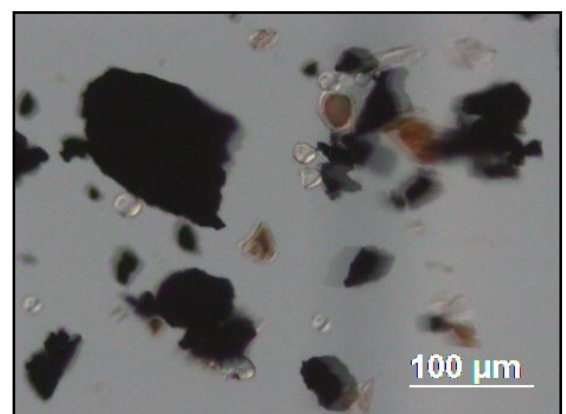
Macroscopic usewear and microscopic residue and use-wear traces preserved on some Egou and Shigu *mobang* rollers were analysed by Li, Liu and colleagues (2010c). These grinding implements were found to have been used in grinding a range of foods including *Quercus* sp. acorns. After analysis of several Tieshenggou *mobang* A. Wilson (2010) suggested that usewear traces were indicative of both acorn and cereal processing.

9.2 Preservation of Organic Residues

Preservation of organic residues was poor for some sites such as Shigu and good for other sites, including Tieshenggou (Figure 9-3). It is unclear why different sites preserved starch grains differently but it may relate to sample size or specific taphonomic processes at sites. More research is needed to fully understand factors affecting starch deposition and preservation.



a) Tieshenggou *mopan* 6 with large cluster of Triticeae starch grains



b) Tieshenggou *mobang* 8 plant residues including charcoal, phytoliths and starch grains

Figure 9-3 Figure 9.3a and b. a) Cluster of starch grains from TSG GS6. b) Plant residues preserved on TSG R8. Eight starch grains (small white-grey objects) were preserved as well as two grass phytoliths (brown) and numerous larger fragments of charcoal (black).

Six of the examined slides from the Tieshenggou site had over fifty starch granules present on the slide. In some cases these were grouped together, as for the cluster of over 70 starch granules on GS6_7_10 (Figure 9-3). The presence of a large cluster of similar types of starch grains allows for the identification of populations of starch grains rather than an individual granule. This may help to make the starch identification more secure.

In other residue samples single or individual starch grains were present in large numbers. This was exemplified on R8 where eight starch grains were visible amid two grass bulliform phytoliths and numerous fragments of charcoal (Figure 9-3).

9.3 Results of the Site Starch Identification and Analysis

Artefacts from three Peiligang sites were examined for starch grains (Table 9-2). In preliminary studies a statistically significant sample of starch grains was recovered from the Egou site including from the ‘foot’ fragment of one *mopan* (Liu, Li, et al., 2010c). However, probably due to the spot nature of sampling, not as many starch grains were recovered from the Egou samples examined for this thesis. In addition, few starch grains were recovered from the Shigu site artefacts examined for this thesis, so only Tieshenggou artefacts were examined in detail.

Table 9-1 *Mopan* Grinding Slabs and *Mobang* Rollers Available for Analysis

Site	Chinese Site Name	No. Grinding Slabs Sampled	No. Roller / Pestles Sampled	Collection Provenance
Egou	莪沟	6	8	excavation
Shigu	石固	3	3	excavation
Tieshenggou	铁生沟	27	22	Dug up by farmers and collected by archaeologists†

†Probably originally from Peiligang burials in the Tieshenggou area.

9.3.1 Plant Residues from Egou Grinding Implements

Twelve samples collected from ten artefacts examined from the Egou site were processed (Table 9-2). Multiple samples were prepped from two artefacts to check whether different areas of the artefacts preserved different types or numbers of starch grains. In total only 87 starch grains were recovered. This is an average of 8.7 grains per artefact and less per sample meaning that this is not a statistically significant sample of starch grain preservation. Due to this small starch count the Egou samples were not processed or analysed further.

As well as starch, small numbers of other plant remains were present on the one Egou artefact examined for such residues (Figure 9-4). Several non-diagnostic phytoliths were recovered including non-diagnostic tracheids and multi-cellular eudicot phytoliths. No grass husk phytoliths were recovered suggesting that the artefacts were probably not used to dehusk cereals. This is significant as they were typically considered to be used to grind cereals (e.g., Chang 1986: 80-92).

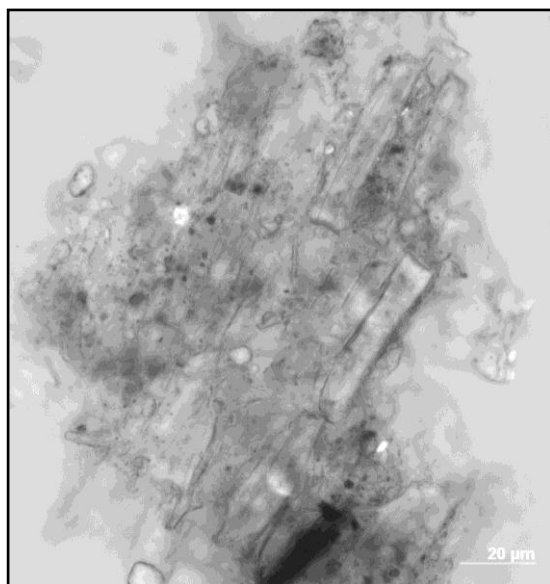
Bordered pits were also noted; these typically occur in conifers (Evert & Eichhorn, 2006: 260-261). They may occur in other plants as shown by modern references. Bordered pits

are therefore potentially indicative of the use of wood although more research and a more accurate identification of the type of bordered pits present on the artefact are needed to confirm this. Phytolith and other plant residue analysis were not continued further.

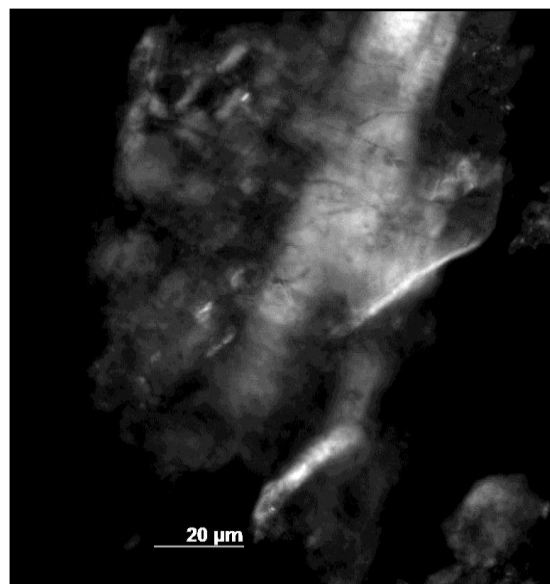
Table 9-2 Starch Recovered from Egou Grinding Implements

Artefact No.	Implement Type	No Samples	No Samples Examined	Artefact Details	Total No. Starch Grains Recovered	Other †
GS30	grinding slab	1		T17 M36:1		
GS31	grinding slab	2		T4 M26		
GS32	grinding slab	2	2	TP1 M68:1	4	
GS34	grinding slab	3	1 (c)	M57:1	6	
GS35	grinding slab	2	2	M57	34	
GS36	grinding slab	3	1	M57	1	Tracheids; charcoal; bordered pits; bulliforms; dicot multi-cell
R23	roller/pestle	2	1 (a)	M40:6	8	
R25	roller/pestle	1		M55:6		
R26	roller/pestle	3	1(a)	M36	15	
R27	roller/pestle	2	1(a)	T4 M26:2	4	
R28	roller/pestle	1	1	H36:1	0	
R29	roller/pestle	3	1(a)	T10:2	11	
R30	roller/pestle	1		H39:3		
R31	roller/pestle	1	1	(none given)	4	
Total			11		87	

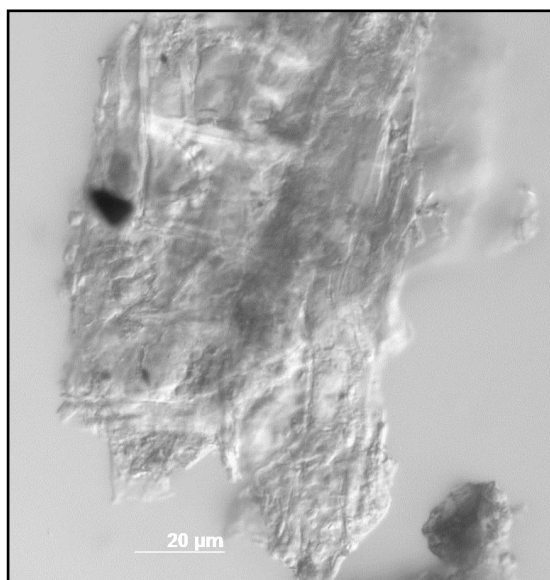
† Only selected samples were checked for phytoliths and/or other plant remains. After preliminary results and testing, the research focus was to recover starch from grinding slabs as phytoliths present were rarely diagnostic.



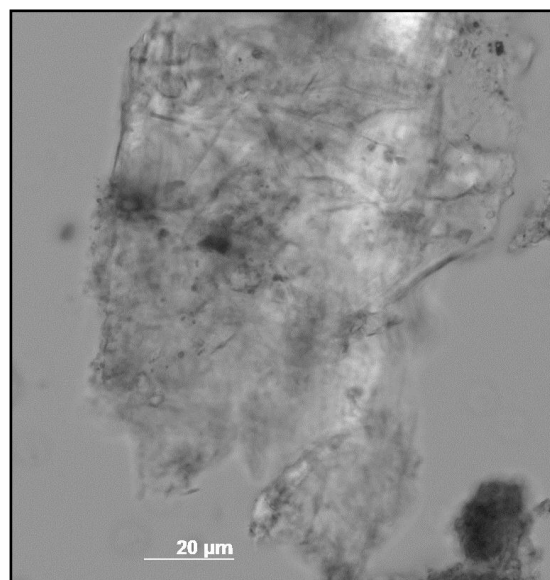
a) Multicellular silica skeleton showing grass long cells under a brightfield filter



b) Bordered pits under a cross-polarising filter



c) Bordered pits under a DIC filter



d) Bordered pits under a brightfield filter

Figure 9-4a–d Plant residues other than starch from the 'foot' of a grinding *mopan* from Egou (GS36)

9.3.2 Plant Residues from Shigu Grinding Implements

A total of three artefacts and five samples were examined from the Shigu site. Fewer than ten starch grains were recovered from this site in total (Table 9-3). Due to the small numbers of starch recovered no further analysis or processing of Shigu samples was carried out.

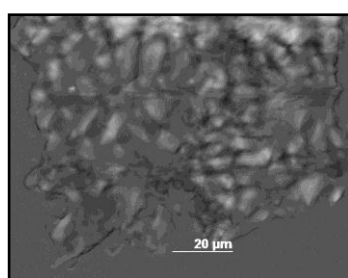
One *mopan* and one *mobang* grinding implement were examined for plant residues other than starch grains. Residues recovered included grass long cells and hair cells (Table 9-3).

No grass husk phytoliths were recovered from the Shigu artefacts, suggesting the implements were not used to dehusk cereals. Other plant remains present included a fragment of plant fibre with pits (Figure 9-5). As discussed above, these may be diagnostic (Kondo, et al., 2002). Further research is required to identify the bordered pits to taxon.

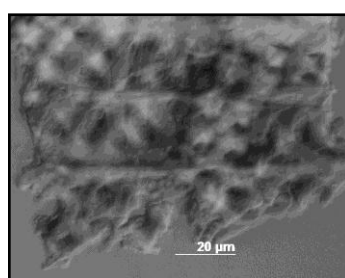
Table 9-3 Starch Recovered from Shigu Grinding Implements

Artefact No.	Implement Type	No. Samples	No. Samples Examined	Artefact Details	Total No. Starch Grains Recovered	Other
GS28	grinding slab	2		215		
GS29	grinding slab	3		AT6z M86:2		
GS33	grinding slab	2	2	AT6z M67	3 †	Grass LC; fibres; bordered pits
R24	roller/pestle	1	1	AT6z M86:3		Bordered pits; fibers; hair cells with base attached
R32	roller/pestle	2				
R33	roller/pestle	1	2	275		
Total			5		3	

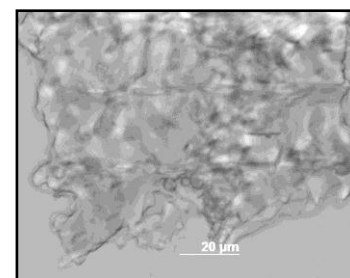
† Two wheatgrass and one unknown



a) Plant fibre with pits under a cross-polarising filter



b) Plant fibre with pits under a DIC filter



c) Plant fibre with pits under a brightfield filter

Figure 9-5a-c Bordered pits from Shigu *mobang* grinding implement (R-24_A)

9.3.3 Plant Residues from Tieshenggou Grinding Implements

A large number of grinding implements were recovered from the Tieshenggou site. The site was probably uncovered by local villagers making bricks in the 1970s (see Chapter 4). Artefacts were then handed in to archaeologists and the site was excavated (Fu, 1980; IACASS, 1986; Gongyi City, 1992; Kaifeng Diqu, 1980). Artefacts were subsequently stored in the Gongyi City museum and sampled for residues in 2007 (Table 9-4; Table 9-5).

Table 9-4 Starch Recovered from Tieshenggou Grinding *Mopan*

Grinding <i>Mopan</i> Artefact No.	No. Samples	No. Samples Examined	Artefact Details	Total No. Starch Grains Recovered
GS1	5		0085-0079	
GS2	7	7	0086-0074	232
GS3	1		0146-23	
GS4	1		0146-9	
GS5	2		0146-21	
GS6	2	2	0146-19	73+
GS7	2	2	0146-16	7
GS8	2		0146-20	
GS9	2		0146-14	
GS10	1	1	0146-18	4
GS11	0		0146-5	
GS12	0		0146-13	
GS13	0		0146-28	
GS14	0		0146-29	
GS15	0		0146-8	
GS16	0		0146-6	
GS17	0		0146-18	
GS18	0		0146-4	
GS19	0		0146-3	
GS20	0		0146-24	
GS21	0		0146-1	
GS22	0		0146-26	
GS23	0		0146-30	
GS24	0		0146-2	
GS25	0		0146-17	
GS26	3	3	0084-0072	300+
GS27	3	1	0083-0071	3
F1	1		1046-41	

Not all of the artefacts held in the museum were suitable for sampling, as visible residue or sediment was not always present. However, a representative sample of the artefacts held in Gongyi Museum was taken. In all, a total of five *mopan* artefacts and 16 *mopan* samples

were examined for residues (Table 9-4). In addition, five *mobang* artefacts and six *mobang* samples were examined for residues (Table 9-5).

Table 9-5 Starch Recovered from Tieshenggou Grinding *Mobang*

Grinding <i>Mobang</i> Artefact No.	No. Samples	No. Samples Examined	Artefact Details	Total No. Starch Grains Recovered
R1	1	1	0146-0184	182
R2	1		0146-0184	
R3	3	1	0146-	2
R4	2		0146-11	
R5	2	1	0146-22	42
R6	1		0146-13	
R7	1		0146-	
R8	1	2	0146-	336+
R9	1	1	0146-	109
R10	1		0146-	
R11	0		0083-0071	
R12	0		0146-25	
R13	0		0146-31	
R14	0		0146-32	
R15	3		0146-33	
R16	0		0146-34	
R17	0		0146-35	
R18	3		0146-36	
R19	0		0146-37	
R20	2		0146-38	
R21	0		0146-39	
R22	2		0146-40	

9.4 Results and Short Summary of Tieshenggou Residue Analysis

To ensure a representative sample of artefacts was examined for this study, samples with over 50 starch grains present were chosen for detailed starch analysis (Table 9-6). This included three *mopan* and three *mobang* grinding implements.

Table 9-6 Tieshenggou Grinding Implements With Over 50 Starch Grains

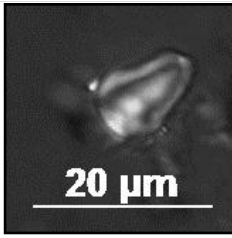
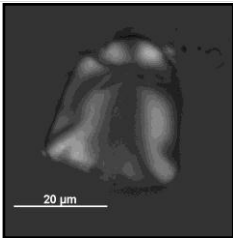
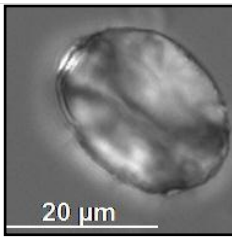
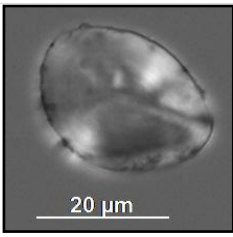
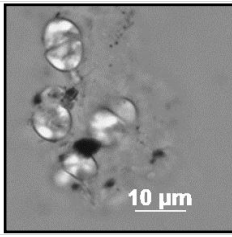
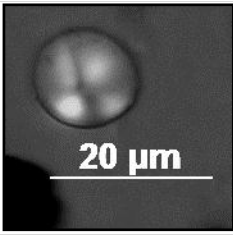
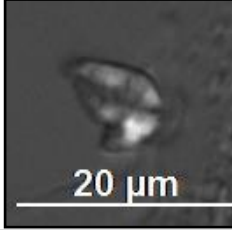
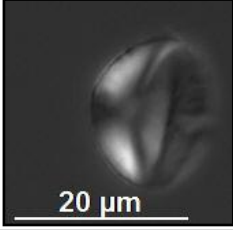
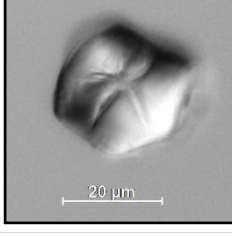
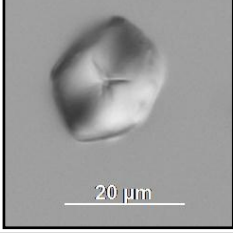
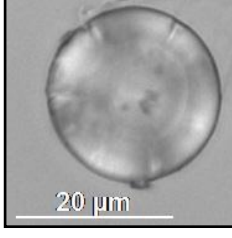
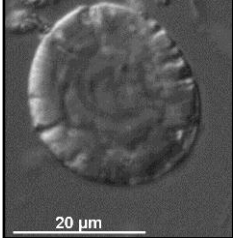
Artefact	Description	Total No. Starch Grains
Grinding Slab 2	Coarse-grained sandstone slab	232
Grinding Slab 6/7/10	Coarse-grained sandstone slab in 3 fragments	71+ in cluster
Grinding Slab 26	Coarse-grained sandstone slab	300+
Roller 1	Coarse-grained sandstone roller in 5 fragments	182
Roller 8	Coarse-grained roller	335+
Roller 9	Coarse-grained roller	109

The starch grains recovered were analysed by size and by shape. A description of the types of identifiable grains recovered is provided below.

9.5 Morphological Classification of Tieshenggou Starch Grains

Approximately six distinct and taxonomically identifiable types of starch were recovered from ancient Tieshenggou samples (Table 9-7). These are diagnostic to varying degrees. Whilst different taxa may have more than one type of starch grain, often not all of these different morphologies or types are diagnostic. The most diagnostically useful granules are outlined below (Table 9-7) and described in more detail later in the chapter. To summarise briefly, these include Dioscoreaceae yam starch, which exhibits granules with an eccentric hilum and typically oval or bell shaped granules. Bean starch is typically large (up to 40 μm) and may exhibit a wobbly fissure with tucks in it as well as faint lamellae. Acorn starch from *Lithocarpus* sp. acorns is typically small (average 10 μm) and round with a slightly eccentric hilum. Starch from *Quercus* sp. acorns is small to medium sized (<15 μm) and triangular in shape. Grass starch from the panicoid subfamily is frequently faceted. However, granules also exhibit a range of rounded to faceted morphologies. Starch from the cf. Andropogoneae tribe in the Panicoideae subfamily exhibits typically medium to large sized granules (17–23 μm) with facets of different lengths. Starch from the cf. Paniceae tribe is typically smaller (maximum of 14 μm but usually less than 10 μm) and may exhibit twinned or compound starch granules. Pooid starch from the cf. Triticeae tribe is typically medium to large sized (15–25 μm) and rounded in shape. The hilum is centric and fissures typically absent.

Table 9-7 Types of Starch Grains Recovered from Artefact Residues

Identification	Type of Starch	Images	
Cf. Underground Storage Organs (yams and tubers)	Large (up to 40 μm) oval to ovate or sometimes bell shaped granules. Hilum is very eccentric and lamellae may be present. Fissures may be present.		
Fabaceae cf. <i>Vigna</i> sp.	Large (up to 40 μm) irregularly round, not faceted, granules. Fissure wobbly not straight and may have several 'tucks' in it. Lamellae may be visible and prominent.		
Fagaceae – <i>Lithocarpus</i> sp.	Frequently small (average of 10 μm) and round to oval starch grains with a hilum that is just eccentric. Hilum usually not hyper-eccentric as in Dioscoreaceae yams starch hila.		
Fagaceae – <i>Quercus</i> sp.	Small to medium (<15 μm) irregularly shaped granules that are sometimes roughly triangular.		
Poaceae – Panicoid subfamily cf Andropogoneae tribe	Medium to large granules (average size between 17–23 μm) with facets that may be of irregular lengths unlike the more regularly faceted millets. May be fissured.		
Poaceae – Pooid subfamily cf Triticeae tribe	Medium to large (usually between 15–25 μm) round granules often with prominent lamellae. Hilum usually centric or very close to it. Cross may be diagnostic.		

In addition to the six taxonomically recognisable groups of starch described above, three other morphologically distinct categories of starch were recognised from the ancient samples. These include less taxonomically distinct categories such as round irregular starch granules (unknown type 1), small round starch granules (unknown type 2) and unidentifiable starch grains. A total of 1,230 starch granules were recovered from these six artefacts with approximately 40 percent or 491 granules being unidentifiable.

An important diagnostic feature of starch grains relates to the size of the grain. Larger starch grains have been identified by Piperno and other colleagues as being indicative of domesticated maize starch rather than wild teosinte grains (Dickau, et al., 2007; Piperno, 1984; Piperno, et al., 2009). The range of starch grain sizes in a population also appears diagnostic to taxa and possibly to species, hence the common use of size graphs in starch publications (Liu, Li, et al., 2010a; 2010b; 2010c; 2011). Hence size ranges of the modern reference samples of starch were compared with ancient samples of starch grains in order to make accurate identifications. The graphs of these starch grain populations are given below.

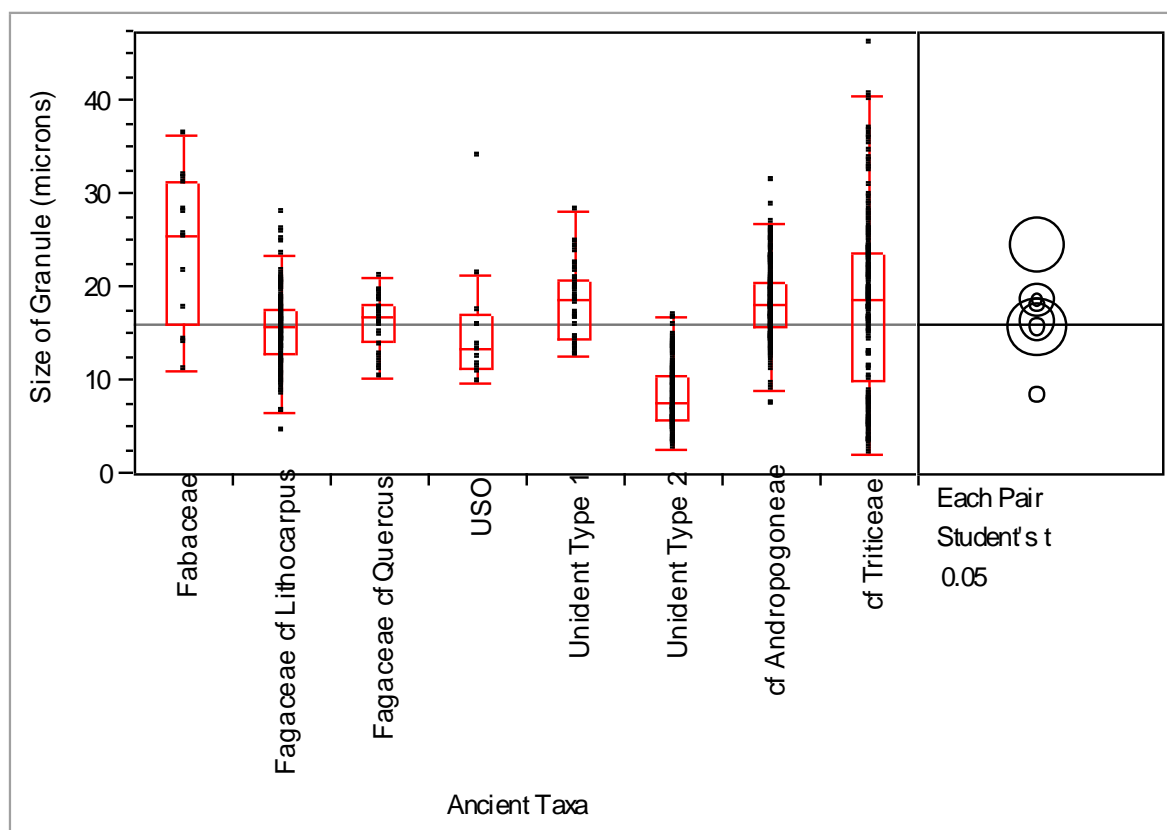


Figure 9-6 Differences between identified taxa from Tieshenggou grinding residues

Table 9-8 Differences between identified taxa from Tieshenggou grinding residues

Level	No. Granules	Minimum	Median	Maximum
Fabaceae	13	11.3	25.74	36.5
Fagaceae cf <i>Lithocarpus</i>	137	4.7	15.89	27.99
Fagaceae cf <i>Quercus</i>	29	10.51	17.13	21.16
Unident Type 1	35	12.7	18.77	28.31
Unident Type 2	134	2.82	7.74	16.95
cf Andropogoneae	195	7.45	18.3	31.49
cf Underground Storage Organ	12	9.79	13.55	34.11
cf Triticeae	176	2.12	18.85	46.27

The 8 types of taxa (6 taxonomic groups and two unknown types of starch) appear to exhibit relatively distinct populations based on size range criteria and mean sizes of populations (Figure 9-6). As expected, there is some degree of overlap between sizes of different groups (Table 9-8; Table 9-9). These different taxa will be discussed below.

Table 9-9 Differences between identified taxa from Tieshenggou grinding residues

Abs(Dif)-LSD	Fabaceae	cf Andropogoneae	Unident Type 1	cf Triticeae	Fagaceae cf <i>Quercus</i>	cf Underground Storage Organ	Fagaceae cf <i>Lithocarpus</i>	Unident Type 2
Fabaceae	-4.3684	2.7005	2.3571	3.2364	4.5314	4.3857	5.6198	12.8678
cf Andropogoneae	2.7005	-1.0843	-1.9414	-0.5839	0.1598	-0.3443	1.7398	8.9843
Unident Type 1	2.3571	-1.9414	-2.6623	-1.5987	-0.5224	-0.8560	0.7658	8.0127
cf Triticeae	3.2364	-0.5839	-1.5987	-1.1906	-0.4222	-0.9174	1.1369	8.3816
Fagaceae cf <i>Quercus</i>	4.5314	0.1598	-0.5224	-0.4222	-2.9248	-3.2274	-1.6751	5.5720
cf Underground Storage Organ	4.3857	-0.3443	-0.8560	-0.9174	-3.2274	-4.5467	-3.3449	3.9032
Fagaceae cf <i>Lithocarpus</i>	5.6198	1.7398	0.7658	1.1369	-1.6751	-3.3449	-1.3657	5.8793
Unident Type 2	12.8678	8.9843	8.0127	8.3816	5.5720	3.9032	5.8793	-1.3761

Positive values show pairs of means that are significantly different.

9.5.1 cf Andropogoneae Tribe of Poaceae Grass Family

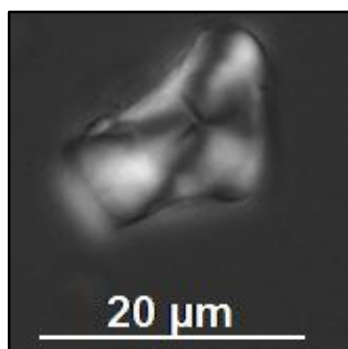
The Andropogoneae tribe of the grass family is one of a number of closely related panicoid grasses. It includes taxa such as sorghum (*Sorghum* sp.), Job's tears (*Coix* sp.) and maize (*Zea* sp.). A total of approximately 41 genera and 204 species from this grass tribe are found in China today (Chen, S. L., B. Sun, et al., 2006). These include five species of

sorghum. However, only *Sorghum nitidum* and *Sorghum propinquum* are considered native to China (Chen, S. L., & Phillips, 2006b). A total of 195 grains or 16 percent of starch grains recovered from the six Tieshenggou artefacts analysed in detail were assigned to this category. These are discussed in detail below.

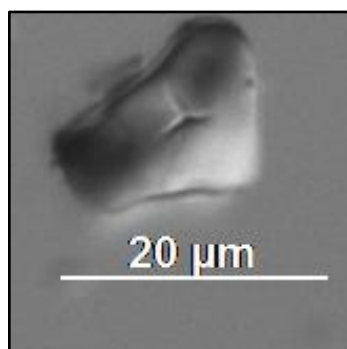
There are similarities between starch grains from grasses in the Andropogoneae tribe and the Paniceae tribe, probably because both these tribes are in the Panicoideae subfamily. Typically, modern reference starch tested from the millet Paniceae tribe is smaller than modern reference starch from the Andropogoneae tribe (Figure 7-30). However, both tribes exhibit common features. Grains may be faceted, rounded or a combination of both faceted and rounded (Figure 9-7; Figure 7-29). Fissures may be present. The hilum is typically centric or approximately centric. Lamellae are rare to absent in both tribes. From the reference material examined it is possible that some Andropogoneae tribe references examined have less regular or even facets than millet tribe starches.

The cf. Andropogoneae tribe starch grains exhibit a complex morphology. They are similar to various published images of grass starch grains including maize (*Zea* sp.) (e.g., Dickau, et al., 2007; Holst, et al., 2007; Piperno, et al., 2009; Zarrillo, et al., 2008). However, maize was domesticated in the Americas (Piperno, et al., 2009) and is an historic period introduction to China. It is highly unlikely that domesticated maize was present in Peiligang period North China. Given the similarity of the ancient granules to modern maize, and after modern contamination has been unequivocally ruled out, the most parsimonious explanation is that a relative of maize is represented in the samples. For this reason the starch grains from several relatives of maize were examined (Figure 9-8; Table 9-10; Table 9-11). These are discussed below.

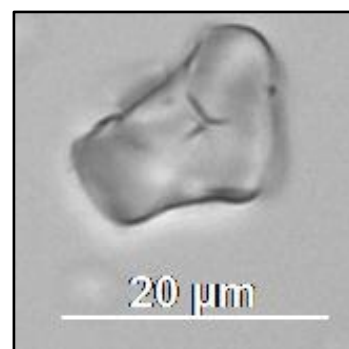
Aside from maize, other economically useful plants in the Andropogoneae tribe in North China include sorghum (*Sorghum* sp.). Sorghum has a similar large granule and faceted morphology to maize and to the ancient cf. Andropogoneae tribe starch grains (Figure 7-29). While *Sorghum bicolor* is another historic period introduction to China there are several other species of sorghum that may be native to China including *Sorghum nitidum* and *Sorghum propinquum* (Chen, S. L., & Phillips, 2006b). These taxa are now considered very rare and it was not possible to obtain a reference sample hence various other *Sorghum* sp. starch grains were examined.



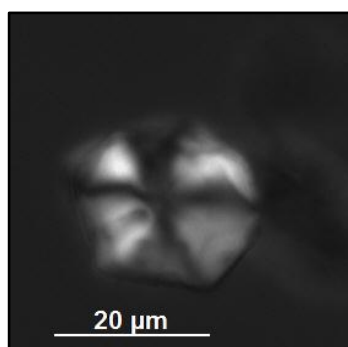
a) TSG_R9_starch61 under a cross-polarising filter



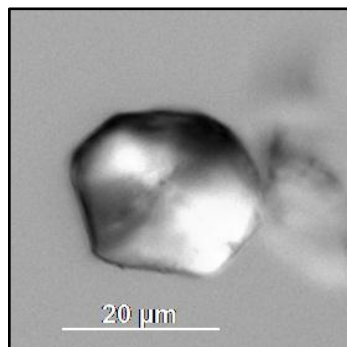
b) TSG_R9_starch61 under a DIC filter



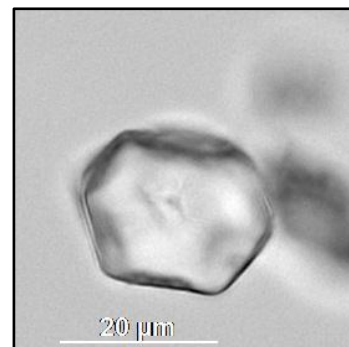
c) TSG_R9_starch61 under a brightfield filter



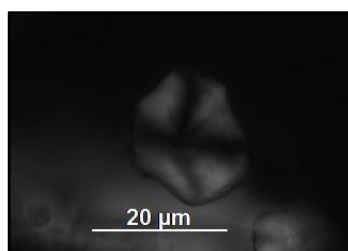
d) TSG_R9_starch16 under a cross-polarising filter



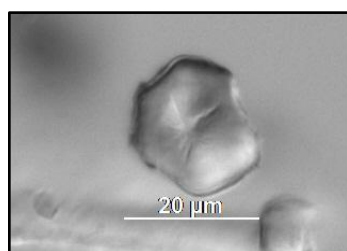
e) TSG_R9_starch16 under a DIC filter



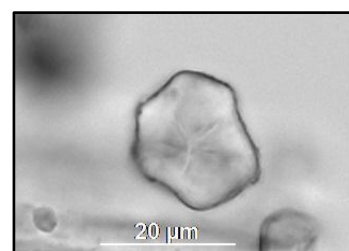
f) TSG_R9_starch16 under a brightfield filter



g) TSG_R9_starch25 under a cross-polarising filter



h) TSG_R9_starch25 under a DIC filter



i) TSG_R9_starch25 under a brightfield filter

Figure 9-7 Ancient cf. *Andropogoneae* tribe starch exhibiting starch grains with irregular facets

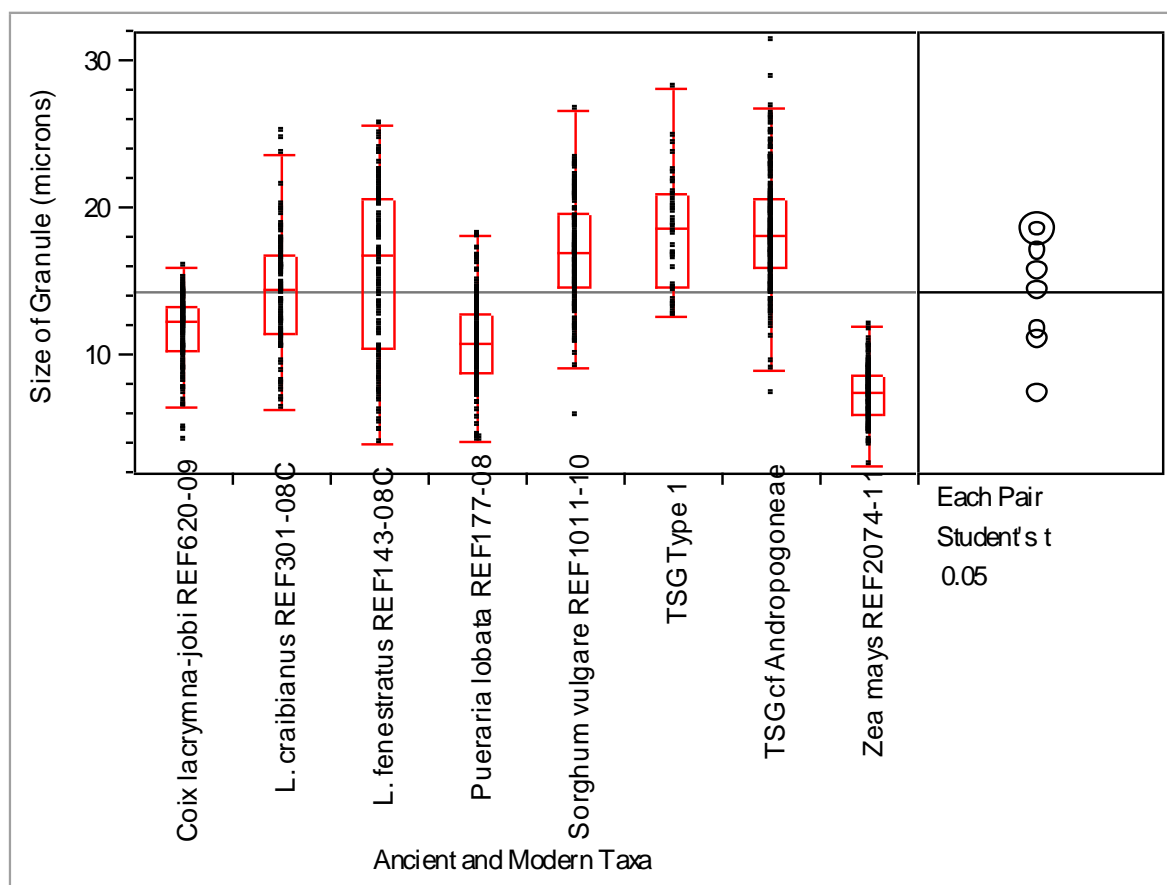


Figure 9-8 Graphical comparison of starch similar to cf Andropogoneae ancient starch.

Table 9-10 Ancient and Modern cf. Andropogoneae Tribe Starch Taxa

Level	No. Granules	Minimum	Median	Maximum
<i>Coix lacryma-jobi</i> REF620–09	116	4.27	12.395	16.1
<i>Lithocarpus craibianus</i> REF301–08C	101	6.37	14.54	25.18
<i>Lithocarpus glaber</i> REF561–08C	109	5.02	12.97	23.18
<i>Pueraria lobata</i> REF177–08	115	4.27	10.99	18.19
<i>Sorghum vulgare</i> REF1011–10	122	5.49	17.42	27.3
TSG Type 1 unknown	35	12.7	18.77	28.31
TSG cf Andropogoneae	195	7.45	18.305	31.49
<i>Zea mays</i> REF2074–11	114	2.57	7.6	12.05

Table 9-11 Ancient and Modern cf. Andropogoneae Tribe Starch Taxa

Abs(Dif)-LSD	TSG cf Andropogoneae	TSG Type 1	<i>Sorghum</i> <i>vulgare</i> REF1011–10	<i>L. fenestratus</i> REF143–08C	<i>L. craibianus</i> REF301–08C	<i>Coix lacryma-</i> <i>jobi</i> REF620– 09	<i>Pueraria</i> <i>lobata</i> REF177–08	<i>Zea mays</i> REF2074–11
TSG cf Andropogoneae	-0.7267	-1.2664	0.6863	1.9565	3.2861	5.9591	6.6885	10.3150
TSG Type 1	-1.2664	-1.7109	0.0946	1.3700	2.7113	5.3708	6.1011	9.7275
<i>Sorghum vulgare</i> REF1011–10	0.6863	0.0946	-0.9240	0.3475	1.6800	4.3496	5.0793	8.7057
<i>L. fenestratus</i> REF143–08C	1.9565	1.3700	0.3475	-0.9480	0.3848	3.0541	3.7837	7.4102
<i>L. craibianus</i> REF301– 08C	3.2861	2.7113	1.6800	0.3848	-1.0022	1.6661	2.3959	6.0223
<i>Coix lacryma-jobi</i> REF620–09	5.9591	5.3708	4.3496	3.0541	1.6661	-0.9398	-0.2102	3.4163
<i>Pueraria lobata</i> REF177–08	6.6885	6.1011	5.0793	3.7837	2.3959	-0.2102	-0.9439	2.6825
<i>Zea mays</i> REF2074– 11	10.3150	9.7275	8.7057	7.4102	6.0223	3.4163	2.6825	-0.9439

Positive values show pairs of means that are significantly different.

Job's tears (*Coix lacryma-jobi*) are thought to have been used in ancient China, with the earliest known record of them occurring in Xinjiang province around 2,000 cal BP (Jiang, H.-E., et al., 2008). However, starch grains of Job's tears are typically rounded and quite distinct from the ancient cf. Andropogoneae tribe starch from Tieshenggou (Figure 7-29). This taxon was therefore excluded from consideration.

Chinese silver grass (*Miscanthus sinensis*) is another taxon in the Andropogoneae tribe of the Panicoid sub-family of grasses. Starch grains from the seeds of Chinese silver grass were examined. They appeared relatively small and faceted and their dissimilarity to the ancient starch granules in terms of size range allowed them to be excluded from consideration. Size ranges of these granules are not presented in this thesis.

There are similarities between the cf. Andropogoneae starch grains from Tieshenggou and the size ranges of some *Lithocarpus* sp. acorns including *L. craibianus* (Figure 9-8; Table 9-10;

Table 9-11). However, it is difficult to see a morphological similarity between ancient cf. Andropogoneae taxa and modern *Lithocarpus* sp. acorns. Some of the kudzu vine (*Pueraria lobata*) starch grains were similar to the cf. Andropogoneae tribe ancient taxa

but the size range of the measured taxa is a poor match. The morphological and size similarity of the ancient cf. *Andropogoneae* starch with other *Andropogoneae* tribe taxa is considerable. For this reason cf. *Andropogoneae* taxa were assigned to a grass (*Poaceae*) rather than an oak (*Fagaceae*) taxonomic grouping. As with all starch identifications presented in this thesis, identifications were made on both morphological (2-D shape) and size (maximum dimension through hilum) grounds.

9.5.2 Underground Storage Organs

Underground storage organs (USO) are common in a range of families including the yam (*Dioscoreaceae*) family and the cucurbit (*Cucurbitaceae*) family. It is difficult to separate out taxa from these families when they occur in archaeological sites and for this reason starch from probable underground storage organs were grouped together.

Starch from the cucurbit family has not been identified archaeologically in China. However, the *Dioscoreaceae* family has diagnostic starch granules (Fullagar, et al., 2006:600; Torrence, et al., 2004) which may include bell-shaped or oval starch granules (Figure 7-13). These were identified on artefacts from several Papua New Guinea sites including on stone tools in the Ivane Valley that date between 44,000 – 49,000 years ago (Summerhayes, et al., 2010). The early agricultural or horticultural site of Kuk Swamp also exhibited *Dioscorea* sp. starch grains dating to approximately 10,200 cal BP (Denham, 2007; Fullagar, et al., 2006). Yam type starch granules were identified at the Shizitan site in North China as residues on Late Palaeolithic grinding implements (Liu, Li, et al., 2011).

A range of different types of USO starch were identified from the Tieshenggou artefacts. Some of these are similar to modern reference samples including the Chinese mountain yam (*Dioscorea oppositifolia*) (Figure 7-13) and tianhuafen (*Trichosanthes kirilowii*) (Figure 7-12). A total of 12 grains or approximately 1 percent of starch in the Tieshenggou assemblage were similar to large, oval or bell-shaped USO starch grains (Figure 9-9; Figure 9-10). These grains exhibited an hyper eccentric hilum and lamellae were sometimes visible. These will be discussed below.

There is an apparent size difference between modern Chinese mountain yam (*Dioscorea oppositifolia*) starch, modern tianhuafen (*Trichosanthes kirilowii*) tuber starch and ancient USO starch from the Tieshenggou grinding implements (Figure 9-11). While the ranges of these starch populations overlap (Table 9-12) student t-test values suggest that the

examined populations of modern yam and tuber starch are significantly different to ancient yam starch, with a minimum t-test value of 0.7271, $df=4$, $p<0.05$ (Table 9-13). This suggests that the means of these size populations are significantly different.

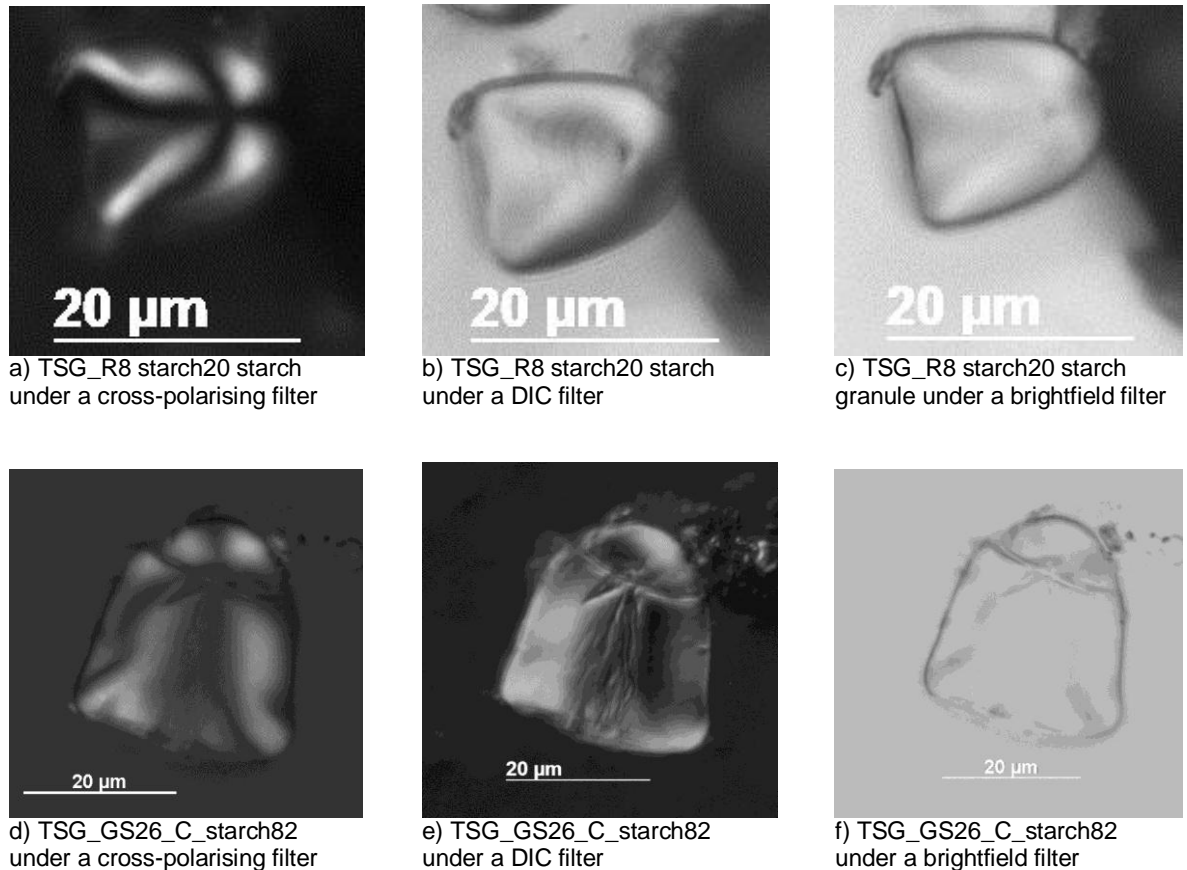
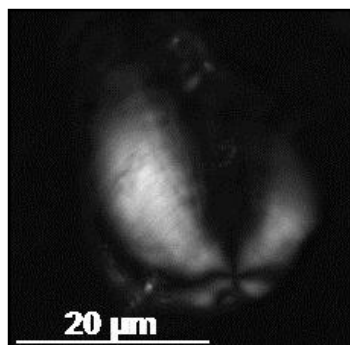


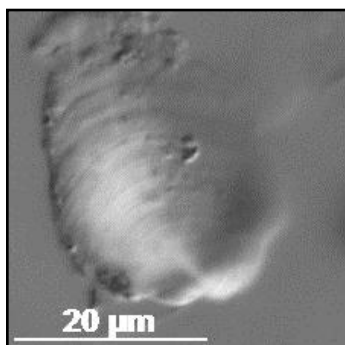
Figure 9-9 Bell shaped morphotypes of USO starch grains from Tieshenggou

It is possible that the small sample size of USO starch identified in the ancient samples ($n=12$) is not large enough to accurately represent the range of the starch population. These ancient granules may represent several different taxa of yam, tuber or USO starch. Another possible reason for the discrepancy in size ranges between ancient USO starch and modern reference starch relates to possible changes that occur under cultivation or domestication. There is no botanically recognised taxonomic difference between garden grown and cultivated *D. opposita* yams and wild *D. opposita* yams. Domestication has been linked in some grasses such as maize to an increased size of starch grains (e.g., Piperno, 1984) and significantly larger foxtail millet starch grains were observed in domesticated references (see Chapter 7). Given that USOs such as yams and tubers are still eaten and used today in China it is possible that some *Dioscorea* sp. yams in China have been cultivated and manipulated for millennia. However, as these cultivars are not considered a separate

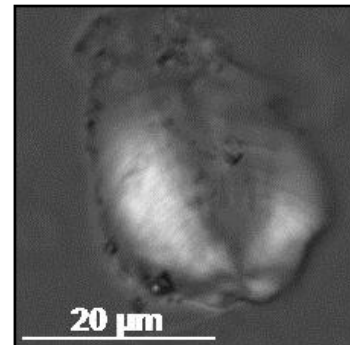
domesticated taxon it is difficult to determine whether ancient yam starch is smaller than modern yam starch. More research is required on this topic.



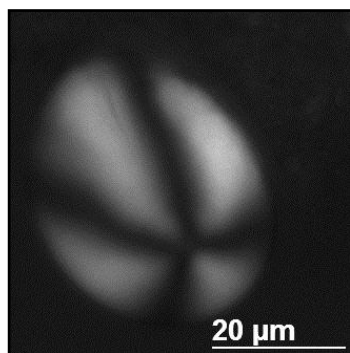
a) TSG-GS26_C_starch136
damaged starch granule under a
cross-polarising filter



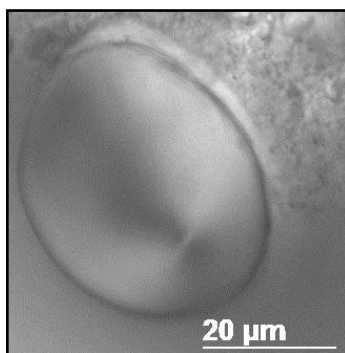
b) TSG-GS26_C_starch136
damaged starch granule under a
DIC filter



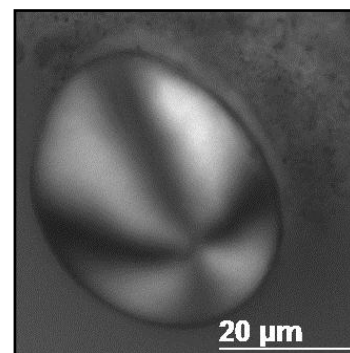
c) TSG-GS26_C_starch136
damaged starch granule under a
brightfield filter



d) TSG_R8_A cf tuber starch
under a cross-polarising filter



e) TSG_R8_A cf tuber starch
under a DIC filter



f) TSG_R8_A cf tuber starch
under a brightfield filter

Figure 9-10 Ovoid morphotypes of USO starch grains from Tieshenggou

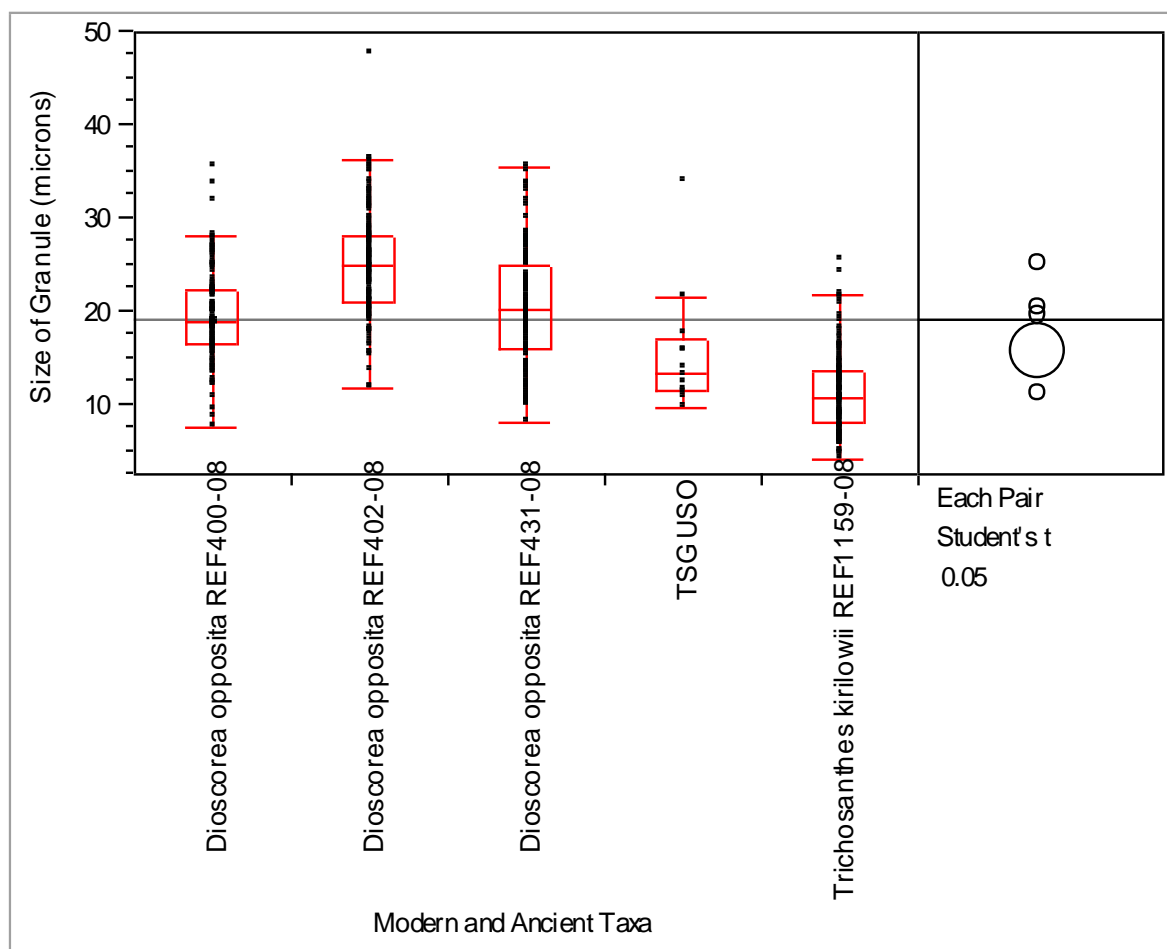


Figure 9-11 Graphical Comparison of USO starch with Ancient Tieshenggou Yam Starch

Table 9-12 Modern USO and Ancient Yam Starch

Level	No. Grains	Minimum	Median	Maximum
<i>Dioscorea oppositifolia</i> REF400-08C	102	7.74	18.87	35.5
<i>Dioscorea oppositifolia</i> REF402-08C	141	11.75	24.95	47.81
<i>Dioscorea oppositifolia</i> REF431-08C	121	8.25	20.4	35.56
TSG USO	12	9.79	13.55	34.11
<i>Trichosanthes kirilowii</i> REF1159-08C	131	4.34	10.84	25.64

Table 9-13 Student's t-test Values for Modern USO and Ancient Yam Starch

Abs(Dif)-LSD	<i>Dioscorea oppositifolia</i> REF402-08C	<i>Dioscorea oppositifolia</i> REF431-08C	<i>Dioscorea oppositifolia</i> REF400-08C	<i>Trichosanthes kirilowii</i> REF1159-08C	TSG cf Tuber
<i>Dioscorea oppositifolia</i> REF402-08C	-1.32135	3.33603	4.15270	12.6265	6.3630
<i>Dioscorea oppositifolia</i> REF431-08C	3.33603	-1.42052	-0.60169	7.8720	1.6360
<i>Dioscorea oppositifolia</i> REF400-08C	4.15270	-0.60169	-1.54600	6.9278	0.7271
<i>Trichosanthes kirilowii</i> REF1159-08C	12.6265	7.8720	6.9278	-1.2902	1.2415
TSG cf tuber	6.3630	1.43841	0.52790	1.2415	-4.2628

Positive values show pairs of means that are significantly different.

9.5.3 Fabaceae

Bean and legume (Fabaceae) family starch grains are distinctive to family level (Henry, et al., 2009). They have been identified at a range of sites including in early Holocene contexts such as the legume type starch grains in the ninth millennium BC in the Balsas River Valley in Mexico (Piperno, et al., 2009: S1). Starch grains identified as cf. *Vigna* sp. beans were identified at Shizitan, Shanxi Province, North China (Liu, Li, et al., 2011). Two grains similar to *Vigna angularis* were identified by X. Y. Yang and colleagues (2009a:1167) at the site of Shangzhai near Beijing, which dates to the early Holocene. A small number of 13 starch grains (approximately 1 percent) from Tieshenggou can be grouped into the Fabaceae cf. Phaseoleae tribe.

Modern beans and legumes tested from the Fabaceae family showed starch grains that exhibited a range of sizes (Table 9-14; Figure 9-12). Some of the largest starch grains recognised came from the adzuki bean (*Vigna angularis*) with the maximum size of this grain being 56 µm (Table 9-14). These are similar to ancient bean like starch from Tieshenggou (Figure 9-13). The closest match in terms of size to the ancient bean like starch comes from *Vigna angularis*, which has a positive student's t-test value of 1.2 at 4df, $p < 0.05$, showing that the mean granule size of this population is significantly different to the mean of the ancient Fabaceae taxa (Table 9-15). This may be because more than one type of bean is present in the Tieshenggou starch samples.

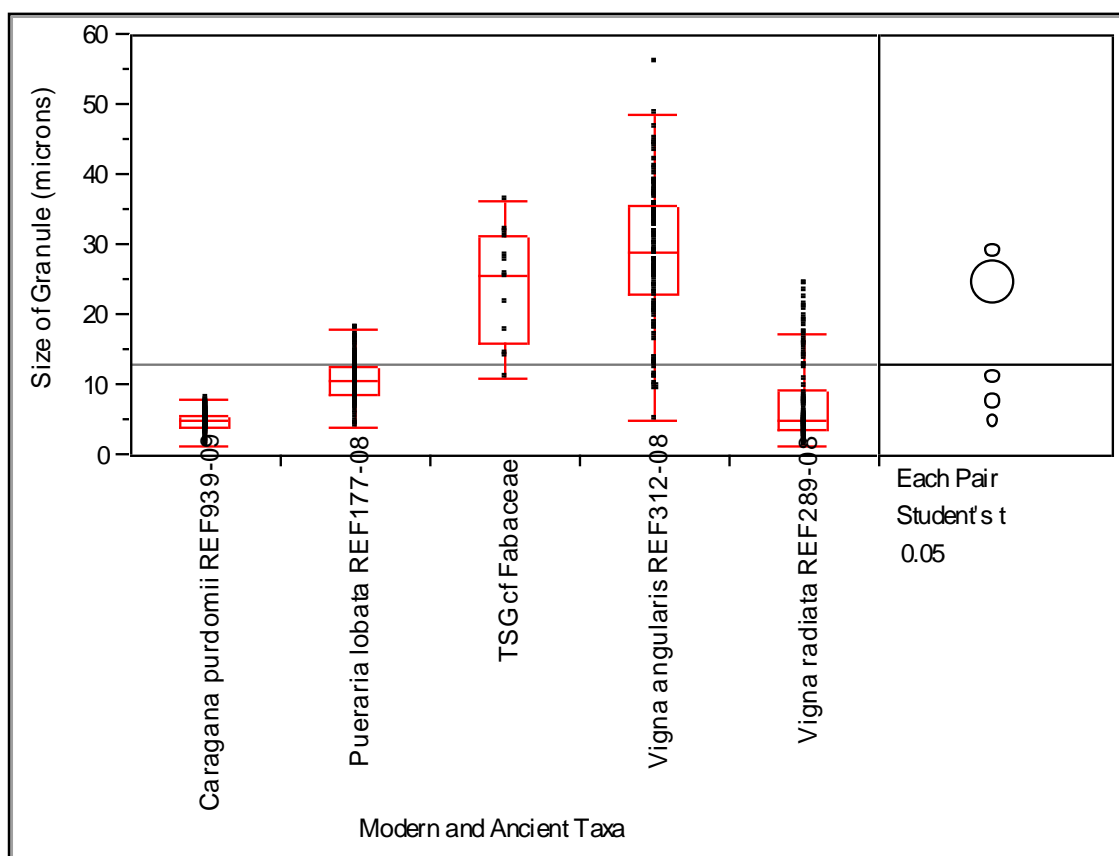


Figure 9-12 Graphical comparison between modern and ancient Fabaceae starch

Table 9-14 Modern and Ancient Fabaceae Starch

Level	No. Granules	Minimum	Median	Maximum
<i>Caragana purdomii</i> REF939-09	134	1.46	5.01	8.05
<i>Pueraria lobata</i> REF177-08	115	4.27	11	18.19
TSG cf Fabaceae	13	11.3	25.74	36.5
<i>Vigna angularis</i> REF312-08	109	5.23	29.28	56.12
<i>Vigna radiata</i> REF289-08	105	1.42	5.05	24.45

Table 9-15 Student's t-test Values for Comparisons of Modern and Ancient Fabaceae Starch

Abs(Dif)-LSD	<i>Vigna angularis</i> REF312-08	TSG cf Fabaceae	<i>Pueraria lobata</i> REF177-08	<i>Vigna radiata</i> REF289-08	<i>Caragana purdomii</i> REF939-09
<i>Vigna angularis</i> REF312-08	-1.5561	1.2049	16.4973	19.7636	22.6669
TSG cf Fabaceae	1.2049	-4.5058	10.0959	13.3812	16.2359
<i>Pueraria lobata</i> REF177-08	16.4973	10.0959	-1.5150	1.7509	4.6555
<i>Vigna radiata</i> REF289-08	19.7636	13.3812	1.7509	-1.5855	1.3170
<i>Caragana purdomii</i> REF939-09	22.6669	16.2359	4.6555	1.3170	-1.4034

Positive values show pairs of means that are significantly different.

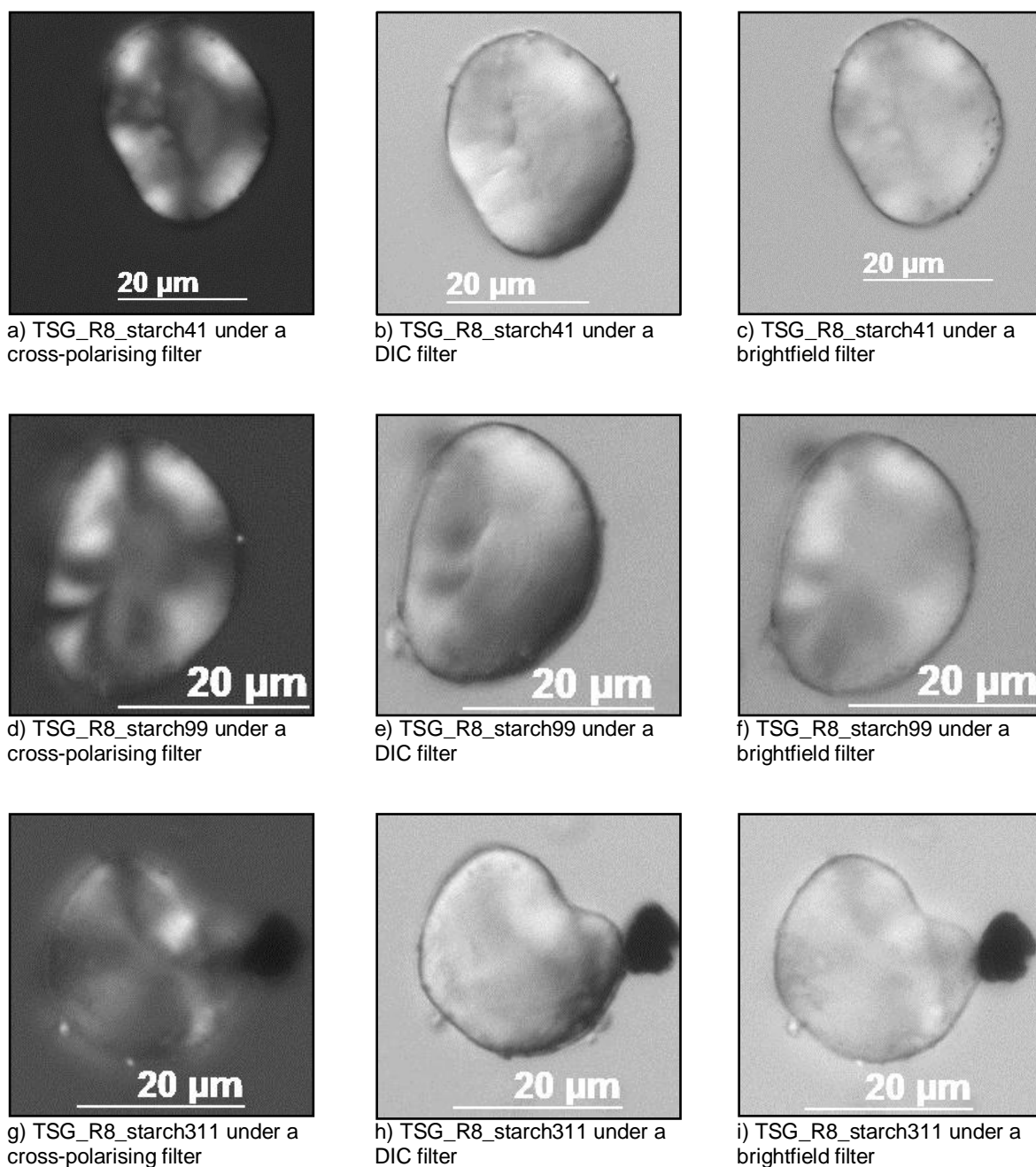


Figure 9-13 Bean like starch grains in the Tieshenggou assemblage

Morphologically the Tieshenggou bean type starch grains match with *Vigna* sp. beans. Apart from their large size, they tend to be irregularly rounded in shape. They also exhibit non-linear fissures with several folds or tucks and some granules have very obvious lamellae. A typical bean extinction cross is also quite diagnostic (Figure 7-16) and may exhibit more than four ‘arms’ when viewed under a polarising filter. For this reason the identification of these ancient Fabaceae taxa is made to cf. Phaseoleae tribe but further investigation is needed.

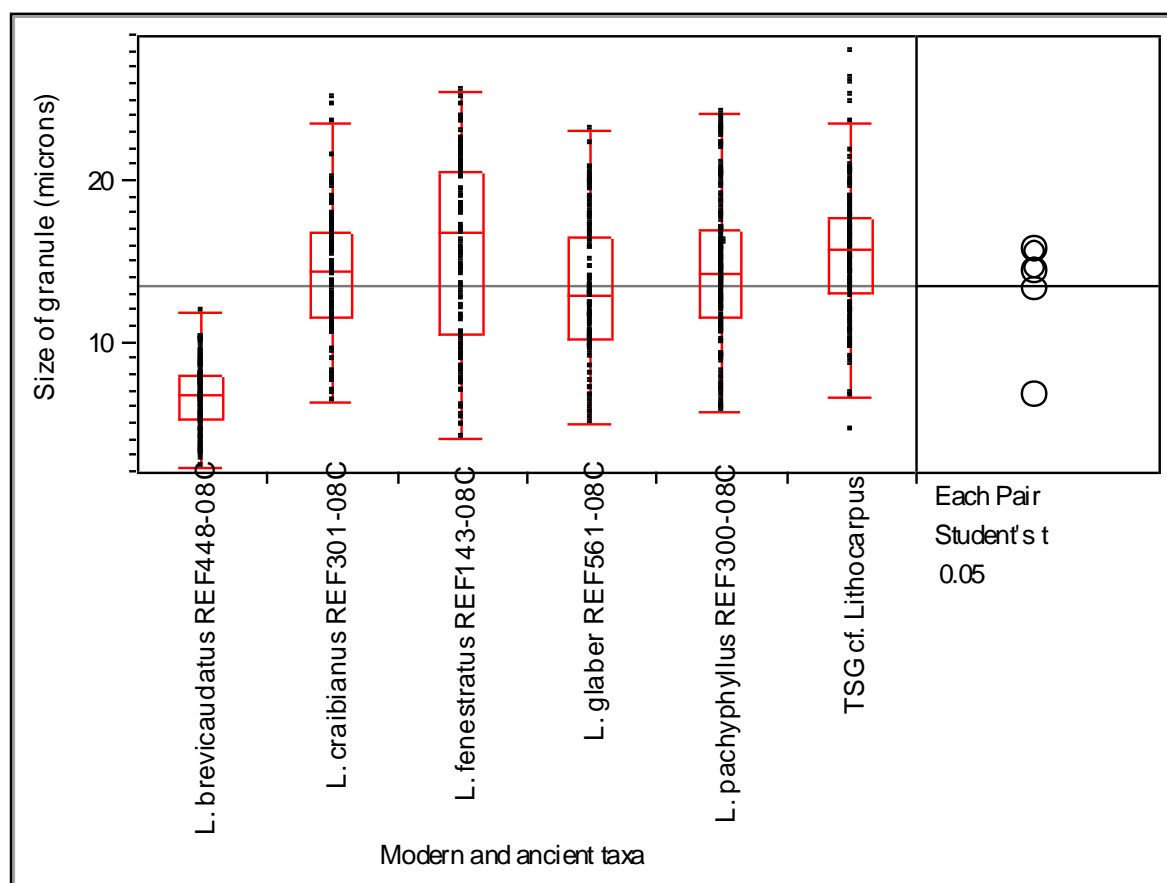
9.5.4 Fagaceae

Several types of acorns were examined and compared to ancient Tieshenggou starch populations. These include *Cyclobalanopsis* sp., *Lithocarpus* sp. and *Quercus* sp. acorns (see chap 7 section 7.3). Ancient starch granules exhibited morphological similarities to both *Lithocarpus* and *Quercus* sp. acorns but not to *Cyclobalanopsis* sp. acorns. The reasons for this are unclear but may relate to the relatively small sample size of grinding implements examined. A total of 137 starch grains or eleven percent of granules were identified as cf. *Lithocarpus* sp. A total of 29 starch grains or 2.4 percent of the total were identified as cf. *Quercus* sp. This makes a total of approximately 13.5 percent of starch grains which can be identified as acorn starch. The similarities of ancient starch to modern *Lithocarpus* sp. and *Quercus* sp. references will be outlined and discussed below.

9.5.4.1 FAGACEAE CF LITHOCARPUS

Lithocarpus sp. starch grains typically are small and round and have a slightly eccentric hilum (Figure 7-23). They are slightly similar to Job's tears (*Coix* sp.), but Job's tears starch grains may be faceted (Figure 7-29) and have a distinctive cross (Ge, et al., 2010). The *Lithocarpus* sp. type starch grains from the Tieshenggou assemblage have a size range between 5–28 μm (Table 9-17). This size range overlaps with several *Lithocarpus* sp. acorns including *L. craibianus*, *L. glaber* and *L. pachyphyllus* (Figure 9-15).

A student's t-test was performed to compare the means of the ancient and modern populations (Table 9-19). This suggests that the ancient *Lithocarpus* type starch grains correspond best with *Lithocarpus fenestratus* starch in terms of mean size and population size. The student's t-test value of -0.9 where a positive value suggests the two populations are significantly different, indicates the similarity of the modern *Lithocarpus* sp. starch with the ancient cf. *Lithocarpus* granules. Thus, ancient Tieshenggou cf. *Lithocarpus* starch may relate best to *L. fenestratus*, but more research on other *Lithocarpus* sp. morphology and a larger reference sample is needed to confirm this identification.

Figure 9-16 Graphical comparison of modern and ancient *Lithocarpus* sp. starchTable 9-17 Modern and Ancient *Lithocarpus* sp. Starch

Level	No. Granules	Minimum	Median	Maximum
<i>L. brevicaudatus</i> REF448-08C	135	2.45	6.88	11.95
<i>L. craibianus</i> REF301-08C	111	6.37	14.54	25.18
<i>L. fenestratus</i> REF143-08C	113	4.13	16.945	25.67
<i>L. glaber</i> REF561-08C	132	5.02	12.97	23.18
<i>L. pachyphyllus</i> REF300-08C	152	5.78	14.41	24.32
TSG cf. <i>Lithocarpus</i>	137	4.7	15.89	27.99

In addition to starch size range and granule morphology, the type of starch packing arrangement in cells may also be diagnostic. Some modern *Lithocarpus* sp. starch grains appear to be loosely packed within the plant cell (Figure 7-23). Modern references typically show starch from grass seeds packed very tightly with numerous granules located in each cell. This packing arrangement is evident in some acorns as well. However, other acorn starch appears to be packed loosely with only one to a few starch granules per cell. This may reflect a taxon specific feature or it may reflect the position of the plant cells

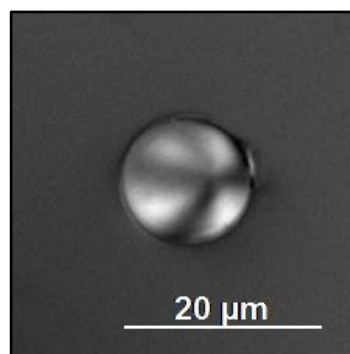
within the acorn. More research is needed to understand the importance of starch packing arrangements and how reliably it can be used as an archaeobotanical diagnostic feature.

Table 9-18 Student's t-test Values for Modern and Ancient *Lithocarpus* sp. Starch

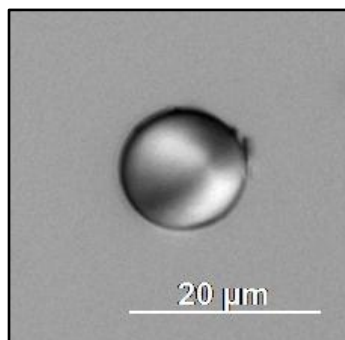
Abs(Dif)-LSD	<i>L. fenestratus</i> REF143–08C	TSG cf. <i>Lithocarpus</i>	<i>L. pachyphyllus</i> REF300–08C	<i>L. craibianus</i> REF301–08C	<i>L. glaber</i> REF561–08C	<i>L. brevicaudatus</i> REF448–08C
<i>L. fenestratus</i> REF143–08C	-1.09082	-0.92264	0.16775	0.23787	1.41692	7.90072
TSG cf. <i>Lithocarpus</i>	-0.92264	-1.00990	0.08185	0.14790	1.32774	7.81115
<i>L. pachyphyllus</i> REF300–08C	0.16775	0.08185	-0.94159	-0.87910	0.30143	6.78451
<i>L. craibianus</i> REF301–08C	0.23787	0.14790	-0.87910	-1.15320	0.02526	6.50935
<i>L. glaber</i> REF561–08C	1.41692	1.32774	0.30143	0.02526	-1.11048	5.37342
<i>L. brevicaudatus</i> REF448–08C	7.90072	7.81115	6.78451	6.50935	5.37342	-1.13123

Positive values show pairs of means that are significantly different.

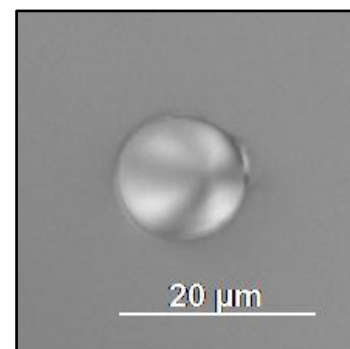
At the present time *Lithocarpus* sp. oaks mainly occur in the warmer and wetter sub-tropical areas of southern China (Huang, C., et al., 1999). However, in the past the climate in North China was thought to be much warmer and wetter, especially during the early Holocene hypsithermal (An, et al., 2000). It is possible that during the Late Palaeolithic and early Holocene period in North China, the range of *Lithocarpus* sp. oak trees extended further north than it does today. Detailed research on climate and the ancient environment of the study region is required to confirm this. However, the possibility of a local extinction of an important food source (see e.g., Fuller and Qin, 2010 regarding decline of oak trees in South China), possibly due to the changing climate and East Asian monsoon front, may have increased the usage and eventual domestication of millet grasses at this time.



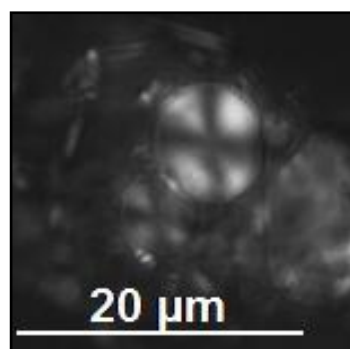
a) TSG-R9_starch69 under a cross-polarising filter



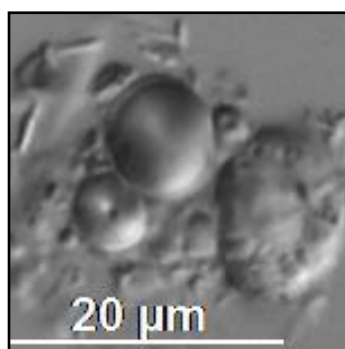
b) TSG-R9_starch69 under a DIC filter



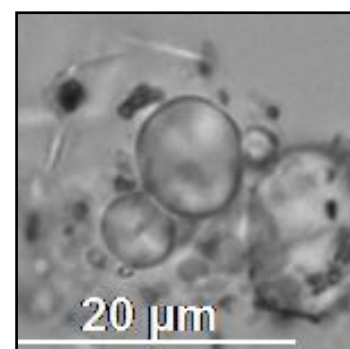
c) TSG-R9_starch69 under a brightfield filter



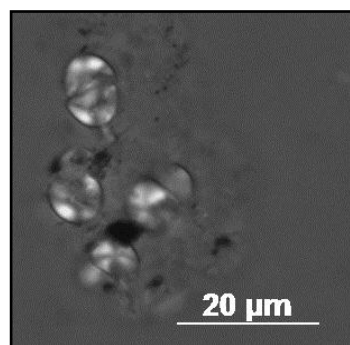
d) TSG_GS26_C_starch9-10 under a cross-polarising filter



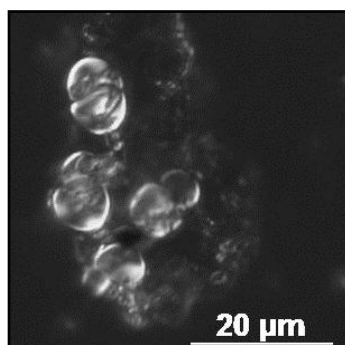
e) TSG_GS26_C_starch9-10 under a DIC filter



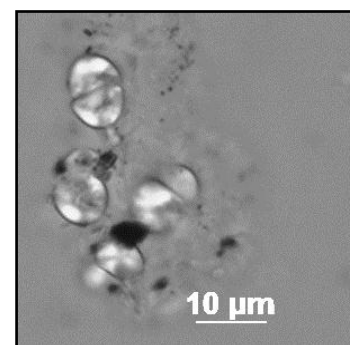
f) TSG_GS26_C_starch9-10 under a brightfield filter



g) TSG_GS26_C_starch291-297 under a cross-polarising filter



h) TSG_GS26_C_starch291-297 under a DIC filter



i) TSG_GS26_C_starch291-297 under a brightfield filter

Figure 9-14a-i Fagaceae cf *Lithocarpus* sp. starch grains from ancient Tieshenggou samples

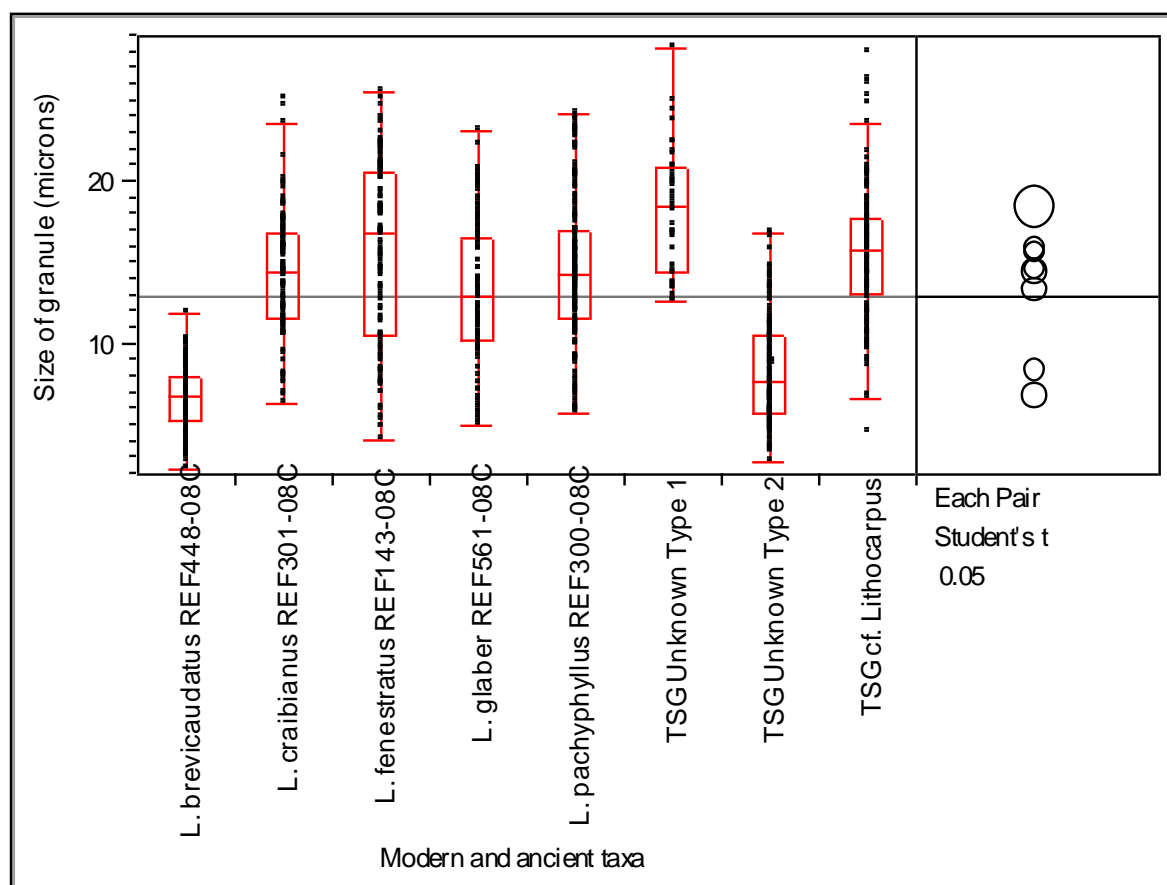


Figure 9-15 Graphical comparison of reference *Lithocarpus* starch compared with ancient Tieshenggou cf. *Lithocarpus* starch and two groups of Tieshenggou unidentified starch

Table 9-19 *Lithocarpus* sp. Starch Grains and Tieshenggou Unknown Starch Types

Level	No. Granules	Minimum	Median	Maximum
<i>L. brevicaudatus</i> REF448-08C	135	2.45	6.88	11.95
<i>L. craibianus</i> REF301-08C	111	6.37	14.54	25.18
<i>L. fenestratus</i> REF143-08C	113	4.13	16.95	25.67
<i>L. glaber</i> REF561-08C	132	5.02	12.97	23.18
<i>L. pachyphyllus</i> REF300-08C	152	5.78	14.41	24.32
TSG Unknown Type 1	35	12.7	18.63	28.31
TSG Unknown Type 2	134	2.82	7.74	16.95
TSG cf. <i>Lithocarpus</i>	137	4.7	15.89	27.99

Some of the unidentified or unknown starch taxa from Tieshenggou may be similar to *Lithocarpus* sp. starch. The unknown type 1 starch grains (round irregular type) overlap most closely with *L. fenestratus* in size ranges (Table 9-19; Figure 9-15) although the student's t-test suggests that the means of the two populations are significantly different with a t-test value of 1.09, df=1, $p < 0.05$. The small sample size of unknown type 1 ancient

starch grains could not be helped. The unknown type 2 starch grains (small indeterminate type) overlap most closely in size range with *L. brevicaudatus* (Figure 9-15) although these two groups are also significantly different at $t=0.5$ where $df=1$, $p<0.05$. It is possible that the unknown types of ancient starch grains represent populations of several different taxa. They are classified as unknown types mainly because at the present stage of research they are similar in shape to each other but do not appear diagnostic to any particular taxon. More research is needed to accurately identify them to genus or species.

Table 9-20 *Lithocarpus* sp. Starch Grains and Tieshenggou Unknown Starch Types

Abs(Dif)-LSD	TSG Unknown Type 1	<i>L. fenestratus</i> REF143-08C	TSG cf. <i>Lithocarpus</i>	<i>L. pachyphyllus</i> REF300-08C	<i>L. craibianus</i> REF301-08C	<i>L. glaber</i> REF561-08C	TSG Unknown Type 2	<i>L. brevicaudatus</i> REF448-08C
TSG Unknown Type 1	-1.8795	1.0946	1.2495	2.3287	2.4336	3.6056	8.5368	10.0928
<i>L. fenestratus</i> REF143-08C	1.0946	-1.0562	-0.8893	0.2001	0.2735	1.4519	6.3964	7.9360
TSG cf. <i>Lithocarpus</i>	1.2495	-0.8893	-0.9778	0.1129	0.1823	1.3614	6.3076	7.8452
<i>L. pachyphyllus</i> REF300-08C	2.3287	0.2001	0.1129	-0.9117	-0.8457	0.3341	5.2817	6.8176
<i>L. craibianus</i> REF301-08C	2.4336	0.2735	0.1823	-0.8457	-1.1166	0.0612	5.0045	6.5456
<i>L. glaber</i> REF561-08C	3.6056	1.4519	1.3614	0.3341	0.0612	-1.0752	3.8689	5.4090
TSG Unknown Type 2	8.5368	6.3964	6.3076	5.2817	5.0045	3.8689	-0.9890	0.5489
<i>L. brevicaudatus</i> REF448-08C	10.0928	7.9360	7.8452	6.8176	6.5456	5.4090	0.5489	-1.0953

Positive values show pairs of means that are significantly different.

Modern references from five *Lithocarpus* sp. and six *Quercus* sp. specimens were grouped together by genus and compared to Tieshenggou acorn type starch (Figure 9-16; Table 9-21). It is known that both these genera exhibit heteromorphic starch grains. The term ‘heteromorphic’ refers to starch populations which exhibit a variety of shapes (ICSN, 2011). The cf. Fagaceae starch from Tieshenggou included both *Lithocarpus* and *Quercus* type granules and may include some unknown type 1 and unknown type 2 granules. These latter both have some similarities to populations of acorn starch (see above) but are not considered diagnostic. When combined with the ancient cf. Fagaceae starch populations the mean values for the size range of the unknown starch type 1 and type 2 and cf. Fagaceae populations are significantly similar with a t-test value of -0.5. This indicates that the combination of cf. Fagaceae type starch (both *Lithocarpus* sp. and *Quercus* sp. combined) have strong affinities with *Lithocarpus* sp. starch in terms of size range (Table 9-21; Table 9-22; Figure 9-16). It is possible that unknown starch type 1 and unknown starch type 2 represent part of the *Lithocarpus* sp. starch population that is non-diagnostic.

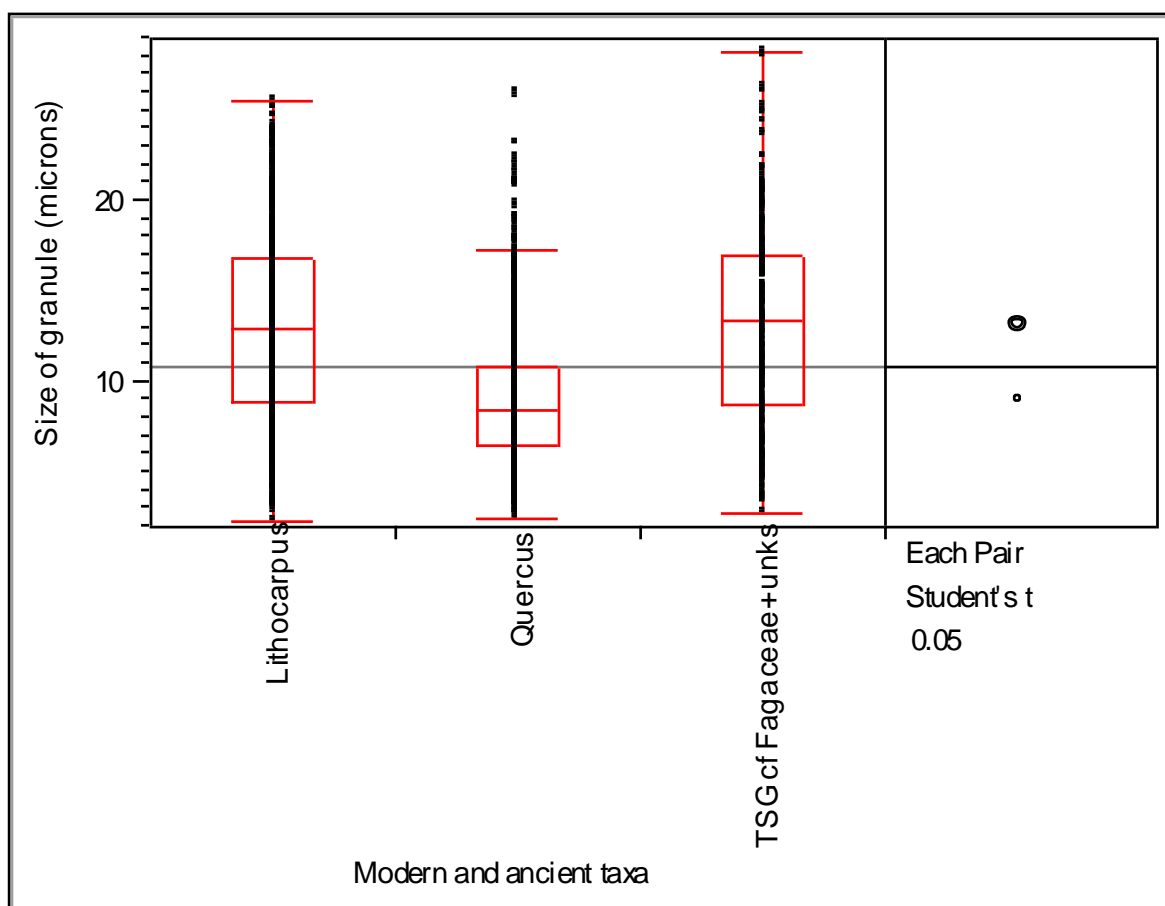


Figure 9-16 Graphical comparison of modern *Lithocarpus* sp. and *Quercus* sp. starch compared to ancient cf. Fagaceae taxa and unknown starch grains (unks)

Table 9-21 *Lithocarpus* and *Quercus* sp. Starch and Ancient Tieshenggou cf Fagaceae Taxa

Level	No. Grains	Minimum	Median	Maximum
<i>Lithocarpus</i>	585	2.45	13.04	25.67
<i>Quercus</i>	1148	2.57	8.53	26.02
TSG cf Fagaceae+unknown starch grains	327	2.82	13.49	28.31

Table 9-22 *Lithocarpus* and *Quercus* sp. Starch Compared to Tieshenggou cf Fagaceae Taxa

Abs(Dif)-LSD	<i>Lithocarpus</i>	TSG cf Fagaceae+unks	<i>Quercus</i>
<i>Lithocarpus</i>	-0.50539	-0.58712	3.63745
TSG cf Fagaceae+unknown starch grains	-0.58712	-0.67494	3.52626
<i>Quercus</i>	3.63745	3.52626	-0.36061

Positive values show pairs of means that are significantly different.

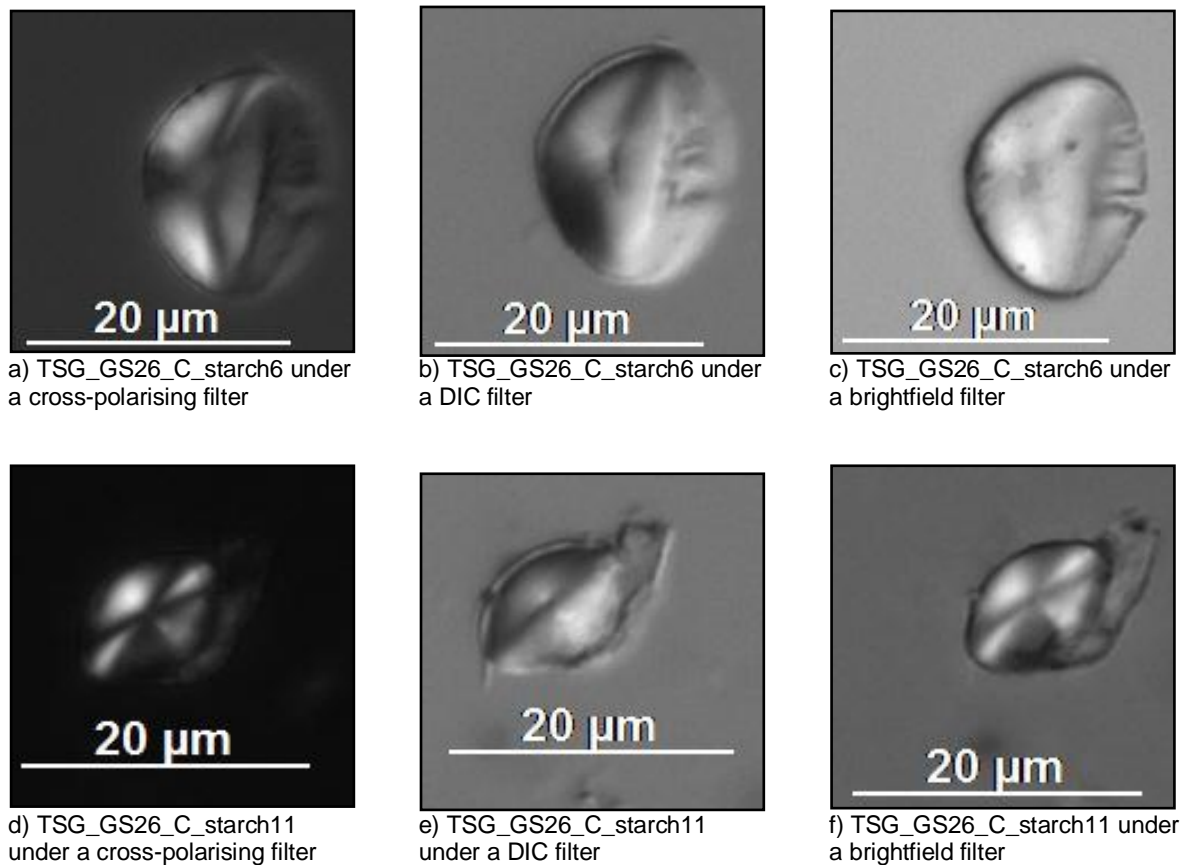
Reichert (1913: 311) describes such non-diagnostic starch in a population as less conspicuous (see also ICSN, 2011). It is possible that when the less diagnostic elements of the cf. Fagaceae ancient starch populations are added to the diagnostic elements of the cf. Fagaceae population, the size graphs match more closely with the modern Fagaceae *Lithocarpus* sp. references. Further research is needed to adequately understand how to characterize ancient heteromorphic starch populations and to identify accurately unknown starch type 1 and type 2.

9.5.4.2 FAGACEAE—*QUERCUS*

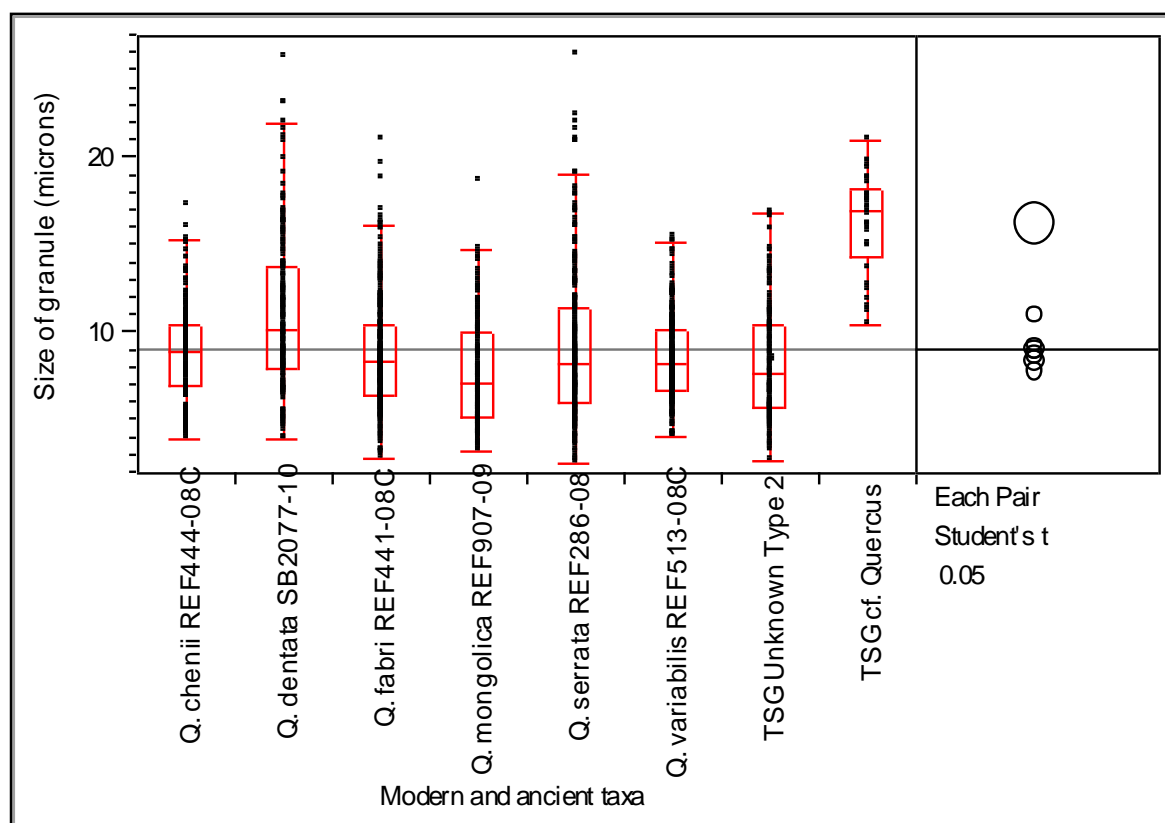
Diagnostic *Quercus* type starch grains are usually triangular in shape and may have a slightly eccentric hilum (Figure 7-24). A small number (n=29) of starch grains recovered from the Tieshenggou artefacts were identified as being similar to *Quercus* sp. starch grains (Figure 9-17).

Quercus sp. starch grains have been identified from a range of other sites in early Holocene North China. *Quercus* sp. starch grains were identified as residues from Donghulin site near Beijing (Liu, Li, et al., 2010b) and from the Baiyingchan site in northeast China (Tao, et al., 2011). Residues from *mopan* grinding implements at the Peiligang type site at Peiligang, Henan Province, also exhibited *Quercus* sp. starch grains (Zhang, Y., et al., 2011). Based on a small number of acorn starch references X. Y. Yang and colleagues (2009b) identified three types of acorns (*Q. mongolicus*, *Q. actuissima* and *Q. dentata*) to species level from a single artefact at the Shangzhai site near Beijing. My research on *Quercus* sp. taxa (section 7.3.3.2) was unable to differentiate ancient acorn starch to species level when recovered from ancient samples.

The small number of *Quercus* sp. granules when compared with *Lithocarpus* sp. granules recovered from residues at the Tieshenggou site may relate to several factors including an apparent absence of *Lithocarpus* sp. acorns and small reference collections in the modern plant assemblages of several Chinese researchers (e.g., Yang, X Y., et al., 2009 b; Zhang, Y., et al., 2011). The similarity of *Lithocarpus* sp. acorns to Job's tears (*Coix* sp.) starch grains may also be a factor.

Figure 9-17 Ancient *Quercus* sp. starch grains

A graph (Figure 9-18) and student's t-test comparisons (Table 9-24) of sizes of *Quercus* sp. starch grains identifies the 29 granules from Tieshenggou as being dissimilar in terms of size to modern *Quercus* sp. starch references. All of the six *Quercus* sp. taxa measured had a population mean that was significantly different from the Tieshenggou *Quercus* acorn starch. It is interesting to note that many *Quercus* sp. acorns have a size range that is statistically indistinguishable from one another (Table 9-23; Table 9-24; Figure 9-18).

Figure 9-18 Ancient cf *Quercus* starch compared with modern *Quercus* sp. starch

Many small *Quercus* sp. starch granules are likely to be unrecognised in the archaeobotanical record. These granules are small and non-diagnostic so are probably typically excluded from morphologically distinctive or conspicuous starch granule counts. Some of these granules are probably included in the unidentifiable starch group or as unknown starch taxa type 2.

Table 9-23 Ancient cf *Quercus* Starch Compared with Modern *Quercus* sp. Starch

Level	No. Granules	Minimum	Median	Maximum
<i>Q. chenii</i> REF444-08C	136	4.03	9.02	17.38
<i>Q. dentata</i> SB2077-10	170	3.96	10.2	25.83
<i>Q. fabri</i> REF441-08C	247	2.85	8.39	21.07
<i>Q. mongolica</i> REF907-09	153	3.26	7.15	18.68
<i>Q. serrata</i> REF286-08	231	2.57	8.34	26.02
<i>Q. variabilis</i> REF513-08C	212	4.14	8.36	15.55
TSG Unknown Type 2	134	2.82	7.74	16.95
TSG cf. <i>Quercus</i>	29	10.51	17.13	21.16

Table 9-24 Student's t-test Values Comparing cf *Quercus* sp. to Modern *Quercus* sp.

Abs(Dif)-LSD	TSG cf. <i>Quercus</i>	<i>Q. dentata</i> SB2077-10	<i>Q. serrata</i> REF286-08	<i>Q. chenii</i> REF444-08C	<i>Q. fabri</i> REF441-08C	<i>Q. variabilis</i> REF513-08C	TSG Unknown Type 2	<i>Q.</i> <i>mongolica</i> REF907-09
TSG cf. <i>Quercus</i>	-1.76382	3.87520	5.70027	5.91493	6.14829	6.35871	6.51913	7.18440
<i>Q. dentata</i> SB2077-10	3.87520	-0.72850	1.12015	1.29140	1.57277	1.77241	1.89132	2.57162
<i>Q. serrata</i> REF286-08	5.70027	1.12015	-0.62495	-0.46070	-0.17152	0.02623	0.13860	0.82114
<i>Q. chenii</i> REF444-08C	5.91493	1.29140	-0.46070	-0.81449	-0.53917	-0.33809	-0.21406	0.46446
<i>Q. fabri</i> REF441-08C	6.14829	1.57277	-0.17152	-0.53917	-0.60437	-0.40702	-0.29599	0.38701
<i>Q. variabilis</i> REF513-08C	6.35871	1.77241	0.02623	-0.33809	-0.40702	-0.65236	-0.53822	0.14372
TSG Unknown Type 2	6.51913	1.89132	0.13860	-0.21406	-0.29599	-0.53822	-0.83307	-0.15492
<i>Q. mongolica</i> REF907-09	7.18440	2.57162	0.82114	0.46446	0.38701	0.14372	-0.15492	-0.76790

Positive values show pairs of means that are significantly different.

When unknown type 2 starch grains (small unidentifiable starch) are grouped with morphologically identified *Quercus* sp. starch the population is a better sample size at $n=160$. When the unknown type 2 (small indeterminate) granules are combined with the *Quercus* sp. acorns from Tieshenggou, the resulting starch population exhibits a size range closer to that of modern *Quercus* samples (Figure 9-19). This suggests that some of the unknown and undiagnostic small starch grains in the population may belong to a number of different taxa including *Quercus* sp. taxa. However it is not possible to determine which of the small unknown starch granules belong to *Quercus* sp. taxa and which do not. They are retained in the unknown category here but it is likely that the occurrence of *Quercus* sp. starch in the assemblage is higher than the diagnostic granules predict.

The heteromorphic nature of *Quercus* sp. starch populations and the fact that not all starch granules from acorns are diagnostic or identifiable in archaeobotanical residue samples, may cause this anomaly. These non-diagnostic or inconspicuous forms of *Quercus* sp. starch should be present in the unknown or unidentified Tieshenggou starch populations, assuming a normal *Quercus* sp. starch distribution in the ancient population. As small unidentifiable granules are numerous in acorn starch populations, it is likely that they affect the size distribution of the population. After combining the small undiagnostic starch grains (common in many *Quercus* spp. populations) with *Quercus* taxa, the size mean of the combined population is statistically indistinguishable from *Quercus serrata* starch grains with a negative t-test value of -0.16 at $df=1$, $p<0.05$ (Table 9-26). The size ranges of the combined ancient population are within the boundaries for all six of the *Quercus* spp. measured (Table 9-25). This suggests that some of the small and undiagnostic granules

grouped as unknown type 2 granules belong to *Quercus* spp. taxa but are non-diagnostic. The similarity of sizes among *Quercus* spp. acorns do not allow for an identification of the presence of *Quercus serrata* in the ancient residue samples, but further research may determine more accurately the exact numbers of each type of acorn or taxon in the ancient samples.

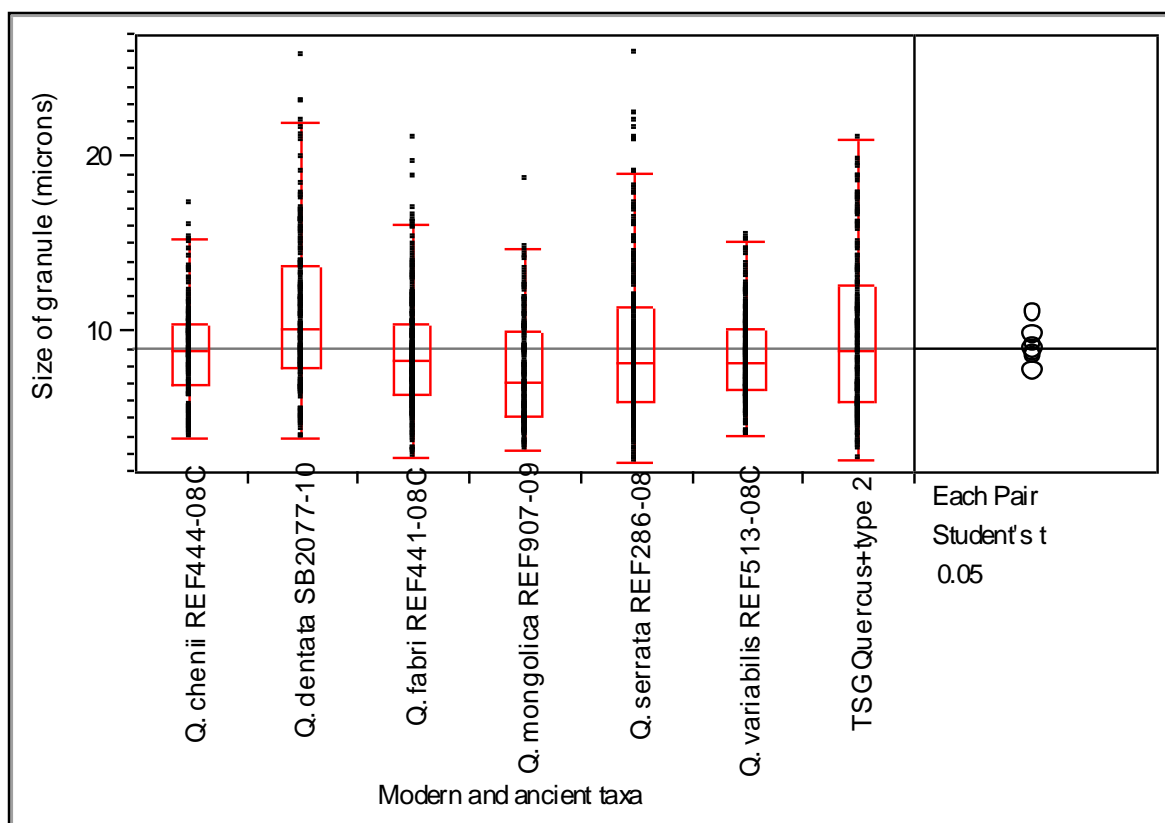


Figure 9-19 Graphic Comparison of Modern, Tieshenggou *Quercus* sp. and Unknown Type 2 starch grains

Table 9-25 Modern, Tieshenggou *Quercus* sp. and Unknown Type 2 Starch Grains

Level	No. Granules	Minimum	Median	Maximum
<i>Q. chenii</i> REF444-08C	136	4.03	9.02	17.38
<i>Q. dentata</i> SB2077-10	170	3.96	10.2	25.83
<i>Q. fabri</i> REF441-08C	247	2.85	8.39	21.07
<i>Q. mongolica</i> REF907-09	153	3.26	7.15	18.68
<i>Q. serrata</i> REF286-08	231	2.57	8.34	26.02
<i>Q. variabilis</i> REF513-08C	212	4.14	8.36	15.55
TSG <i>Quercus</i> +type 2	160	2.82	8.97	21.16

Table 9-26 Student's t-test Comparison of Modern and Tieshenggou *Quercus* sp. and Unknown Type 2 Starch Grains

Abs(Dif)-LSD	<i>Q. dentata</i> SB2077-10	TSG <i>Quercus</i> +type 2	<i>Q. serrata</i> REF286-08	<i>Q. chenii</i> REF444-08C	<i>Q. fabri</i> REF441-08C	<i>Q. variabilis</i> REF513-08C	<i>Q. mongolica</i> REF907-09
<i>Q. dentata</i> SB2077-10	-0.76275	0.45743	1.08825	1.25507	1.54130	1.73990	2.53644
TSG <i>Quercus</i> +type 2	0.45743	-0.78869	-0.15903	0.00947	0.29383	0.49288	1.29045
<i>Q. serrata</i> REF286-08	1.08825	-0.15903	-0.65433	-0.49483	-0.20042	-0.00380	0.78823
<i>Q. chenii</i> REF444-08C	1.25507	0.00947	-0.49483	-0.85277	-0.57288	-0.37278	0.42725
<i>Q. fabri</i> REF441-08C	1.54130	0.29383	-0.20042	-0.57288	-0.63278	-0.43658	0.35452
<i>Q. variabilis</i> REF513-08C	1.73990	0.49288	-0.00380	-0.37278	-0.43658	-0.68302	0.11023
<i>Q. mongolica</i> REF907-09	2.53644	1.29045	0.78823	0.42725	0.35452	0.11023	-0.80400

Positive values show pairs of means that are significantly different.

9.5.5 Triticeae Tribe of Pooideae Sub-family of Grasses

The Triticeae tribe of the grass family includes wheat and barley, both of which were introduced to China approximately 4,500 cal BP (Zhao, Z., 2009). Starch grains similar to those from the Triticeae tribe have been recovered from several sites in ancient China (Liu, Li, et al. 2010b; 2010c) including pre-agricultural sites such as Shizitan (Liu, Li, et al. 2011).

Triticeae starches are typically round and large (Figure 7-43; Figure 7-44; Figure 7-45). They may have lamellae present and are comparable with wild *Agropyron* sp. grasses. It is possible that some of the starch grains classified as Triticeae tribe are similar to certain sp. acorns including *Cyclobalanopsis jenseniana* (Figure 7-21). However, differences between the two species include small elongate fissures in the margins of *Cyclobalanopsis jenseniana* (Figure 7-21) that are not present in Triticeae taxa.

A total of 176 starch grains or almost 15 percent of the total grains from the six analysed artefacts at Tieshenggou exhibited Triticeae tribe starch grains. They were present on all six of the analysed artefacts.

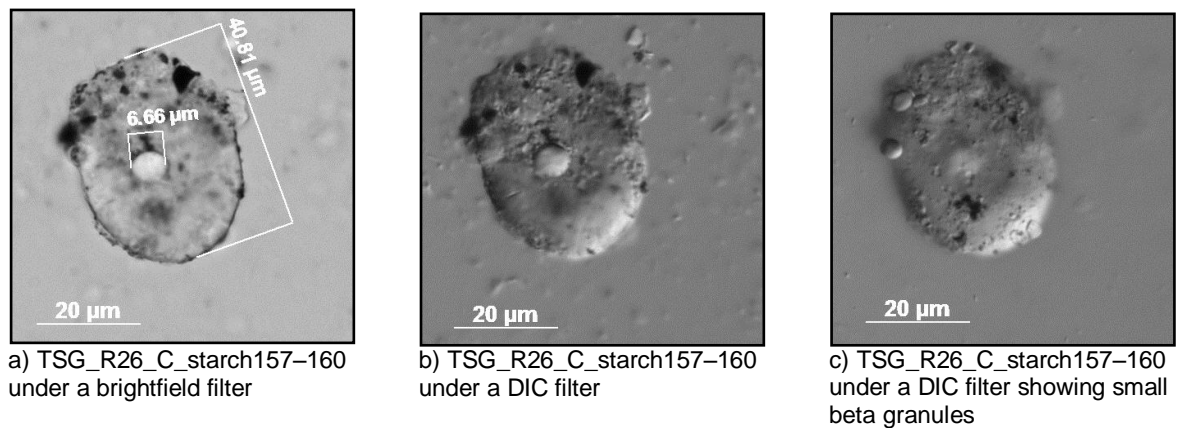


Figure 9-20 The occurrence of alpha and beta starch granules may be diagnostic to Triticeae tribe grasses

Diagnostic features of Triticeae tribe starch include the clusters of alpha and beta granules (Lindeboom, et al., 2004) (Figure 7-43; Figure 7-44). The size range of Triticeae tribe starch also tends to be larger than that of many other grasses including the Panicoideae tribe (Piperno, et al., 2004). The size ranges of ancient of Triticeae taxa correspond well to several other genera in this group including *Aegilops* sp. (goat grass).

A student's t-test comparison of means suggests that taxa in the Triticeae tribe exhibit relatively similar size ranges (Table 9-27). The population of ancient Triticeae tribe taxa from Tieshenggou is statistically indistinguishable from two specimens in the reference collection. The closest taxon population to the ancient taxa is *Agropyron cristatum* with a student's t-test value of -0.23. The other similar sized taxon, *Aegilops crassa*, which has a student's t-test value of -1.54 when compared to the ancient Triticeae starch, is not native to China (USDA, 2012).

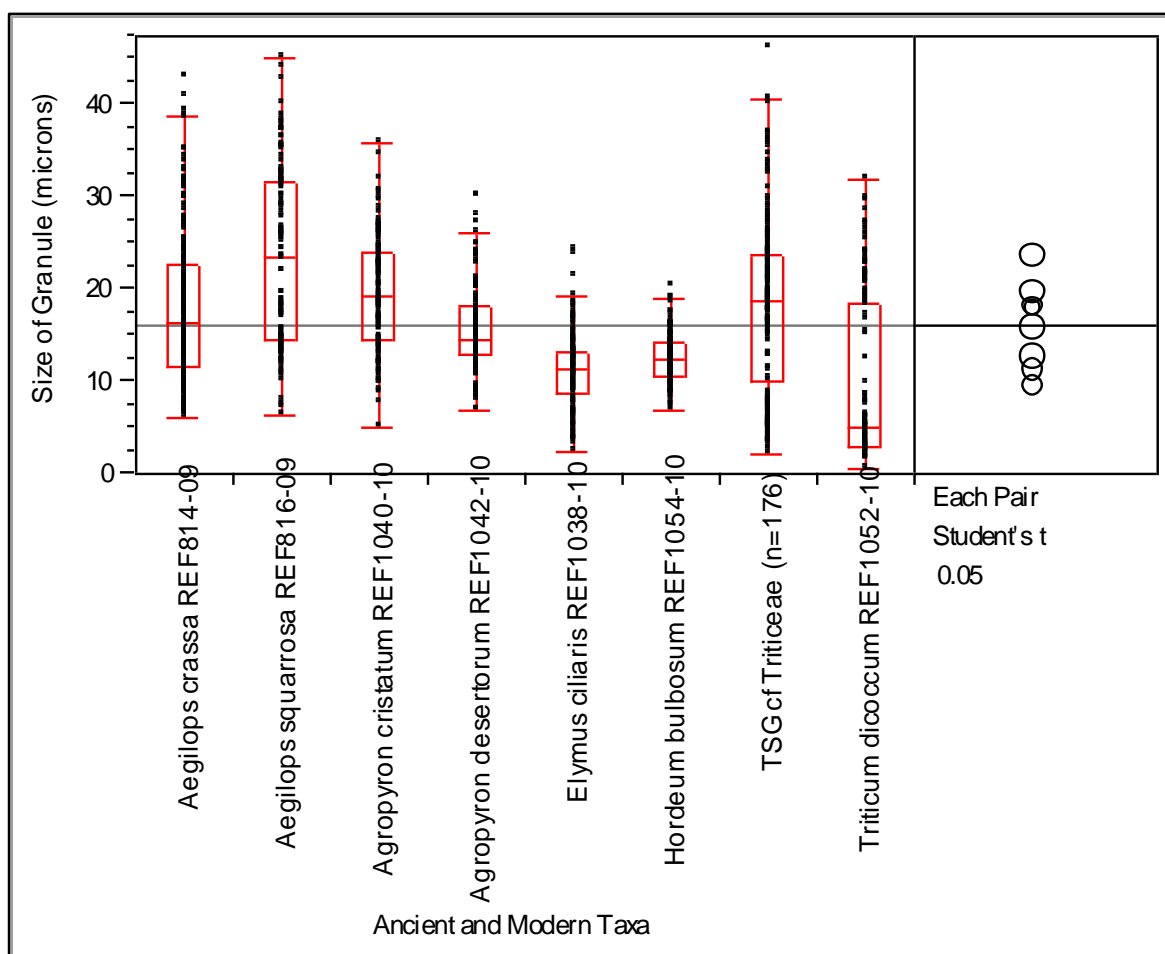


Figure 9-21 Graphical comparison of Triticeae taxa and TSG of Triticeae starch

Table 9-27 Triticeae Taxa and TSG of Triticeae Starch

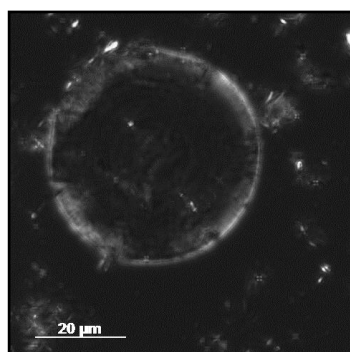
Level	No. Granules	Minimum	Median	Maximum
<i>Aegilops crassa</i> REF814–09	196	6.18	16.37	43.16
<i>Aegilops squarrosa</i> REF816–09	112	6.34	23.51	45.19
<i>Agropyron cristatum</i> REF1040–10	113	5.02	19.47	35.96
<i>Agropyron desertorum</i> REF1042–10	104	7.01	14.77	30.31
<i>Elymus ciliaris</i> REF1038–10	124	2.53	11.54	24.32
<i>Hordeum bulbosum</i> REF1054–10	112	6.92	12.64	20.47
TSG of Triticeae (n=176)	176	2.12	18.85	46.27
<i>Triticum dicoccum</i> REF1052–10	133	0.79	5.17	31.94

Table 9-28 Triticeae Taxa and TSG of Triticeae Starch

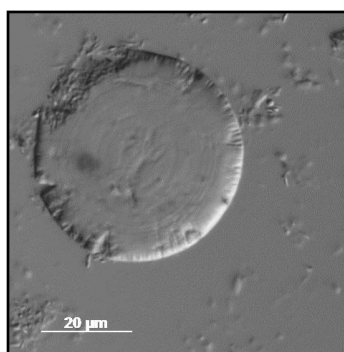
Abs(Dif)-LSD	<i>Aegilops squarrosa</i> REF816–09	<i>Agropyron cristatum</i> REF1040–10	TSG of Triticeae (n=176)	<i>Aegilops crassa</i> REF814–09	<i>Agropyron desertorum</i> REF1042–10	<i>Hordeum bulbosum</i> REF1054–10	<i>Elymus ciliaris</i> REF1038–10	<i>Triticum dicoccum</i> REF1052–10
<i>Aegilops squarrosa</i> REF816–09	-1.9268	1.9982	3.6836	3.8695	5.6624	8.9035	10.4005	12.1327
<i>Agropyron cristatum</i> REF1040–10	1.9982	-1.9183	-0.2324	-0.0464	1.7459	4.9870	6.4841	8.2164
TSG of Triticeae (n=176)	3.6836	-0.2324	-1.5415	-1.3505	0.4123	3.6570	5.1592	6.8948
<i>Aegilops crassa</i> REF814–09	3.8695	-0.0464	-1.3505	-1.4565	0.2992	3.5448	5.0481	6.7846
<i>Agropyron desertorum</i> REF1042–10	5.6624	1.7459	0.4123	0.2992	-1.9996	1.2408	2.7369	4.4685
<i>Hordeum bulbosum</i> REF1054–10	8.9035	4.9870	3.6570	3.5448	1.2408	-1.9268	-0.4298	1.3025
<i>Elymus ciliaris</i> REF1038–10	10.4005	6.4841	5.1592	5.0481	2.7369	-0.4298	-1.8312	-0.0982
<i>Triticum dicoccum</i> REF1052–10	12.1327	8.2164	6.8948	6.7846	4.4685	1.3025	-0.0982	-1.7682

Positive values show pairs of means that are significantly different.

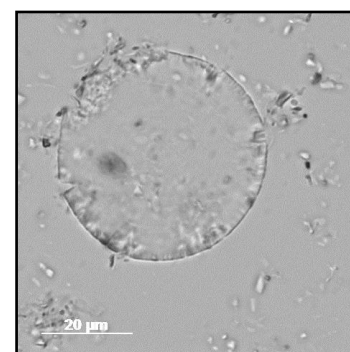
As expected, ancient Triticeae starch grains had the typical rounded shape, sometimes with lamellae visible (Figure 9-22). Henry and colleagues (2011; 2009) suggested that certain types of concentric rings similar to lamellae in Triticeae tribe grasses may be indicative of cooked starch. In their investigation of the Xishan site in northwestern China, Ge and colleagues (2010: Figure 2 and 3) have also identified these concentric rings as an indication of Triticeae starch damage by cooking. Therefore, some of the lamellae present on Triticeae tribe starch taxa from Tieshenggou may represent cooked starch (Figure 9-22a-f). However, Collins and Copeland (2011) have suggested that such starch may simply appear damaged due to old age. Further research is needed to determine whether the Triticeae tribe starch taxa represented at Tieshenggou were cooked prior to their processing on the grinding implements.



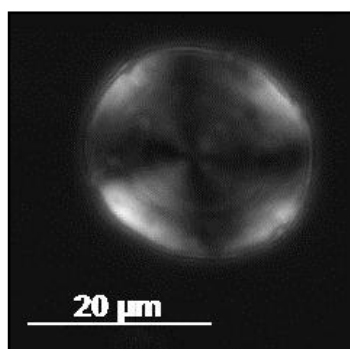
a) TSG_GS26_C_starch148
under a cross-polarising filter



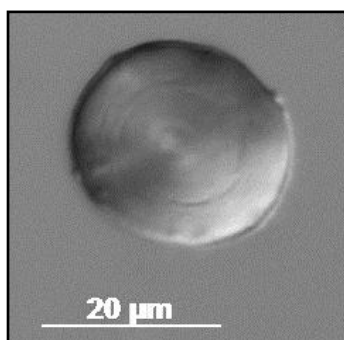
b) TSG_GS26_C_starch148
under a DIC filter



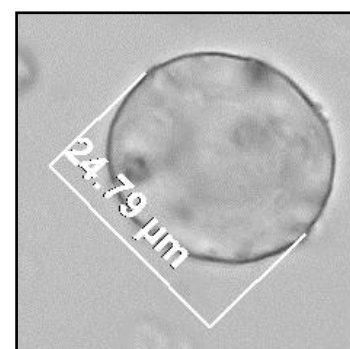
c) TSG_GS26_C_starch148
under a brightfield filter



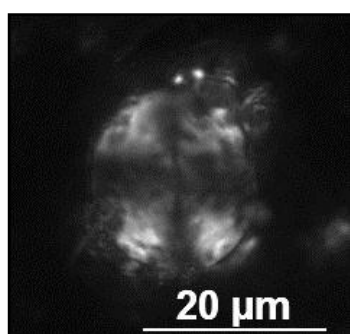
d) TSG_R9_starch84 under a
cross-polarising filter



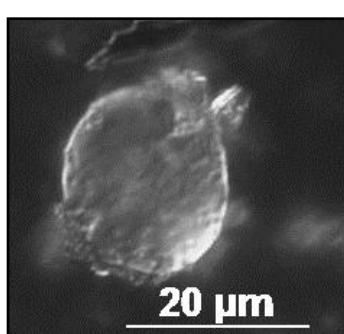
e) TSG_R9_starch84 under a
DIC filter



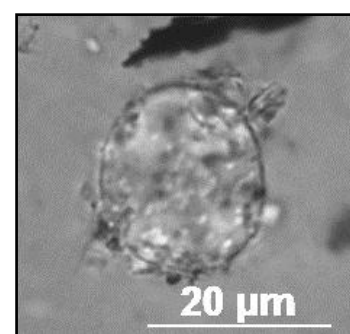
f) TSG_R9_starch84 under a
brightfield filter



g) TSG_GS26_C_starch194
under a cross-polarising filter



h) TSG_GS26_C_starch194
under a DIC filter



i) TSG_GS26_C_starch194
under a brightfield filter

Figure 9-22 Ancient Triticeae tribe starch granules from grinding implements

9.5.6 Bean or Wheatgrass

Less than one percent of the total number of starch granules ($n=8$) from Tieshenggou were classified as either bean or wheatgrass starch granules. Rounded shapes and the presence of lamellae are characteristic of both Fabaceae and Triticeae taxa. No further analysis was carried out on these granules.

9.5.7 Unknown Starch Grains

Approximately 40 percent of starch grains from Tieshenggou cannot be identified with certainty. These granules are not diagnostic or may be blurred or have diagnostic features obscured. No further analysis was carried out on these granules.

9.5.8 Round Irregular Type Starch Granules (Unknown type 2)

Approximately three percent of granules (n=35) were classified as rounded and irregular type starch granules. These granules are consistent with some Fagaceae type starch grains, but more research is needed to identify them with certainty.

9.5.9 Small Round Non-Descriptive Starch Granules (Unknown type 1)

Small round starch granules are not very diagnostic (Figure 9-23). It may not be possible to accurately identify the plants or processing tasks which resulted in deposition of numerous small starch granules on Tieshenggou artefacts. As discussed above they may represent smaller portions of heteromorphic acorn starch. They may also represent transient starch which occurs in leaves and stems of a range of plants. In the case of the latter such starch may represent various plant processing tasks including reed processing or processing of woody parts of plants. Small, non-diagnostic starch grains are similar to a number of small grasses including millet tribe grasses. The likelihood that some or all of these ancient granules belong to the Paniceae tribe is discussed below.

9.5.10 Paniceae (Millet) Tribe in Poaceae Grass Family

The Poaceae family includes approximately 28 tribes, 226 genera and 1795 species in China (Chen, S. L., D. Z. Li, et al., 2006). The millet (Paniceae) tribe includes 27 genera and 145 species in China today including some modern introductions (Chen, S. L., S. M. Phillips, & S. A. Renvoize, 2006). Paniceae tribe taxa include domesticated taxa such as some *Echinochloa* sp., *Pennisetum* sp., *Panicum* sp. and *Setaria* sp. Other weedy panicoid grasses include *Digitaria* sp. which was present in the Peiligang period at Jiahu (Zhao, Z. & J. Zhang, 2009). Starch from these taxa is generally similar looking (Figure 7-32; Figure 7-33; Figure 7-35; Figure 7-38) and the grains are typically small, hence for discussion purposes they are grouped together here.

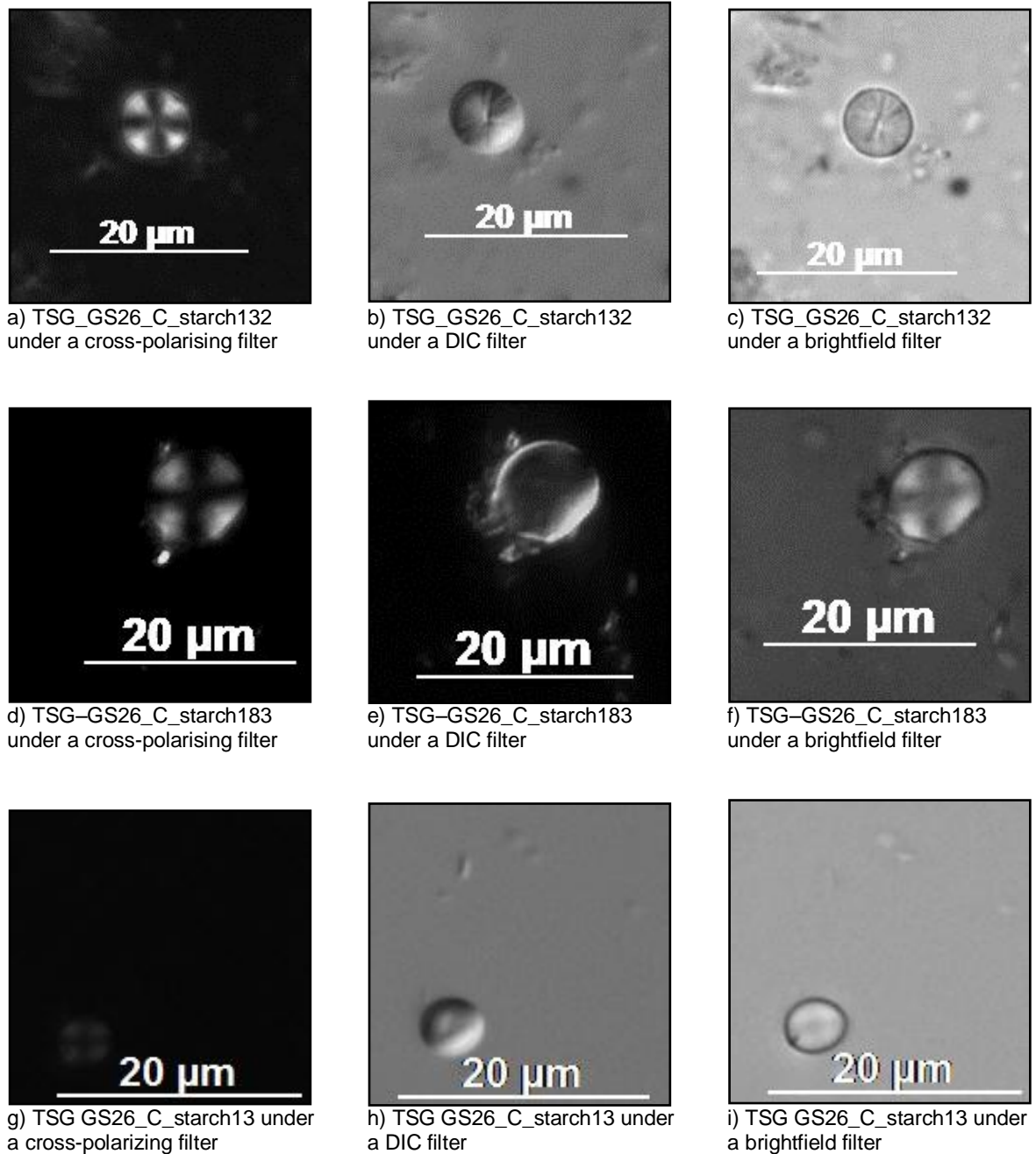
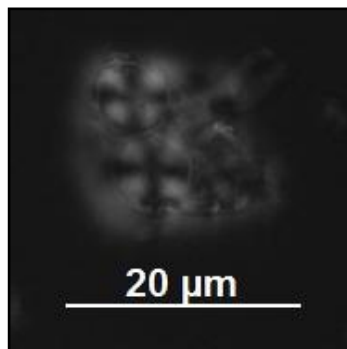


Figure 9-23 Small round non-diagnostic ancient starch grains

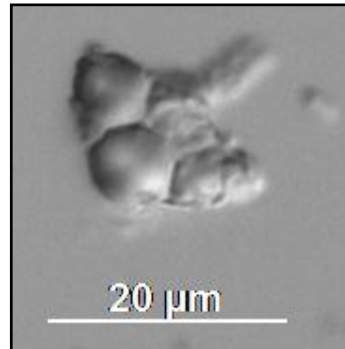
One of the more diagnostic features of these starch grains is the fact that they are often found together in clusters or as twinned granules. This distinguishes them from small and rounded transient starch grains which may occur in vegetative plant parts as starch is transported from storage organs throughout the plant. In cases where a population of smaller granules is present the growth or packing habit of these starch granules may be diagnostic. See Chapter 7 for more details regarding the identification and similarities of millet tribe taxa. Some of the clustered small round granules from Tieshenggou (Figure 9-23) are similar to a number of small grass starch taxa including those in the Panicoideae,

Ehrhartoideae and Chloridoideae sub-families. They are also similar to other small starch grains including some Cyperaceae tuber granules.

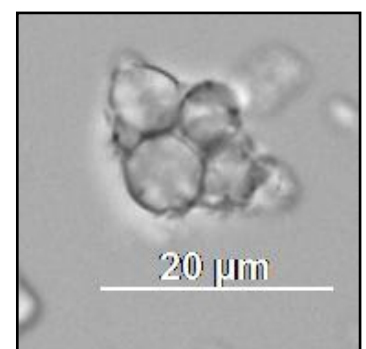
The Tieshenggou ancient starch grains unknown type 2 (small round indeterminate grains) overlap in size range and morphological shape with a number of small millet grasses including domesticated *Setaria* sp. and *Panicum* sp. starch grains. They also correspond in size and shape to a range of other taxa including wild millet tribe grasses such as *Digitaria* spp. and *Echinochloa* spp. taxa. All four of these genera are known from flotation samples within the study location and time period, hence the reason for their inclusion in the reference collection and millet size graphs.



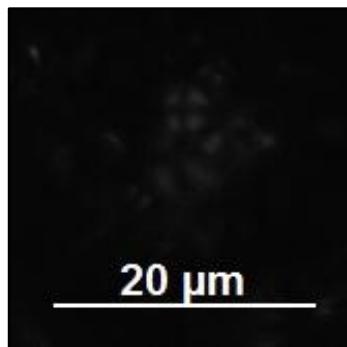
a) TSG_R9_starch78–82 under a cross-polarising filter



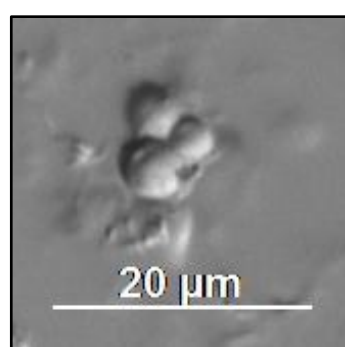
b) TSG_R9_starch78–82 under a DIC filter



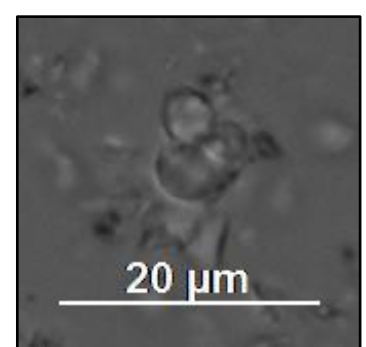
c) TSG_R9_starch78–82 under a brightfield filter



d) TSG_GS26_C_starch44–46_under a cross-polarising filter



e) TSG_GS26_C_starch44–46_under a DIC filter



f) TSG_GS26_C_starch44–46_under a brightfield filters

Figure 9-24 Small compound or clustered starch granules may belong to small grained grasses including millets

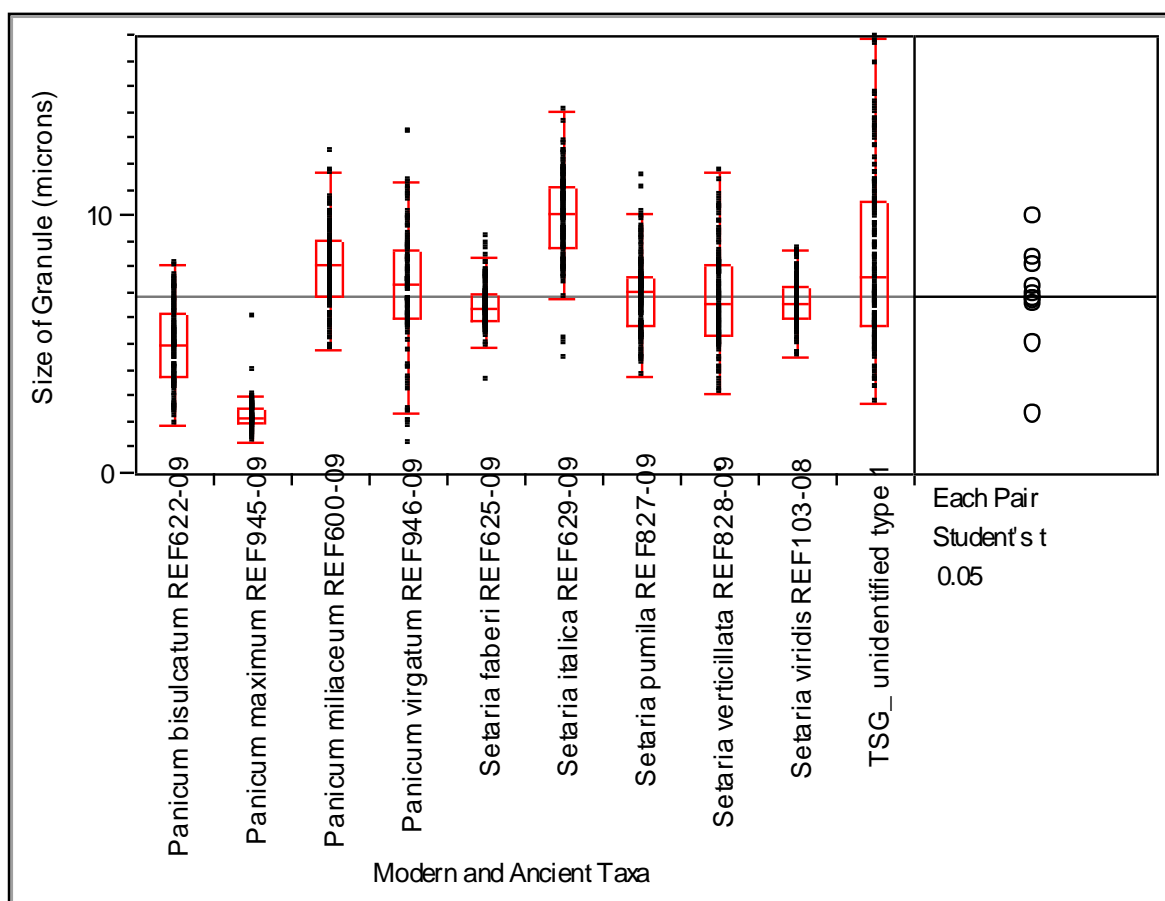


Figure 9-25 Graphic comparison of millet tribe starch and ancient type 1 granules

Table 9-29 Millet Tribe Starch and Ancient Type 1 Granules

Level	No. Granules	Minimum	Median	Maximum
<i>Panicum bisulcatum</i> REF622–09	107	1.89	5.07	8.19
<i>Panicum maximum</i> REF945–09	102	1.27	2.23	6.06
<i>Panicum miliaceum</i> REF600–09	100	4.86	8.17	12.48
<i>Panicum virgatum</i> REF946–09	111	1.2	7.37	13.26
<i>Setaria faberi</i> REF625–09	111	3.65	6.48	9.17
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	101	4.52	10.18	14.1
<i>Setaria pumila</i> REF827–09	140	3.82	7.12	11.59
<i>Setaria verticillata</i> REF828–09	109	0.16	6.65	11.74
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	103	4.55	6.67	8.71
TSG_unidentified type 1	134	2.82	7.74	16.95

Table 9-30 Millet Tribe Starch and Ancient Type 1 Granules

Abs(Dif)-LSD	<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	TSG_ unknown type 1	<i>Panicum miliaceum</i> REF600–09	<i>Panicum virgatum</i> REF946–09	<i>Setaria pumila</i> REF827–09	<i>Setaria verticillata</i> REF828–09	<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	<i>Setaria faberi</i> REF625–09	<i>Panicum bisulcatum</i> REF622–09	<i>Panicum maximum</i> REF945–09
<i>Setaria italica</i> ssp. <i>italica</i> REF629–09	-0.43663	1.11980	1.44192	2.28827	2.57864	2.70851	2.77648	2.95268	4.47643	7.22490
TSG_ unknown type 1	1.11980	-0.44161	-0.11941	0.72696	1.01719	1.14722	1.21522	1.39138	2.91515	5.66365
<i>Panicum miliaceum</i> REF600–09	1.44192	-0.11941	-0.47133	0.37518	0.66455	0.79551	0.86373	1.03960	2.56355	5.31220
<i>Panicum virgatum</i> REF946–09	2.28827	0.72696	0.37518	-0.47974	-0.19061	-0.05940	0.00888	0.18467	1.70867	4.45736
<i>Setaria pumila</i> REF827–09	2.57864	1.01719	0.66455	-0.19061	-0.42718	-0.29761	-0.22971	-0.05342	1.47027	4.21870
<i>Setaria verticillata</i> REF828–09	2.70851	1.14722	0.79551	-0.05940	-0.29761	-0.48412	-0.41581	-0.24007	1.28396	4.03267
<i>Setaria italica</i> ssp. <i>viridis</i> REF103–08	2.77648	1.21522	0.86373	0.00888	-0.22971	-0.41581	-0.49803	-0.32241	1.20170	3.95048
<i>Setaria faberi</i> REF625–09	2.95268	1.39138	1.03960	0.18467	-0.05342	-0.24007	-0.32241	-0.47974	1.04426	3.79295
<i>Panicum bisulcatum</i> REF622–09	4.47643	2.91515	2.56355	1.70867	1.47027	1.28396	1.20170	1.04426	-0.49093	2.25782
<i>Panicum maximum</i> REF945–09	7.22490	5.66365	5.31220	4.45736	4.21870	4.03267	3.95048	3.79295	2.25782	-0.50046

Positive values show pairs of means that are significantly different.

The range for Paniceae tribe starch is between 1–14 μm (Table 9-29) and many of the Tieshenggou type 2 unknown starch grains fall within this range. It is possible that a number of taxa are represented in this unknown ancient sample. However, the only taxon with a statistically similar population mean to the Tieshenggou unknown type 2 mean is broomcorn millet (Table 9-30). The student's t-test value for this comparison is $t=-0.12$ when $df=1$, $p<0.05$ which suggests that the mean of the broomcorn millet population measured is significantly similar. Due to the considerable overlap between many of the millet tribe taxa with several starch populations significantly similar to each other (Table 9-30), this does not identify the ancient granule population. It is not clear that the group of type 2 unknown starch granules does indeed represent a single population. Further research and a greater number of modern reference samples are required to identify the ancient starch granules to a taxonomic grouping.

9.6 Detailed Analysis of Tieshenggou Artefacts

Of the 27 fragments of *mopan* grinding slabs sampled from the Tieshenggou site a number were processed for residues. Six of the artefacts with large amounts of starch (over 70

granules present) were selected for detailed analysis (Table 9-31; Figure 9-26). Thus three *mopan* grinding slabs and three *mobang* grinding handstones were examined in detail for starch granules. Each individual artefact is discussed briefly below.

Table 9-31 Percentages of Types of Starch

Artefact	GS2	GS6	GS26	R1	R8	R9	Total
USO	1 (0.4%)	0 (0%)	6 (1.9%)	1 (0.5%)	2 (0.6%)	2 (1.8%)	12 (1%)
Fabaceae	1 (0.4%)	0 (0%)	6 (1.9%)	0 (0%)	6 (1.8%)	0 (0%)	13 (1.1%)
Fagaceae - <i>Lithocarpus</i>	8 (3.4%)	0 (0%)	4 (1.3%)	102 (56%)	20 (6%)	3 (2.8%)	137 (11.1%)
Fagaceae - <i>Quercus</i>	13 (5.6%)	0 (0%)	0 (0%)	5 (2.7%)	9 (2.7%)	2 (1.8%)	29 (2.4%)
Poaceae – cf. <i>Andropogoneae</i>	45 (19.4%)	0 (0%)	3 (0.9%)	1 (0.5%)	110 (33.1%)	36 (33%)	195 (15.9%)
Poaceae – cf <i>Triticeae</i>	14 (6%)	73 (100%)	51 (16.9%)	6 (3.2%)	12 (3.6%)	20 (18.3%)	176 (14.3%)
Bean/ wheatgrass	0 (0%)	0 (0%)	5 (1.6%)	0 (0%)	3 (0.9%)	0 (0%)	8 (0.7%)
Unknown type 1	0 (0%)	0 (0%)	3 (0.9%)	0 (0%)	32 (9.6%)	0 (0%)	35 (2.8%)
Unknown type 2 (small)	2 (0.8%)	0 (0%)	69 (22.3%)	12 (6.6%)	43 (12.9%)	8 (7.3%)	134 (10.9%)
Unknown	148 (63.8%)	0 (0%)	155 (51.3%)	55 (30.2%)	95 (28.6%)	38 (34.8%)	491 (39.9%)
Total	232	73	302	182	332	109	1230

9.6.1.1 TIESHENGGOU GRINDING *MOPAN* 2 (GS2)

Over 200 grains were recovered from this *mopan* (n=232) with more rounded than faceted or angular granules being recovered. Over half of these granules (60 percent) were unidentifiable taxa and cf. *Andropogoneae* starch comprised 20 percent of taxa.

Wheatgrass (*Triticeae* tribe) and *Quercus* sp. acorn starch contributed about 6 percent of starch each. *Lithocarpus* sp. starch grains accounted for 3 percent of starch taxa and one grain each of bean and cucurbit/yam starch was present. No husk type phytoliths were recovered.

9.6.1.2 TIESHENGGOU GRINDING *MOPAN* 6/7/10 (GS6)

A cluster of a minimum of 71 measurable starch grains was recovered from grinding *mopan* fragment 6 (fragments GS 7 and GS 10 are also part of this slab). An additional two granules were recovered from a second sample of GS6. Starch granules recovered from a

single cluster probably represent a single taxon, with a cluster being a homogenous group of granules found together on a slide. Numerous granules, both large and small, were recovered in this cluster; this combination of alpha and beta granules is characteristic of Triticeae tribe starch (Lindeboom, et al., 2004). In general, most of the starch granules in this cluster were rounded, rather than angular in shape and very few had facets. Some of the larger granules exhibited fissures and a few had prominent lamellae. It was difficult to tell whether granules smaller than about 8 μm in size had lamellae visible or fissures present and these details were not recorded for the majority of the smaller granules photographed. Where granules were partly obscured by cellular material or other starches it was also not always possible to record all shape and size details. Granules smaller than about 5 μm are also difficult to measure accurately and so were not recorded from this cluster (although they have been recorded for other clusters of 5 or fewer granules). No husk type phytoliths were recovered.

9.6.1.3 TIESHENGGOU GRINDING *MOPAN* 26 SAMPLE C (gs26)

Over 302 starch grains were recovered from this sample; counting stopped at around 300 grains in accordance with suggestions by Piperno (2006: 115) who suggested that this represents an adequate sample for phytolith counts. A large number (estimated at greater than 1000) of extremely small starch grains (<2 μm in maximum dimension) were noted on this artefact but their small size made them difficult to identify them or to note distinguishing characteristics or features. Due to their small size these granules were not included in the 'official' starch count, nor were they photographed as filters at this level of magnification tended to be poor.

The occurrence of large numbers of small starch grains may suggest a difference in the type of starchy plants ground on this *mopan* or a different level of maturity of the starchy foods being ground. It is also possible that differential preservation conditions including microclimates allowed the prolonged existence of smaller starch granules. After artefact collection from the field and during storage in the museum, all grinding *mopan* artefacts were stored in similar conditions so it would appear that post-collection storage conditions have not unduly affected or altered the starch. This is an important point for researchers who are concerned about post-excavation sample contamination. However, research by Barton (2007) on museum stored artefacts did not find contamination damage.

Other starch grains from this grinding *mopan* included over 50 percent of unidentifiable granules. Over twenty percent of granules were small and rounded unknown type 2 granules. As discussed previously, it is possible for these granules to be assigned to a range of taxa including small acorn starch or small grass starch grains. Over 15 percent of granules were assigned to the cf. Triticeae tribe and some of the small, non-diagnostic unknown type 2 starch grains may belong to small beta wheat tribe granules. In addition, small numbers of USO and of bean starch grains account for almost two percent of starch grains each. *Lithocarpus* sp. acorn starch, cf. Andropogoneae tribe starch and unknown type 1 starch accounts for one percent each of starch. No husk type phytoliths were recovered.

9.6.2 Tieshenggou *Mobang* style rollers

Mobang style grinding implements from Tieshenggou are similar to rollers or pestles and may be up to c. 40 cm long, although most were broken into fragments. The ends of several *mobang* also appeared to have been used in a pestle type manner, meaning these artefacts may be described in the literature as roller-pestles. The exact method of holding is unknown. Their use is ambiguous and probably multi-functional (Liu, Li, et al., 2010c). Several of the 22 rollers recovered from the Tieshenggou site were processed and three samples with over 70 starch grains each were selected for detailed analysis. The results of this analysis are presented below.

9.6.2.1 TIESHENGGOU MOBANG 1 (R1)

A total of 182 starch grains were recovered from this sample, including over 50 percent *Lithocarpus* sp. starch grains. In addition, 30 percent of grains were unidentified. About seven percent of grains were small and non-diagnostic unknown type 2 granules and three percent of granules were assigned to *Quercus* sp. and cf. Triticeae taxa respectively. One grain each of cf. Andropogoneae and USO starch was also present on the artefact. No husk type phytoliths were recovered.

9.6.2.2 TIESHENGGOU MOBANG 8 (R8)

Over 300 grains were recovered from this *mobang* including a faceted starch grain in association with eudicot type phytoliths. Approximately 30 percent of granules were unidentified while 33 percent represented cf. Andropogoneae type starch. Around 10 percent of granules were large and rounded unknown type 1 granules, while 13 percent

were small and non-diagnostic unknown type 2 granules. Small numbers of USO, bean and Triticeae tribe granules were recorded as well as about 30 acorn starch grains.

Many burnt phytoliths and burnt charcoal fragments were noted. It is possible that the artifact broke in ancient times and was discarded into an ash pit. It is also possible that the *mobang* was used near a cooking fire or to grind charcoal but this latter seems unlikely. No husk type phytoliths were recovered.

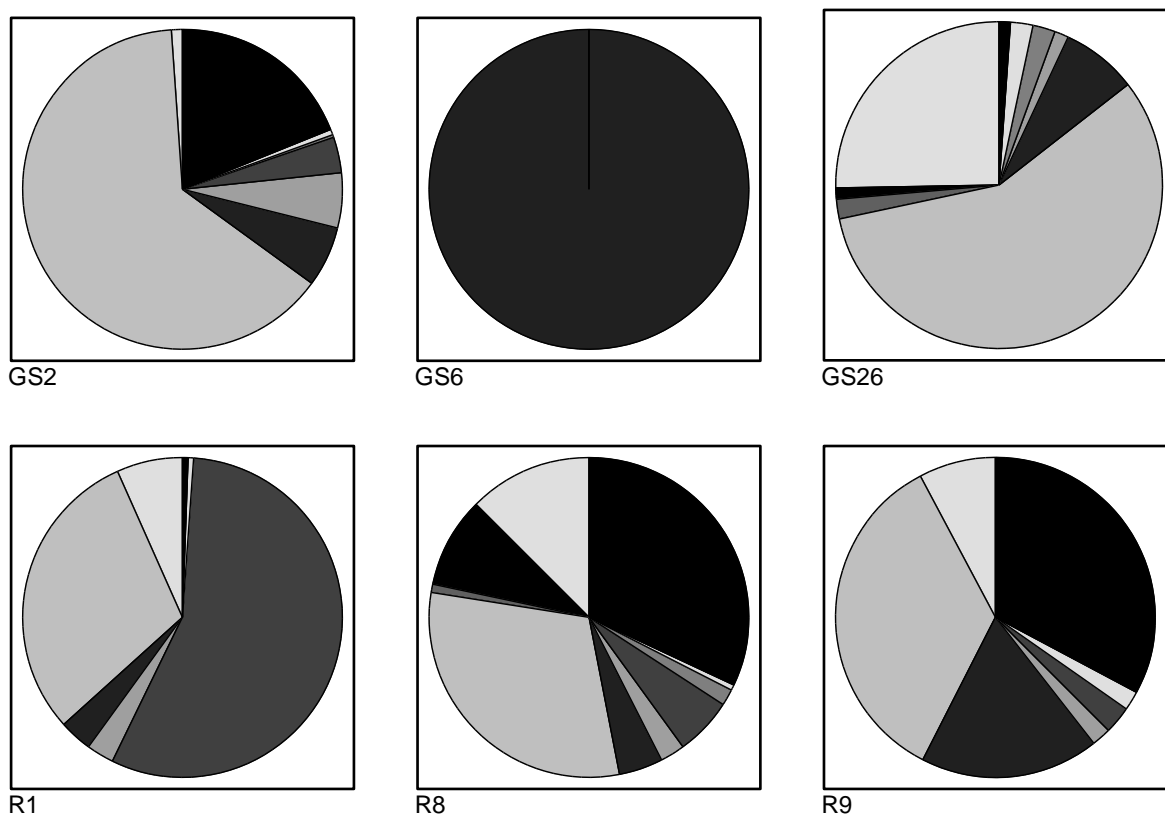
9.6.2.3 TIESHENGGOU *MOBANG* 9 (R9)

A total of 109 grains were recovered from this *mobang* including 35 percent unknown granules and 33 percent cf. Andropogoneae tribe starch grains. Approximately 20 percent of granules were cf. Triticeae tribe starches. Around seven percent of small and round unknown type 2 granules were present. Acorn starch included three percent *Lithocarpus* sp. and two percent *Quercus* sp. starch. Two USO starch grains were recovered. No husk type phytoliths were recovered.

9.6.3 Percentages of the Ten Taxa Types on Tieshenggou Artefacts

The following figures have sorted the starch grains from TSG analysed samples into ten categories based on size as well as on morphological features. The morphological features relevant are outlined in Chapter 7 and include the overall shape of the grain and whether it has facets or a rounded margin; the placement of the hilum, the presence of lamellae or fissures and the shape of the extinction cross when viewed under polarising filters.

Approximately 40 percent of starch granules from the six Tieshenggou artefacts analysed in detail were unidentified and are probably not diagnostic. Other types included almost 15 percent each of grass type starches cf Andropogoneae and cf Triticeae. These two grass taxa include a range of panicoid grasses and pooid grasses respectively but are also similar to some acorn taxa (see below). Acorns account for at least 10 percent of the taxa at Tieshenggou and probably more, representing an important use for these grinding implements. Small and non-diagnostic starch grains also made up over 10 percent of the taxa. These may represent small grasses, acorn and oak taxa or possibly transient starch from leaves and stems of lignified or other plants. Other diagnostic taxa at Tieshenggou include approximately one percent each of USO and bean (Fabaceae) starch, suggesting that these were at least minor components of the diet.



Graph legend

Figure 9-26 Percentages of the recognised ten types of taxa in six analysed Tieshenggou samples

Table 9-32 Percentages of Starch Types Present

Taxon	Total n	Percentage
cf Andropogoneae	195	15.9
USO	12	1
Fabaceae	13	1.1
Fagaceae cf <i>Quercus</i>	29	2.4
Fagaceae cf <i>Lithocarpus</i>	137	11.1
cf Triticeae	176	14.3
Unknown	491	39.9
Bean or wheatgrass	8	0.7
Round irregular type	35	2.8
Small round indeterminate type	134	10.9
Total	1230	100

9.6.4 Tieshenggou Starch Grains Analysed by Size

Differential preservation of wet and dry starch samples was observed when processing grinding implement samples. This may account for large numbers of starch grains being preserved in some samples but not in others. The nature of spot sampling may also account for low starch counts from some artefacts and high counts from the same artefacts, or from different artefacts in the same assemblage. Given the large numbers of samples processed, only grinding artefacts with over 70 starch grains recovered were subject to statistical analyses.

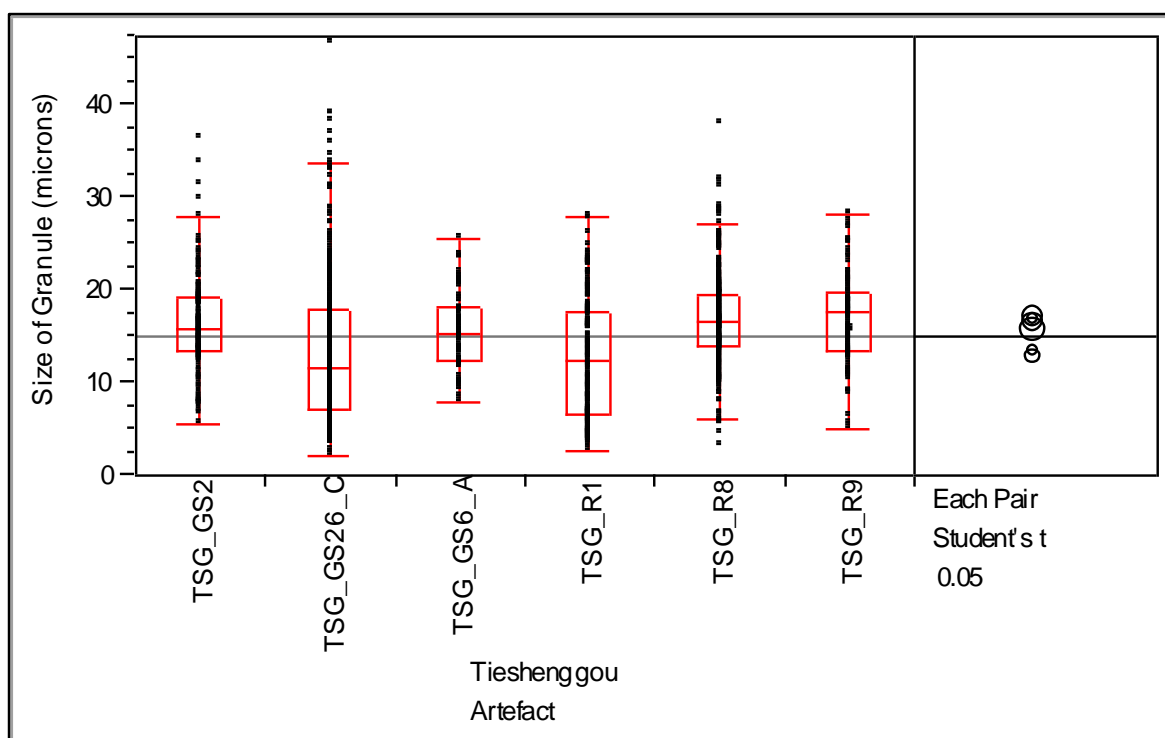


Figure 9-27 Comparison of Tieshenggou Grinding *Mopan* and *Mobang* on starch size

When starch grains from the six Tieshenggou artefacts are analysed they appear to fall into two major size categories (Figure 9-27). One category has a 50 percent quantile range of approximately 11 μm and the other has a 50 percent range of approximately 5–6 μm .

Four of the six Tieshenggou artefacts analysed have statistically similar population means based on a student's t-test where $df=1$, $p<0.05$ (Table 9-34). These are *mobang* 8 and 9 and *mopan* 2 and 6. These four artefacts are statistically dissimilar to *mobang* 1 and *mopan* 26 based on a student's t-test. However, the ranges of all six artefacts overlap (Figure 9-27; Table 9-33). These four artefacts may have been used in a more similar manner than *mobang* 1 and *mopan* 26, and this data may relate to individual food preferences or other

causes, including seasonal or locational causes for a slightly different change in diet. However more research is required to understand reason for this.

Table 9-33 Tieshenggou Artefact Starch Granules

Level	No. Granules	Minimum	Median	Maximum
TSG_GS2	232	5.79	15.85	36.5
TSG_GS26_C	302	2.12	11.77	46.83
TSG_GS6_A	73	7.94	15.5	25.73
TSG_R1	182	2.88	12.44	27.99
TSG_R8	332	3.4	16.79	38.23
TSG_R9	109	5.08	17.69	28.34

Table 9-34 Student's t-test Comparison on Tieshenggou Artefacts

Abs(Dif)-LSD	TSG_R9	TSG_R8	TSG_GS2	TSG_GS6_A	TSG_GS26_C	TSG_R1
TSG_R9	-1.64500	-1.19982	-1.05354	-0.47398	2.20140	2.84244
TSG_R8	-1.19982	-0.92791	-0.86244	-0.33892	2.47156	3.06502
TSG_GS2	-1.05354	-0.86244	-1.50167	-0.93304	1.76697	2.40002
TSG_GS6_A	-0.47398	-0.33892	-0.93304	-2.01471	0.60384	1.26237
TSG_GS26_C	2.20140	2.47156	1.76697	0.60384	-0.93936	-0.34501
TSG_R1	2.84244	3.06502	2.40002	1.26237	-0.34501	-1.26343

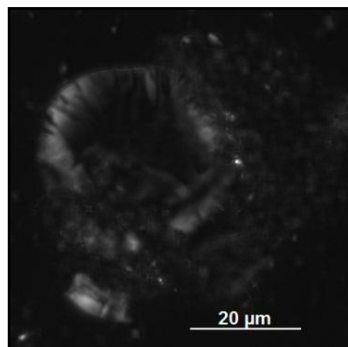
Positive values show pairs of means that are significantly different.

9.7 Damaged Starch Granules

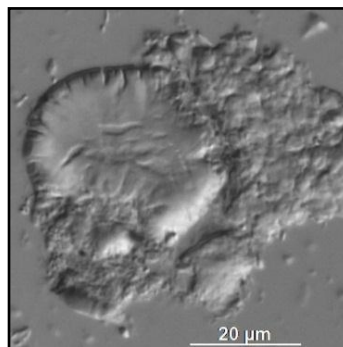
The presence of large numbers of damaged or morphologically altered starch granules from the grinding implements is typical of an ancient starch assemblage (e.g., Liu, Li, et al., 2011). Ancient starch is more likely to be damaged in some way. Is it possible that damaged granules may have been ground or processed as their presence on grinding implements indicates.

Damaged starch granules (Figure 9-28) may represent starch that has been processed or ground in some manner (Henry, et al. 2009, 2011) or they may merely represent old starch granules (Collins and Copeland, 2011). In either case the presence of damaged or ancient granules suggests contamination of the sample with modern starches is unlikely.

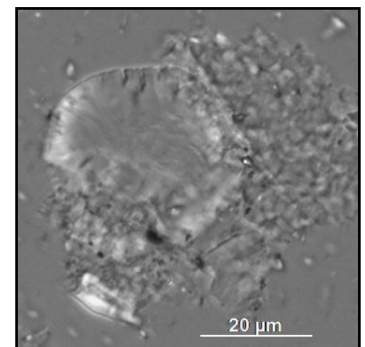
Damage in the Tieshenggou assemblages included starch grains that had lost their shape (Figure 9-28), starch grains with an extremely diffuse extinction cross (Figure 9-28) and starch grains with visible pitting or craters as well as pronounced lamellae. A range of food processing may be represented on grinding *mopan*, including dehusking of a seed, possible boiling or cooking and, probably last in a sequence of activity, grinding. More research is needed to determine what stage of food processing the grinding implements represent.



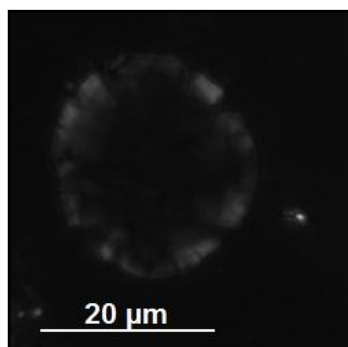
a) TSG_GS26_C_starch grain 43 under a cross-polarising filter



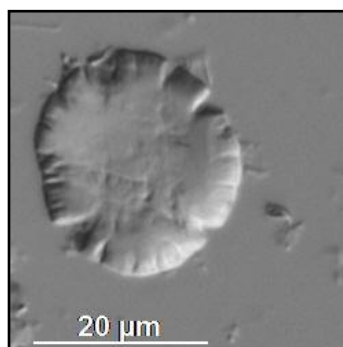
b) TSG_GS26_C_starch grain 43 under a DIC filter



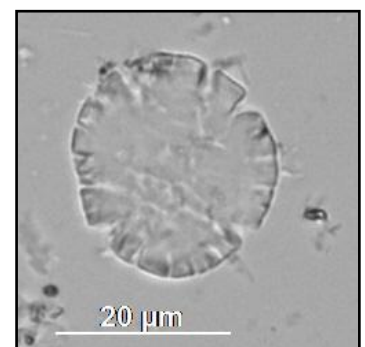
c) TSG_GS26_C_starch grain 43 under a brightfield filter



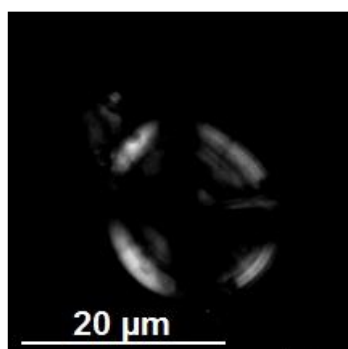
d) TSG_GS26_C_starch22 under a cross-polarising filter



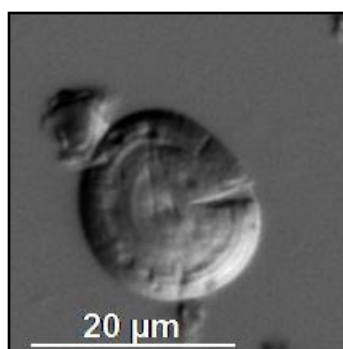
e) TSG_GS26_C_starch22 under a DIC filter



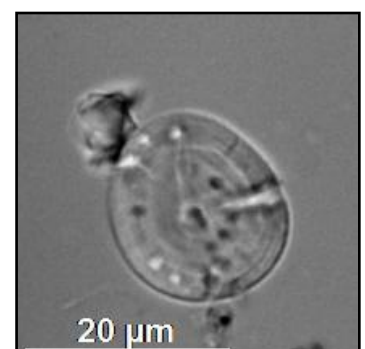
f) TSG_GS26_C_starch22 under a brightfield filter



g) TSG-GS26_C_starch17 with concentric lamellae and some pitting craters under a cross-polarising filter



h) TSG-GS26_C_starch17 with concentric lamellae and some pitting craters under a DIC filter



i) TSG-GS26_C_starch17 with concentric lamellae and some pitting craters under a brightfield filter

Figure 9-28 Damaged Triticeae tribe starch grains. Damage may be caused by a number of events including starch processing methods such as cooking or grinding, and the age of a starch granule

9.8 Other Plant Remains

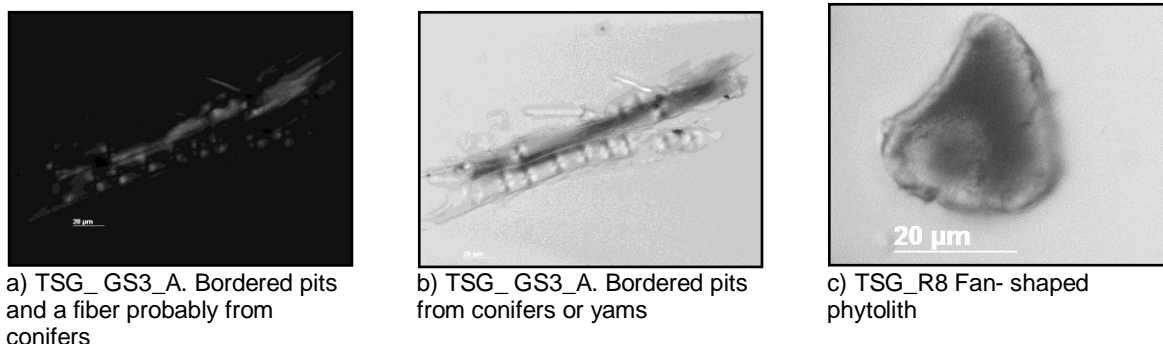


Figure 9-29 Other plant remains from Tieshenggou artefacts including (a-b) bordered pits and (c) fan-shaped phytolith

Other plant remains from the Tieshenggou artefact residues include bordered pits and small numbers of phytoliths (Figure 9-29). Generally these plant remains were not diagnostic and have not been exhaustively investigated.

The presence of bordered pits may indicate some type of woody plant processing.

Bordered pits are common in conifers (Evert & Eichhorn, 2006: 260-261) and may also occur in yams. More research is needed to accurately identify the types of bordered pits present on the artefacts.

The presence of grass stems and leaves was evident from fan shaped, bulliform and long cell phytoliths while phytoliths from husks were rare or non-existent on most samples. This suggests that if grasses were processed on these implements, they were dehusked prior to grinding. It is possible that small numbers of leaves and stems of grasses were processed with the analysed implements or found their way onto the artifact during grinding.

9.9 Summary of Starch from Tieshenggou Grinding Artefacts

The taxa recovered from Tieshenggou artefacts through the analysis of starch granules are consistent with other published Peiligang starch analyses including those from the Egou and Shigu sites (Liu, Li, et al., 2010b) and the Peiligang type site at Peiligang in Henan Province (Zhang, Y., et al., 2011). A range of taxa and types of starch grains were identified on the six Tieshenggou grinding artefacts analysed in detail. These included grass starch from two different subfamilies (Pooideae and Panicoideae) as well as starch from two genera of acorns (*Lithocarpus* and *Quercus* spp.). Starch grains from underground storage organs (yams or cucurbits) and beans (Fabaceae) were also present as residues on grinding implements. This is consistent with current hypotheses regarding the

use of Peiligang *mopan* and *mobang* artefacts (e.g., Liu, Li, et al., 2010b; Zhang, Y., et al., 2011). The implements were probably multi-functional plant food processing tools.

The lack of seed husk phytoliths suggests that the grinding *mopan* and *mobang* were not used to de-husk grass seeds. It appears that, if grass seeds were processed on these implements, they had already been dehusked. The presence of bordered pits on some artefacts may suggest a function in grinding wood or secondarily lignified plant taxa although further research is required to establish this with certainty.

The individual differences between artefacts in terms of the types and percentages of starch granules recovered are difficult to interpret. They may reflect individual household differences in plant processing. Different residues on different artefacts may also reflect some of the last uses of the items prior to their deposition as burial goods in female graves (cf. Henansheng, 1999). A large number of starch grains may be present on an artifact yet still represent the processing of only a single seed, bean or tuber. This makes it difficult to compare quantities of microfossil remains with quantities of macrobotanically collected data to establish the importance of various proportions of plant foods in the diet. However, given the occurrence of 15 percent each of cf. *Andropogoneae* and cf. *Triticeae* tribe starch grains, compared to only 11 percent *Lithocarpus* sp. starch and less than three percent *Quercus* sp. acorn starch, it appears that grass grinding was important at Tieshenggou. In addition, ten percent of starch grains were small, round and non-diagnostic granules that may represent a number of taxa including both grass or acorn starch. Small amounts of bean and USO starch were also present, indicating that these taxa were minor components of the diet. Given the necessity of grinding acorns to remove toxins through a grinding and leaching process, it is likely that acorn grinding was an important function of these artefacts.

Chapter 10: Sickle Residue Analyses

Denticulate flakes are present in the late Palaeolithic Xiachuan culture of North China (IACASS, et al., 1978; Wang, J., et al., 1978). It has been suggested that these evolved into the denticulate sickles of the North Chinese Peiligang period (Shi, X. B., 1989) but more research is needed to test this assumption. Use-wear on the Xiachuan sickles led T. D. L. Lu (2001) to suggest they were used for harvesting grasses. However, no residue studies or use wear were carried out on these important Peiligang artefacts until recently (Bestel, et al., 2011; Fullagar et al., in press). This chapter will describe experimental and residue research aimed at understanding the functions of these sickles.

K. C. Chang (1986: 91-93) notes that denticulate stone sickles are considered characteristic of the Peiligang and related cultures. Their occurrence in the archaeological record appeared to coincide with the initial advent of domesticated millets. Prior to the advent of use-wear and residue studies it was generally assumed that these stone 'sickles' were used to process the newly domesticated foxtail millet (Chang, K. C., 1986: 91-93; Wu, J. A., 1989).

Sickles are typically defined as crescent shaped stone artefacts used to harvest cereals. In China the typical form for a sickle is a curved stone flake with a denticulate cutting edge (Lu, T. L. D., 1999: 11). In a Chinese archaeological definition a sickle is typically an asymmetrical denticulate implement used for harvesting (Chen, W., 2000: 101). In contrast, in China a knife is an almost symmetrical cutting tool that may be rectangular in shape (Chen, W., 2000: 102). In English terminology the term 'sickle' carries with it an implication for the use of such an artefact to harvest cereals or grasses. This is not necessarily the case in Chinese archaeological definitions and a sickle is not necessarily a tool used to cut domestic plants.

Twenty-three denticulate stone knives stored at the Henan Provincial Institute of Archaeology were sampled for residues (Figure 10-1). The sampling strategy and methodology used is discussed in Chapter 5. Some dirtier samples were processed for phytolith and starch extraction using a heavy liquid while cleaner residues with little visible sediment extracted were mounted immediately on glass slides. All samples were mounted in 50 percent glycerol or water and scanned using a Zeiss Axioskop microscope and associated Zeiss 4.7 or 4.8 software. Residues were identified using the plant reference

collection outlined in Chapter 7. Comparative reference residues taken from the working edges of stone knives used in experimental research to cut grass, reeds and to remove acorns from dicotyledonous oak trees were also examined (Fullagar, et al., in press).



a) SK5 Egou M47:2



b) SK5 Egou M47:2



c) SK3 Shigu AT33:H122:1



d) SK3 Shigu AT33:H122:1



e) SK8 Jiahu T12(3): 2



f) SK8 Jiahu T12(3): 2

Figure 10-1a-f Selected examples of the stones sickle sampled for residues

The results of these extractions and identifications are set out and discussed below.

Sonicated water or water droplets were sampled and some dry sediment was also scraped

from stone knife blades. Due to the nature of sampling only presence/absence counts of phytoliths are presented here. Generally phytolith numbers in sediment or non-residue samples number in the millions and an adequate count is considered about 200–300 single phytoliths (Piperno, 2006: 115). The sampled phytolith count is then multiplied as a proportion of total phytoliths on the slide. However, plant remains, such as starch and phytoliths present as residues on cutting artefacts, are typically found only in low numbers, unlike grinding implements which may preserve large numbers of starch. Hence presence/absence counts are presented here.

10.1 Hypotheses Regarding Function of Peiligang ‘Knives’ or ‘Sickles’

Recently, several hypotheses have been proposed regarding the use and main function of denticulate stone sickles taken as characteristic markers of agriculture and also of the Peiligang period. These hypotheses are discussed below.

10.1.1 Sickles as Agricultural Tools

Function hypotheses proposed for the use of the characteristic Peiligang denticulate stone knives include suggestions that they were used to harvest cereals (Chang, K. C., 1986: 91). Cereals were newly domesticated during the Peiligang period (see Chapter 8) hence the term ‘sickle’ is popularly used in the literature to describe these artefacts (Chang, K. C., 1986: 91-93). These sickles, along with Peiligang four legged grinding slabs, are typically considered a proxy for agriculture in Chinese archaeology (Chang, K. C., 1986: 91; Liu, Li, et al., 2002-2004).

10.1.2 Sickles Used to Make Mats or Baskets

It is possible that denticulate sickles may have been used to harvest reeds used for basketry or matting during the Peiligang period. With the exception of the Jiahu site, the drier Peiligang area of the central plains region in Henan Province in North China is typically lacking in sites which would preserve basketry impressions. The Jiahu site preserved impressions of basketry or matting on the base of pots (Henansheng, 1999: 883). Impressions of matting on the base of pots are also known from waterlogged sites such as the c. 8,000 BP site of Kuahuqiao in Zhejiang Province, South China (Jiang, L. & Li Liu, 2005: Figure 7).

The lack of pottery at Palaeolithic sites such as Shizitan also makes the use of containers such as wood containers or reed baskets more likely. The earliest pottery in China occurs at the Yuchanyan site in south China around 18,000 cal BP (Yuan, Jiarong, 2002). Several other sites in the South China region also have early pottery (Yasuda, 2002a). In North China the earliest known pottery occurs at sites such as Hutouliang and Nanzhuangtou (Guo & J. Li, 2002). Despite early suggestions that the creation of pottery was linked to agriculture (e.g., Lu, T. L. D., 1999: 5) it appears that pottery containers occur much earlier than currently accepted dates for the beginnings of agriculture in China (Yasuda, 2002b; Yuan, Jiarong, 2002). So matting and basketry probably had an earlier origin than pottery containers, despite the lack of preserved plant evidence for this.

The use of reeds to separate layers of millets—possibly as a form of matting or basketry—is also suggested by layers of phytoliths of *Phragmites* sp. reeds from ash pits at the Cishan site (Lu, H., et al., 2009a). Reeds were probably cut with some kind of wood, shell or stone implement prior to being made into baskets or mats. Shell sickles have been found from Baijia in Shaanxi, dating to around 8,000 cal. BP (Underhill, 1997: 120). A shell knife was also found at the Yangshao period Yulinzhuang site during Yiluo region fieldwork but was not tested for residues.

10.1.3 Sickles as Arboreal ‘Rakes’ or Implements to Harvest Nuts

Nuts of various types are known from several Peiligang sites in North China. Although flotation is still not routinely practiced in China such nuts may have been noted in past excavations because they are macroscopically visible. These include hackberry nuts (*Celtis* sp.) from Donghulin near Beijing (Hao, et al., 2008). Systematically floated sites in North China include Jiahu (Zhao, Z. & J. Zhang, 2009) where *Quercus* sp. acorns and hickory nuts (*Carya* sp.) were recovered. Walnut (*Juglans regia*), hazel (*Corylus heterophylla*) and hackberry (*Celtis bungeana*) were recovered from the Cishan site (Handan Wenwu, 1977; Hebeisheng, 1981; Tong, 1984).

It has been suggested that the characteristic four legged Peiligang grinding slabs, traditionally used as proxies for millet cereal grinding and therefore agriculture, were actually multi-purpose implements (Liu, Li, et al., 2010c). Starch residues suggest they were used to grind a variety of foodstuffs including large amounts of nuts (Liu, Li, et al., 2010c). Acorn starch similar to that recovered from *Quercus* sp. makes up a large proportion of the starch granules recovered from some of the tested Peiligang grinding

artefacts (Liu, Li, et al., 2010c). Certain types of acorns need to be processed to remove toxins prior to consumption by humans (McCorriston, 1994; Ortiz, 1991), although some acorns may be consumed without processing in other parts of the world including Turkey (Mason & Nesbitt, 2009: 75).

While evidence has recently emerged for the grinding and use of acorns in Peiligang China, the entire process of acorn use is still not clear. For example, it is not clear if nuts were collected from the ground, as in Ohlone-Miwok Indian traditional societies where black oak (*Quercus kelloggii*) acorns were collected once they had ripened and dropped (Ortiz, 1991). It is possible that in some cultures, nuts were collected from trees prior to the fruit ripening or dropping, to prevent animals first eating the fruit.

A recent re-evaluation of the evidence relating to the origins of agriculture in China has raised questions regarding the use of denticulate Peiligang period sickles. It is possible that they were hafted to long wooden or bamboo poles and used to harvest nuts from trees. Modern arborists in China use a long handled 'rake' to pull down tree branches for evaluation and examination and also to collect nuts. Acorns known from several Peiligang sites including Jiahu (Zhao, Z. & J. Zhang, 2009) may have initially been harvested from trees in this manner. More research is needed to fully understand acorn gathering, leaching, processing and grinding technology in ancient North China.

10.2 Experimental Research

These three hypotheses were evaluated by experimental research during a workshop held at La Trobe University in 2009 (see Fullagar, et al., in press, for details of part of this research). The research was funded by Professor Li Liu and carried out by graduate students at La Trobe University. Thus the discussion of this experimental sickle use is part of group research in which SB participated. However, the extraction of comparative residue samples from the experimental sickles and photographic examination of them under magnification was carried out entirely by SB.

Stone sickles were made from available rock using an angle grinder in the workshop at La Trobe University (Figure 10-2). The only available rock was slate so this was used although sickles are typically made of several different raw materials in China including fine grained limestone or siltstone. Rudy Frank made the sickles and Professor Li Liu created the denticulate 'teeth' on each sickle by filing the soft slate with an iron file. Rudy

made a hole in each sickle and then hafted the sickles using modern techniques to a short or long handle. The short handle was made of available material and was a chair leg. The long handle was also created from material to hand and so was made of a broom handle.



Figure 10-2 Pictures of experimental sickles

Each experimental sickle was used for approximately half an hour to cut three different types of plants. One sickle with a shorter hafted handle was used to harvest *Typha* sp. reeds. One sickle was hafted to a long handle and used to harvest *Quercus* sp. acorns from a tree. This oak tree was planted on a lawn near the Language Institute at La Trobe University and the lawn was watered regularly. This may have increased the possible phytolith count retained in the sickle residues (Rosen & Weiner, 1994). One sickle with a shorter handle was used to harvest relatively dry September grasses of various species.

10.2.1 Results of Experimental Sickle Research—Comments on Harvesting Reeds

There are twelve species of *Typha* (Typhaceae) in China (Sun & Simpson, 2010) and it was thought possible that some of these reeds were utilized in basketry or matting in ancient China. During harvesting it was found difficult to cut *Typha* sp. reed stems and leaves without pulling some of the reeds and their roots from the soft earth around the ‘moat’ or river bed at La Trobe University.

This research on reeds was carried out prior to publication of the article by H. Lu and colleagues (2009a) which suggested that *Phragmites* sp. reeds may have been used to form mats at the Cishan site. There are three species of *Phragmites* reeds growing in China (Liu, Liang & Philips, 2006). Subsequently phytoliths and cellular material from *Phragmites* sp. reeds were examined (Figure 7-3). While *Phragmites* sp. reeds do preserve diagnostic phytoliths (Ollendorf, et al., 1988) (Figure 7-3), less diagnostic *Phragmites* sp. phytoliths are the same as those of grasses. This is because technically *Phragmites* sp. is actually a

grass in the Poaceae family and not a true Juncaceae family reed. Diagnostic *Phragmites* sp. reed residues were not recovered from ancient sickles during this research.

10.2.1.1 RESULTS OF EXPERIMENTAL SICKLE RESEARCH—COMMENTS ON HARVESTING ACORNS

While harvesting acorns, it was noted that the denticulate sickle came into frequent contact with oak leaves, twig bark and branches. Thus these residues would be likely to preserve on the sickles. The denticulate sickle did not often break or scratch the acorn shell or cap itself, meaning that phytoliths from these parts of an oak tree would be less likely to preserve as residues on sickles or tree harvesting implements.

10.2.1.2 RESULTS OF EXPERIMENTAL SICKLE RESEARCH—COMMENTS ON HARVESTING GRASSES

The use of a denticulate sickle to harvest grass was easier than using a straight margin stone sickle. A sawing motion was found to be the most effective way to use the sickle to cut grasses. However, sometimes the grass came out of the dry Australian earth by the roots rather than through the inflorescence being cut or removed. It is possible that sickles were used partly to harvest grasses.

10.2.2 Residues Preserved on Experimental Sickles

After experimental cutting or harvesting of reeds, acorns and grasses, residues on sickles were examined immediately. It is possible that while attempting to harvest grass, for example, other plants may also have accidentally been cut with the sickle. Thus residues other than grasses may have been preserved on the sickle. This type of accidental residue preservation is useful in specifying the activity that led to the creation of the residue. It is therefore recorded below along with the main type of residue present (Table 10-1).

Table 10-1 Residues on Experimental Sickles

Plant Cut or Harvested	Presence of Grass (Poaceae) Phytoliths	Presence of Reed or Sedge Phytoliths	Presence of Eudicot Phytoliths	Presence of Starch	Notes
<i>Typha</i> sp. reeds	✓	✗	✓	✓	Fewer phytoliths; some raphides
Poaceae grasses	✓	✗	✓	✓	Lots of single starch grains
<i>Quercus</i> sp. acorns	✗	✗	✓	✓	Numerous small starch grains clustered in cells

10.2.2.1 RESIDUES ON REED HARVESTING SICKLE

The sickle used to harvest reeds had several type of cellular remains present (see Table 10-1; see also pictures of cellular remains in Figure 10-4). Plants in the Typhaceae family are considered to have few, if any, phytoliths (Piperno, 2006: Table 1.1). Thus while cellular remains were preserved as residues on experimental sickles, they are not peculiar to *Typha* sp. reeds. This means that the likelihood of being able to identify *Typha* sp. reeds from ancient residue samples is minimal.

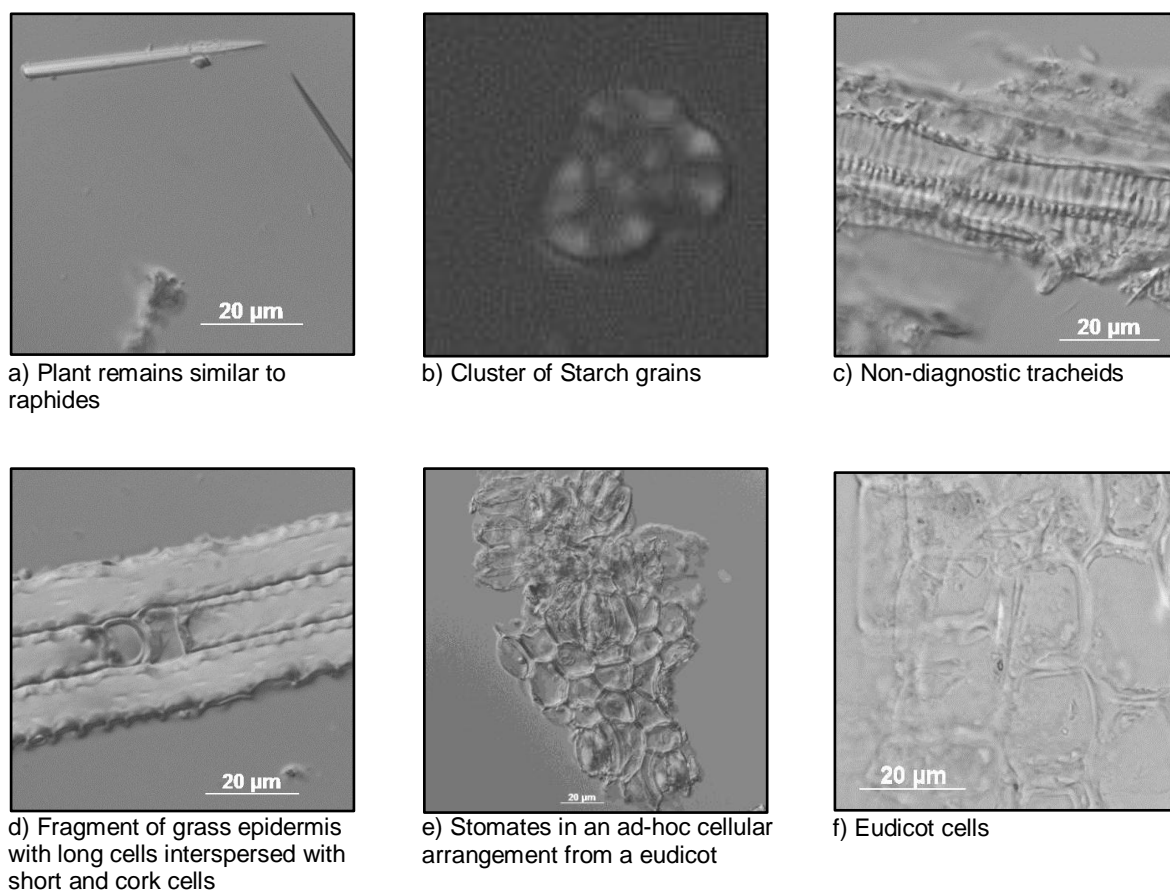


Figure 10-3 Residues from sickle XSK02 used to harvest *Typha* sp. reeds

Another reed known to have been used in ancient China at the Cishan site (Lu, H., et al., 2009a: 7369) does preserve diagnostic phytoliths. *Phragmites* sp. reeds occur commonly throughout the world including along rivers and lakes in China (Lu, Liang & Phillips, 2006). Phytoliths from this genus of reeds like plants were also examined as a prelude to identifying ancient residues (Figure 7-3). The ‘plateaued saddles’ or ‘saddle topped short trapezoids’ of *Phragmites* sp. reeds are distinctive (Ollendorf, et al. 1988; Piperno, 2006: 33).

Cellular remains preserved on experimental sickle XSK02 include mesophyll-like cells with stomatal pores arranged in an apparent random order (Figure 10-3). Other phytoliths include tracheids, hairs, and long and short cells together in a silica skeleton (Figure 10-4).

The reeds of *Typha* sp. have starchy edible roots which were used by Aboriginals in Australia as a staple food source (Gott, 2006: 62-64). Small starch grains were detected in the residues and it is possible that during reed harvesting the sickle may have slipped and cut some of the *Typha* tubers. Starch may also have been present in leaves and stems of the reeds, as it is typically created through photosynthesis in plant leaves and moved to storage in tubers. This may explain the presence of starch on the experimental sickle.

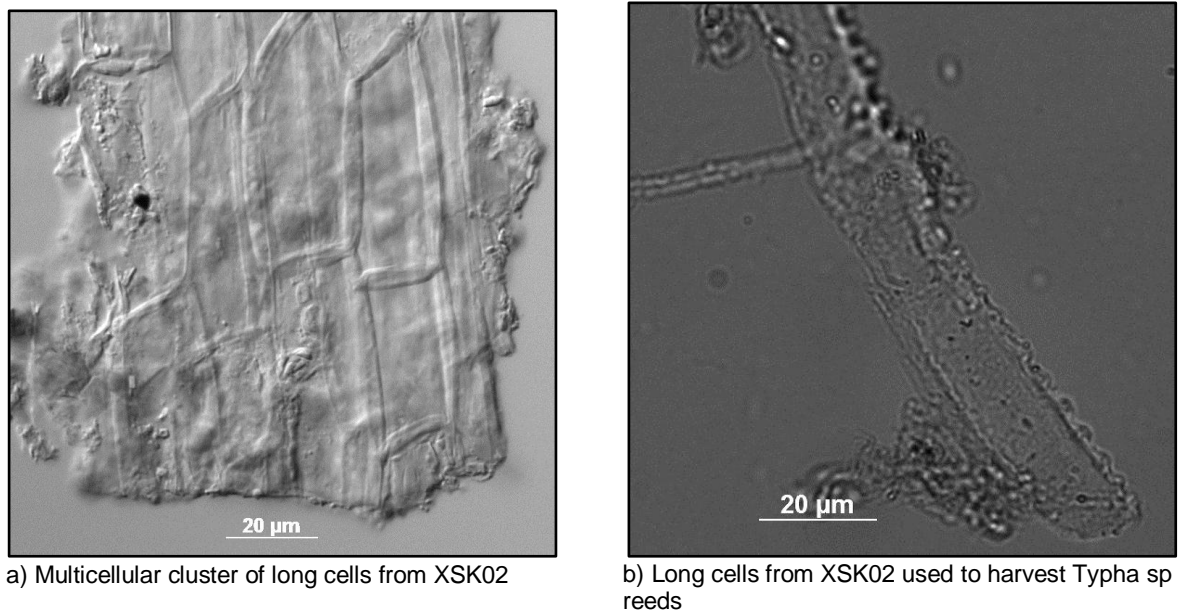
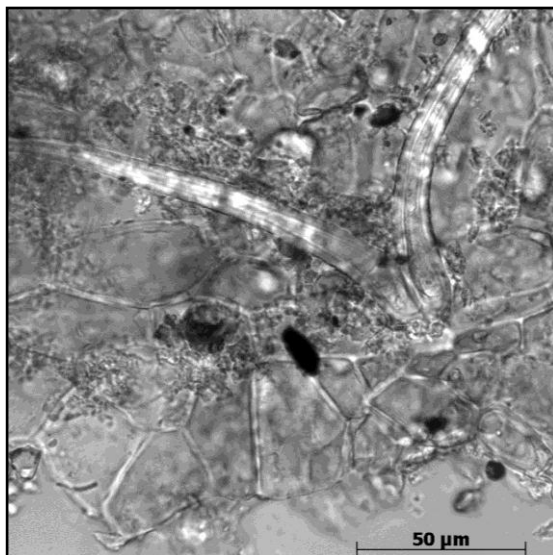


Figure 10-4 Grass or sedge long cells from experimental sickle XSK02 used to harvest *Typha* sp. reeds

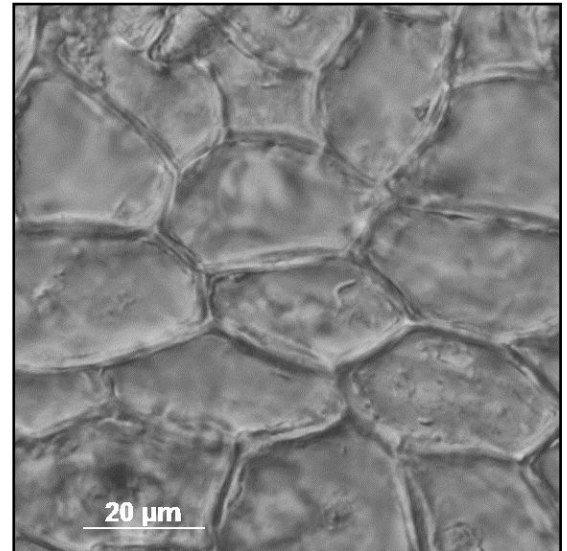
10.2.2.2 RESIDUE ON ACORN HARVESTING SICKLE

The sickle used to harvest acorns from trees had several typical dicot type phytoliths present (Figure 10-5). These included hair bases and isolated oblong or rectangular phytolith forms. It is not clear whether these were cells that had transferred onto the sickle during harvesting or phytoliths composed of silica. However, when silica taken up through groundwater precipitate out inside the plant (Piperno, 2006: 5) they take on the same shape as the plant cell itself. Thus modern cellular remains on the sickles may not have been silicified and may not warrant the term 'phytolith'.

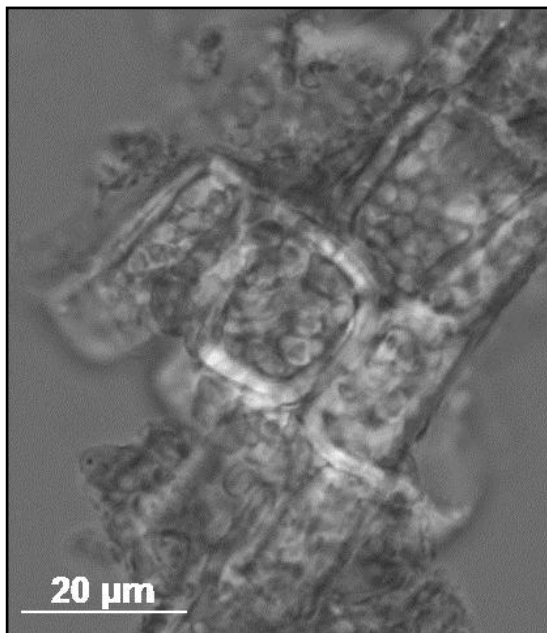
During testing of phytolith reference material, faceted forms noted by Piperno (2006: figure 2.6d) in *Lithocarpus* sp. acorns were not found. Similar phytoliths were not evident on the experimental sickle used to harvest *Quercus* sp. acorns although it is not clear whether *Quercus* sp. caps produce phytoliths. Phytoliths were not detected in experimental research on *Quercus* sp. caps.



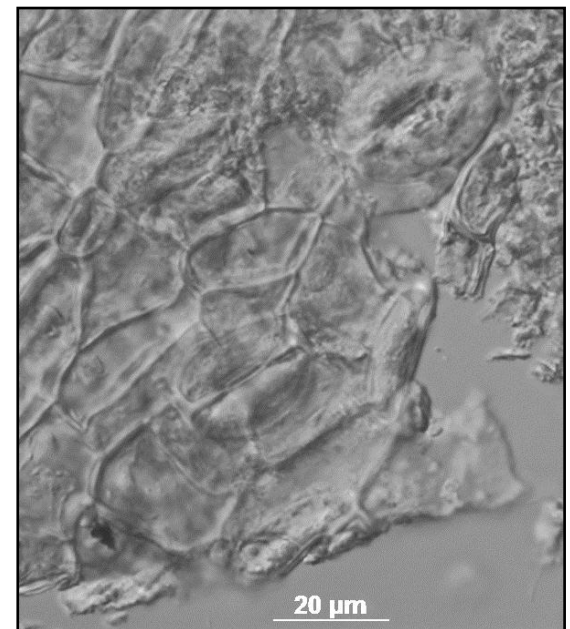
a) Acorn leaf hair cell base showing hairs and epidermal cells as well as small starch grains



b) Irregularly shaped eudicot plant cells (monocot grass cells are more more regularly shaped)



c) Cells from an acorn leaf containing starch grains



d) Stomates and epidermal leaf cells

Figure 10-5 Examples of *Quercus* sp. acorn residues on experimental sickle XKS01

Numerous clusters of tiny starch grains were also visible on the residue slide taken from the acorn harvesting sickle. These starch grains were typically less than 5 µm in maximum dimension and were often clustered together. They may have been transient starch or

perhaps starch that formed in the leaf during photosynthesis prior to being transported to storage elsewhere in the plant.

Of all the three sickles tested for plant residues, the sickle used to harvest tree crops was the only one that did not appear to preserve residues from other plants. This may be because in typical grassland and sometimes reed communities a number of small herbaceous plants are also present. These other plants may represent accidental harvesting. It is also possible that phytoliths from other plants either fall into ground covering grass or reed communities; for instance, deciduous tree leaves may fall onto the grass below the tree. Such leaves may have either decayed on the grass, leaving their phytoliths behind or may have been accidentally harvested along with grasses and reeds. However, there were no tall trees around the oak tree that could have allowed leaves to fall onto the oak in this experiment.

10.2.2.3 RESIDUE ON GRASS HARVESTING SICKLE

Sickles used to harvest grasses preserved a range of residues typical of the Poaceae family (see Figure 10-6; see also chap 6 for pictures of typical grass phytoliths). Phytoliths included long cells with various margin types as well as stomatal pores and mesophyll fragments. Short cells of phytoliths were also present and included bilobes, fan cells and bulliform cells. Hair cells including trichomes were also present. No husk phytoliths were noted. This is not entirely unexpected as harvesting or reaping cereals typically aims to remove the ear of grain without harming the seeds protected by cereal husks. Some of the grasses cut using this method did exhibit cereal husks or ears on the cut stems. This means that stem cells including long cells and short cells as well as stomates were expected in the residues.

Starch was present in the residues from experimental grass cutting and included isolated grains in various shapes and size categories, as well as clusters of smaller Poaceae starch (Figure 10-6). Phytoliths and starch grains not necessarily typical of grasses were also present. These included eudicot like plant hairs and bean like starch grains (Figure 10-6). This may reflect weedy species growing among the grasses being harvested, as would be likely to a certain extent with weeds growing in a crop field. Small herbaceous plants and possibly even leaves dropped from nearby trees, may have contributed to the range of plant residues not typical of grasses that were recovered from experimental XSK03.

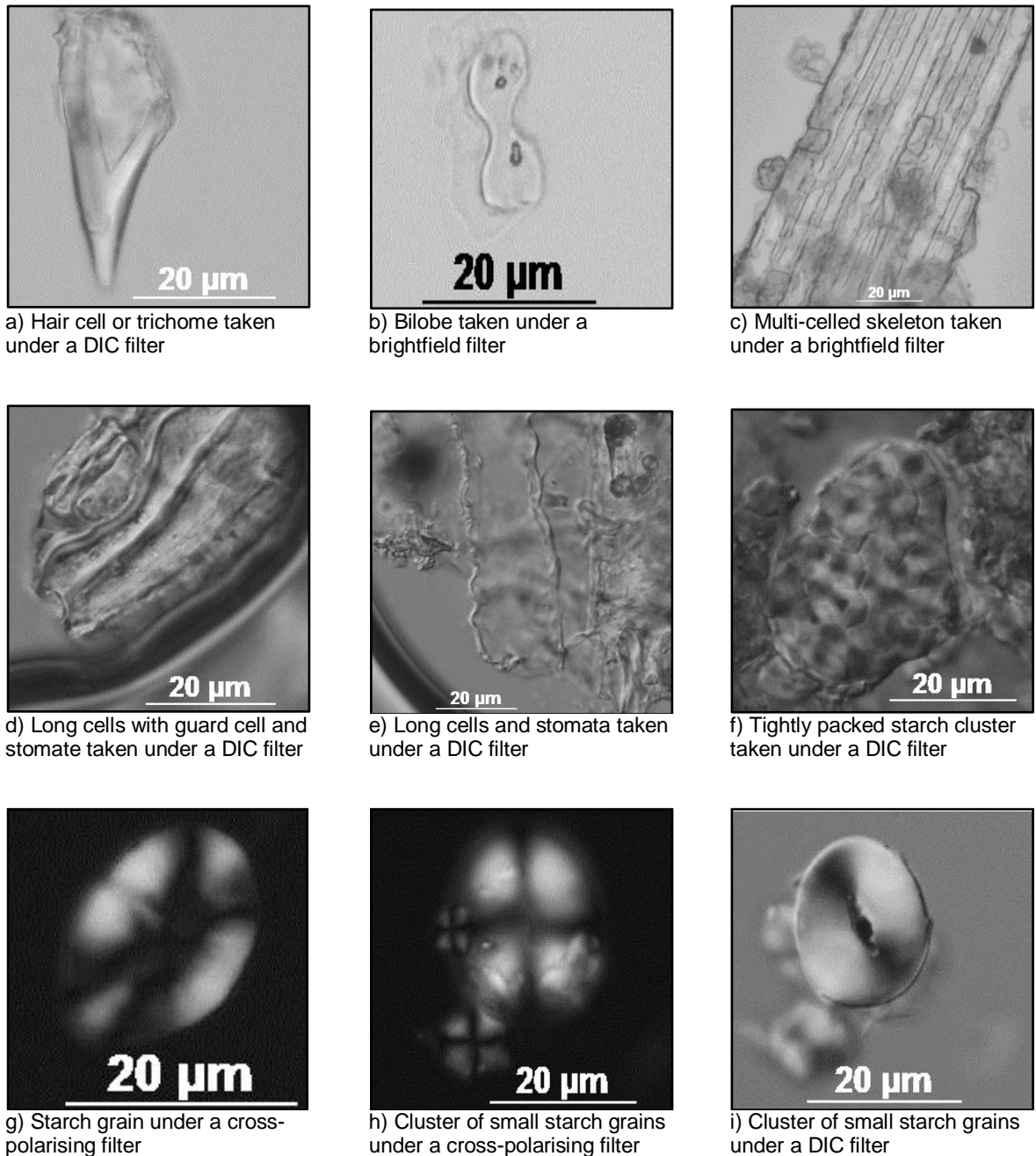


Figure 10-6 Phytoliths and starch grains from experimental sickle XSK03

10.3 Results from Ancient Sickle Residues

Sickles were examined for visible plant residues including starch and phytoliths. Given the assumption that the sickles were used to harvest the stems of cereals, it was expected that grass long cells from stems, leaf sheathes and leaves would be recovered. It was not expected that a sickle used to harvest grass would have had much contact with the starchy seeds or the seed husks of the grass being harvested. Therefore phytoliths from husks and starch from seed endosperms were not expected to be present in large numbers in the sickle residue samples. However, it was considered possible that small amounts of such remains

(starch and husk phytoliths) may have been present on the sickle from when the sickle slipped or perhaps cut a lower standing ear of grain. Residues from ancient sickles were collected as outlined in Chapter 5. They were mounted on slides and examined under x400 magnification using a Zeiss microscope.

Table 10-2 Sickles Sampled and Presence of Selected Residues

Sickle No.	Grass Phytoliths Present?	Reed / Sedge Phytoliths Present?	Dicot Phytoliths Present?	Conifer	Starch	Notes
1	✓	✗	✓	?	✗	Some pine-like phytoliths
2						
3	✓	✗	✓	✗	✓	Trichome
4	✓	✗	✓	✓	✓	
5	✓	✗	✓	?	✗	Some pine-like phytoliths
6	✗	✗	✗	?	✗	Some pine-like phytoliths
7	✓	✗	✓	✗	✓	
8	✓	✗	✓	✗	✓	
9	✗	✗	✓	✗	✓	
10	✓	✗	✓	✗	✗	Plant hair x1
11	✓	✗	?	✗	✓	
12						
13						
14						
15	✓	✗	✓	✗		
16						
17						
18	✓	✗	✓	✗	✗	
19						
20	✓	✗	✓	✗	✗	
21						
22						
23						

✓ = present

✗ = absent

? = uncertain identification

10.3.1 Presence/Absence of Plant Residues from Ancient Sickles

Samples were collected from twenty-three stone knives and sickles from three Peiligang sites. Only thirteen of these were processed and tested for plant residues. Of these thirteen, several sickles had multiple residue samples extracted.

Samples were taken from both the working edge and the hafted edge of each sickle or sickle fragment, where possible.¹² The details of plant residues taken from the two types of surfaces are outlined below.

10.3.1.1 PRESENCE OR ABSENCE OF SAMPLES FROM HAFTED EDGE

A single fragment of sickle from the Shigu site (SK1_B) was analysed to determine whether hafting residues were present. Only grass long cells and bulliform cell phytoliths were present so it appears that no special hafting residue was preserved on this sickle specimen. Further research on other sickles may reveal traces of hafting residue.

10.3.1.2 PRESENCE OR ABSENCE OF SAMPLES FROM WORKING EDGE

Residues from thirteen sickles were examined for working edge residues. Twelve of the thirteen sickles examined produced plant residues. These residues were identified as dicotyledonous phytolith cells (probably from a tree or shrub), grass phytoliths including bilobes and starch grains.

10.3.1.3 REED RESIDUES FROM ANCIENT SICKLES

The experimental research on cattails or *Typha* sp. reeds growing by the side of the damp 'moat' at La Trobe University produced no phytoliths. Members of the Typhaceae family are thought to produce few to no phytoliths (Piperno, 2006: 7) and reference slides of *Typha* sp. reeds confirmed this. *Typha* sp. phytoliths were thus not detected in the samples analysed.

Raphides were present in some of the *Typha* sp. modern residue samples taken from experimental sickles (Figure 10-3). They were also present as residues on some ancient sickles including SK7 from Jiahu site. Raphides are common in underground storage

¹² As some sickles were only fragmentary or broken it was not always possible to identify the presence of a hafted end or a working edge. In other cases, residue was not visible on the sickle.

organs of various plants including wild bananas (*Australimusa* sp.) (Lentfer, 2009). They were detected with taro starch residues (*Colocasia esculenta*) in Lapita pottery from New Ireland (Crowther, 2005: 62). At this stage of research it was not possible to identify these raphides taxonomically.

The seeds of *Typha* sp. reeds occur in various archaeological sites including Neolithic lake dwellings (Brombacher, 1997) and Liangchengzhen in the eastern Chinese Shandong province (Crawford, et al., 2005). Aranguren and colleagues (2007) claim to have identified *Typha* sp. starch grains in the Upper Palaeolithic of Europe from a 25,000 year old grinding stone and grinder. However, their published starch images identified as *Typha* sp. do not appear from the photographs to be diagnostic (see Aranguren, et al., 2007: 851). Starch from modern reference samples of *Typha* sp. roots and seeds were examined but were not detected in the archaeological record. Thus there is no phytolith or starch evidence for the use of stone sickles to process or harvest *Typha* sp. reeds.

In fact, true reeds from the Juncaceae family have little or no phytoliths (Piperno, 2006: 7). If the stone sickles were used to cut true reeds evidence of this is unlikely to preserve as phytolith or starch residues. However, sedges (family Cyperaceae) typically grow together with reeds in damp or waterside environments. It is possible that while reeds were being cut, sedges were cut by accident and then weeded out of the final matting or basketry sample. Sedges have diagnostic and unique phytoliths (Piperno, 2006: 7). Sedge phytoliths were also examined for this reason (Figure 7-10) although they were not purposely cut during experimental research on reeds. However, no sedge phytoliths were recovered from ancient or modern samples.

10.3.1.4 PRESENCE OR ABSENCE OF DICOTYLEDONOUS TYPE RESIDUES FROM WORKING EDGE

Experimental research on using long handled hafted sickles to remove nuts from trees produced intriguing results. Residues present on the experimental sickle used to harvest *Quercus* sp. acorns included leaf cells (Figure 10-7) and phytoliths including leaf hair phytoliths (Figure 10-7). Numerous tiny starch grains inside a leaf cell were also noted (Figure 10-5). While starch grains are typically found in storage organs such as seeds or roots, they may be transported through plant stems and mobilised as transient starch.

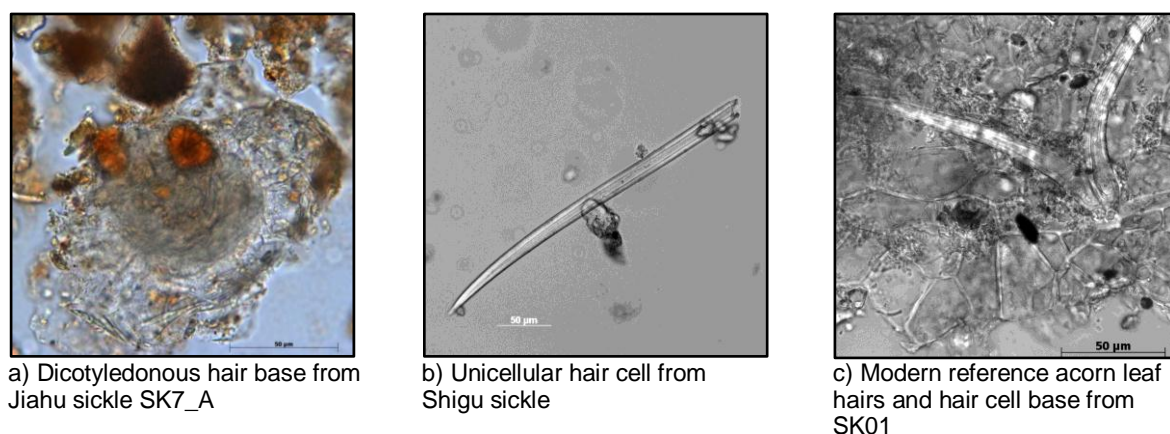


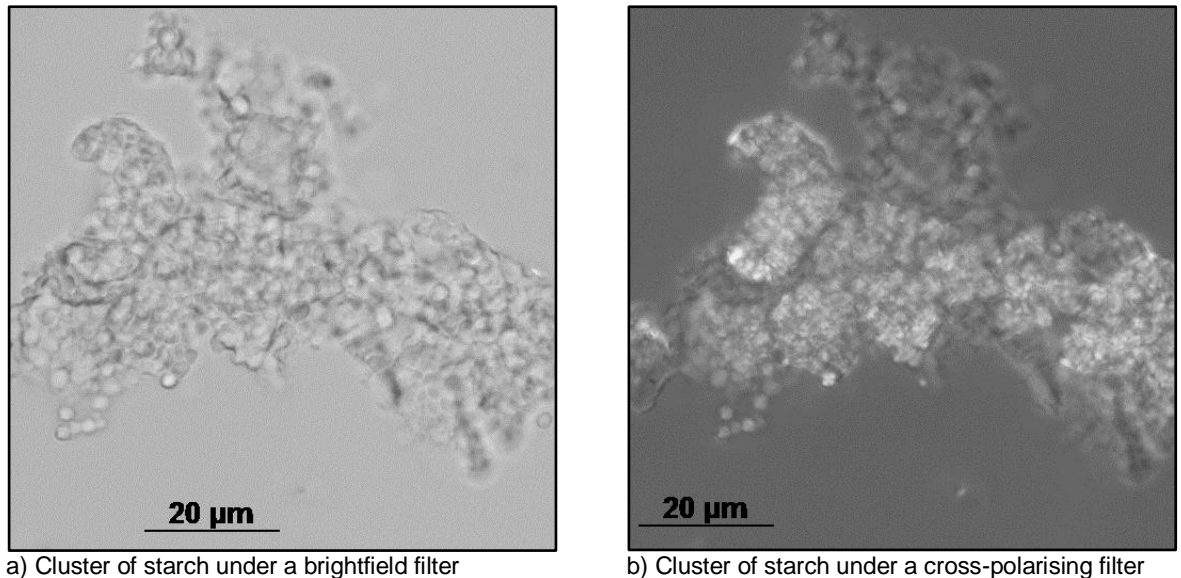
Figure 10-7 Comparison of modern and ancient eudicotyledonous hair bases and leaf hairs

It is generally considered that phytoliths from dicotyledonous tree leaves are non-diagnostic (Piperno, 2006: 20). In this case, the presence of platy dicot phytoliths in several of the Jiahu sickle residue samples suggests that perhaps the sickles were used in some manner for processing dicotyledonous plants.

Phytoliths recovered from the sickle samples that are typical of nut or tree type plant remains include platy phytoliths and leaf hair phytoliths (Figure 10-7). These phytoliths are generally typical of leaves from a large range of plants including walnuts (*Juglandaceae*), hackberry (*Celtis* sp.) and acorns (*Fagaceae* family including *Cyclobalanopsis*, *Lithocarpus* and *Quercus* sp.). Phytoliths from *Lithocarpus* sp. acorns in the *Fagaceae* family are recognised by Piperno (2006: 43) while Y. Wang and H. Lu recognise several different shapes of phytoliths from *Quercus* sp. oaks (1992: plate 10, plate 12). Phytoliths from *Quercus* sp. oaks are known from ancient Palaeolithic sediments in Kebara Cave in Israel (Albert, et al., 2000). However, acorn or oak phytoliths diagnostic to genus level are not currently known from the study area.

Small starch grains (<0.5µm in max dimension) were also present in large numbers in several of the sickle residue samples (Figure 10-8). In several cases they appeared to occur in large clusters as possible membrane or cellular bound vessels. These are not dissimilar to those noted from the experimental sickle residues and are presumed to come from the starch reserves in oak leaves or branches. The small sizes of such starch granules and their rounded clustering is dissimilar to the starch from rice and other small grasses in the modern reference collection. However, some of the small clusters are of a similar size to transient starch clusters in *Quercus* sp. oak leaf and bark residues present on the experimental acorn sickle. The similarity of such remains to walnut and hackberry trees

has not been evaluated. However starch grains were not detected in reference slides of walnut and hackberry (see chap 7 section 7.3.3). Walnut nutmeat is comprised of about 3 percent starch (Savage, G. P., 2001: Table 1). Thus, it is unlikely much starch would be produced in the leaves of such plants.



a) Cluster of starch under a brightfield filter

b) Cluster of starch under a cross-polarising filter

Figure 10-8 Ancient starch residues from Jiahu sickle SK8_A

10.3.1.5 PRESENCE OR ABSENCE OF GRASS TYPE RESIDUES FROM WORKING EDGE

Grass phytoliths were present on residues from the working edges of eleven of the thirteen sickles (Figure 10-9). While phytoliths from the husk of grasses were not detected, residues from leaves and stems of grasses were present. These include bulliform and fan shaped phytoliths as well as long cells and in some cases bilobes (Figure 10-9). The bilobes are not short and squat like those of domesticated *Setaria* sp. grasses but are all longer and more typical of wild *Setaria* sp. grasses and of panicoid grasses generally. At this stage it is not possible to identify the small numbers of bilobes recovered. However, it is possible that some of the sickles were used to harvest bilobe bearing or panicoid grasses including *Setaria* sp. and *Panicum* sp.

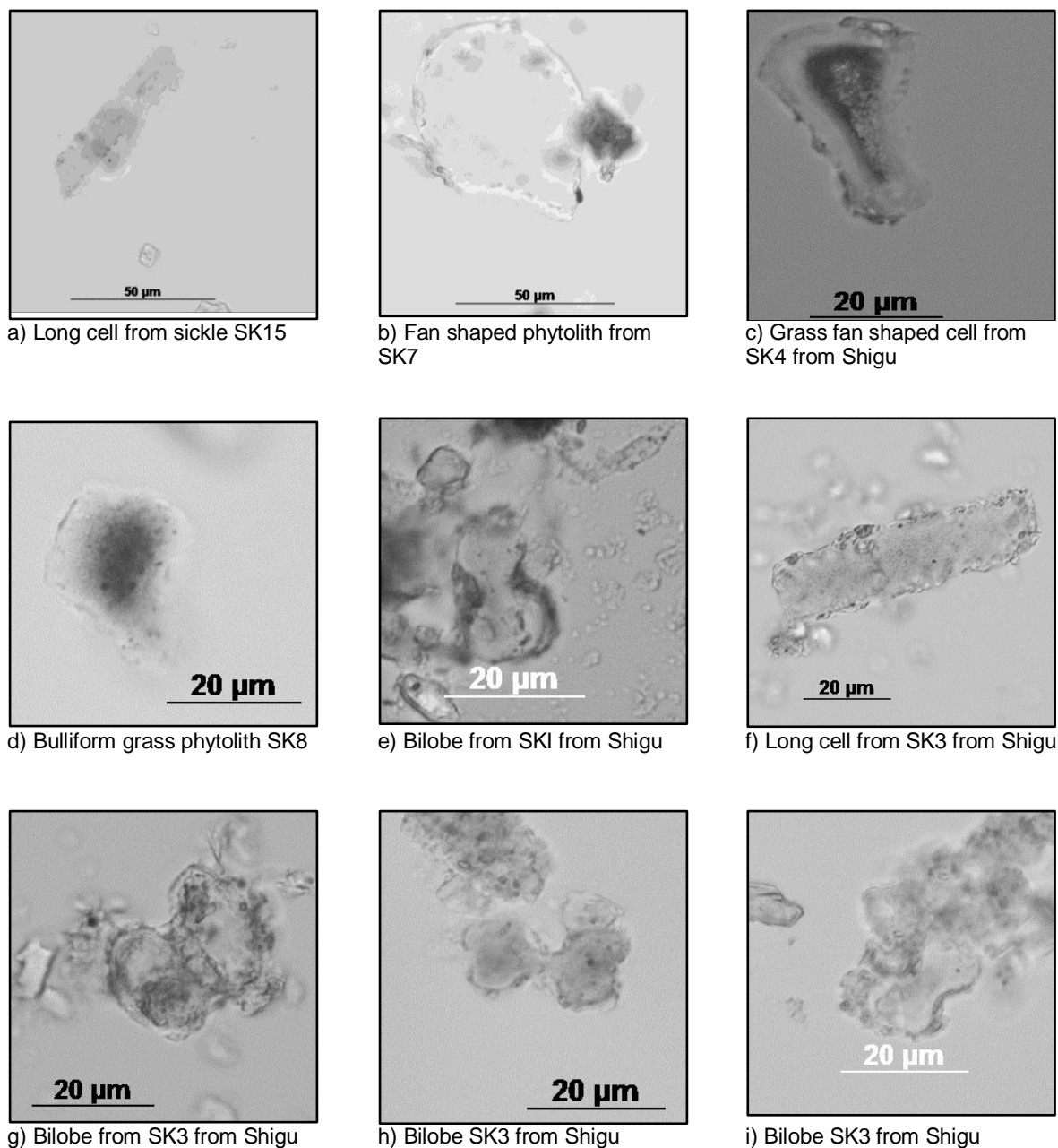


Figure 10-9 Grass Residues from Ancient Sickles

Bilobate phytoliths occur in several of the grass tribes recognised by the grass phylogeny working group (GPWG, 2001). Piperno (2006: figure 2.2 page 30–31) identified bilobate shapes in Bambusoideae, Ehrhartoideae, Aristoideae, Chloridoideae and Panicoideae tribes. H. Lu and colleagues (2009b) have suggested that it is possible to differentiate between domesticated phytoliths from foxtail millet (*Setaria italica* ssp. *italica*) and broomcorn millet (*Panicum miliaceum*). However, the study by H. Lu and colleagues (2009b) was based on a reference sample of 27 panicoid grasses including mainly

domesticates with only a few wild grasses included in the analysis.¹³ Their morphometric phytolith analysis suggested that cross shaped bilobes are present in domesticated *Setaria italica* spp. *italica* while the bilobe shaped type of phytolith occurs in *Panicum miliaceum* (2009b: 3).

Research in recent years has focused on identifying rice phytoliths (Pearsall, et al., 1995). Unfortunately a number of plants produce fan shaped phytoliths (Pearsall, et al., 1995: figure 4; Wang, Y. & H. Lu, 1992: Plate 1) so the presence of fan shaped phytoliths alone cannot accurately be used to identify the presence of rice in the archaeological record. Only the double peaked glume phytoliths of rice can be used to distinguish *Oryza* sp. husks from other grasses (Zhang, W. X., 2002).

10.3.1.6 OTHER PLANT RESIDUES

Several unidentified residues include phytoliths similar to coniferous or Pinaceae phytoliths. This may suggest that the sickles were used to cut or process wood in some way although evidence for this is not clear. Further experimental research on cutting wood with sickles is needed to ascertain the types of plant remains including phytoliths that might be present as residues from such an activity.

10.4 Sickle Analysis by Site

Sickles from three different sites were analysed. None of the sites presented diagnostic reed or sedge remains. All three sites presented both grass and dicotyledonous plant remains.

10.4.1 Egou

Of the two Egou sickles analysed, no residues were recognised from sickle SK6. Sickle SK5 had both grass and dicotyledonous plant remains present.

¹³ The reference collection used by H. Lu and colleagues and colleagues (2009a) includes 9x *Setaria italica*, 12x *Panicum miliaceum*, 2x *Panicum bisulcatum*, a single *Setaria viridis* and two other *Setaria* sp., *Setaria plicata* and *Setaria glauca*. A single specimen of *Echinochloa crus-galli* was also included in their analysis. See H. Lu and colleagues (2009a:2) for complete details.

10.4.2 Shigu

Four sickles from Shigu site were sampled. Of the three analysed all produced phytoliths from grass and from dicotyledonous plants.

10.4.3 Jiahu

Seventeen sickles were sampled from the Jiahu site and residues from eight of them were analysed for this thesis. None had reed or sedge type remains present. However, five out of eight samples had both grass and dicotyledonous plant remains present. Sickle 9 had only dicotyledonous plant remains present, while on sickles 11 and 15 only grass residue phytoliths were recognised. The grass phytoliths present included some fan shaped phytoliths (Figure 10-9), but these are dissimilar to typical rice fan shaped phytoliths.

10.5 Discussion

The similarities and differences between residues from experimental and ancient sickles will be outlined below. Implications for understanding the use of ancient sickles, based on modern experimental sickle residues, will be discussed.

10.5.1 Experimental Sickles

Typha sp. reeds do not produce diagnostic phytoliths (Piperno, 2006: 7), so searching for evidence of *Typha* sp. reed use using phytoliths is not a valid exercise. Based on the experimental research, it appears that while sickles used to harvest cattails may not preserve phytoliths from *Typha* sp. reeds, they may preserve residues from other plants accidentally harvested. These other plants may include sedge like plants, which may have diagnostic phytoliths, or reeds such as the Juncaceae, which tend not to have diagnostic phytoliths. Grasses may also grow together with the reeds being harvested and so may preserve as residues on sickles. Unidentified dicotyledonous plants may also be accidentally harvested along with *Typha* sp. or other types of reeds.

Experimental sickle harvesting of grasses produced a wide range of phytoliths, including bilobes similar to those from the Paniceae (millet) tribe. Dicotyledonous plant remains were present as residues after harvesting grasses.

Dicotyledonous tree harvesting produced the least amount of interference or incidental residues, probably due to the absence of grasses from the harvesting area. Sobollik (1996) studied use-wear and residues present on lithic tools from a southwestern archaic cave site

in the US. With the exception of general rounding and polishing usewear correlating to the presence of phytoliths and druse plant crystals, she found no correlation between usewear and the types of organic residues (fibres, hairs) present on the lithics studied (1996: 466). Experimental research presented here suggests there is some correlation between experimental activity and the residues preserved on sickle tools. However, incidental residues from activities that were not the main focus of work may also be present.

It is difficult to rule out small amounts of possible post-depositional contamination of residues from the sickles analysed. However, the experimental research presented here suggests that sickles used primarily for one activity such as harvesting grass, may preserve residues such as dicotyledonous tree cells that are inconsistent with this focal activity (see also Sobolik, 1996). This complicates the identification of tool usage activities based purely on plant residue analyses. It is likely that a range of analyses including use-wear and identification of other residues such as blood or feather traces may assist in evaluating ancient tool use.

10.5.2 Ancient Sickle Residues

Due to a lack of diagnostic phytoliths, it is difficult to ascertain whether ancient sickles were used to harvest *Typha* sp. reeds. It is not possible to either confirm or deny presence of *Typha* sp. starch grains on the sickles. Transient *Typha* sp. starch grains appear to be relatively small and non-diagnostic (despite archaeological identifications by Aranguren and colleagues (2007)).

The presence of small starch grains in clusters on SK7, 8 and 9 are similar to those found on the experimental sickle used to harvest acorns. A leaf hair base and several dicot cells preserved on the Jiahu sickles are comparable to modern acorn (*Quercus* sp.) harvesting residues. This suggests that some of the sickles from the Jiahu site may have been used to process tree products or tree crops such as the acorns found in pits at the site (Zhao, Z. and J. Zhang 2009: 94). This would be the first such evidence suggesting some sort of tree management or harvesting, and tree crops, in Neolithic China. However, other possible identifications for these small starch clusters include foxnut starch grains, which exhibit small rounded clusters of starch (Figure 7-15).

Bilobes are indicative of certain sub-families of grasses including the Paniceae millet tribe (Piperno, 2006: Table 2.2; see also Lu, H., et al., 2009b). They were present only at the

Shigu site on sickle SK3. Only one sample from the Egou site preserved residues so this small sample size may explain the absence of bilobes. It is difficult to accurately identify the bilobes present on Shigu site sickles. They did not appear to be the cross shaped foxtail millet (*Setaria* sp.) phytoliths described by H. Lu and colleagues (2009b) but were more similar to *Panicum* sp. bilobes. Consequently, it is not possible to accurately confirm their taxonomic identity at this time.

Panicoideae subfamily grasses including *Digitaria* sp. and *Echinochloa* sp. from the millet Paniceae tribe were present at Jiahu. However, flotation did not preserve any domesticated millet or identifiable wild ancestors of foxtail or broomcorn millet (Z. Zhao and J. Zhang 2009). The absence of these in the archaeological record may explain why bilobes similar to those from Shigu were not present on any of the Jiahu site sickles. Jiahu site is known for its early rice remains (Chen, B. and Q. Jiang 1997; Crawford and Shen, 1998; Zhao, Z. and J. Zhang, 2009) but no diagnostic rice glume husks were present on the sickles. Fan shaped phytoliths were present, but these may belong to a range of plants and are not definitive evidence for rice cultivation or harvesting. There is no absolute evidence for rice cultivation in the residues from Jiahu sickles. However, use for a range of plant processing tools is suggested.

If the stone knives examined for residues were used to collect nuts such as acorns from trees, this may suggest the collection of nuts prior to their being ripe or fully mature. In this case such nuts may have been stored until ripe or possibly laid in the sun to ripen. The implications of such a use for Peiligang sickles should be fully evaluated by further research.

In summary, it is possible that these stone ‘sickles’ were actually multi-purpose implements and preserved a range of residues including possible grass and tree harvesting traces. The small numbers of cereal or grass harvesting phytoliths as well as residue of other plants suggest that they may not have been used only for cereal harvesting.

Chapter 11: Discussion and Conclusion

The aim of the study presented here was to investigate the origins of agriculture in the central loess plains and plateau region of the middle Yellow River Valley, North China. A range of archaeobotanical methods were used to investigate Palaeolithic and Neolithic plant food subsistence. The methods included an investigation of late Palaeolithic, Peiligang and Yangshao seeds and macrobotanical charred remains recovered from flotation samples. Despite the minimal seed numbers recovered, this study represents the first attempt to systematically examine a chronological sequence of flotation samples beginning with the late Palaeolithic and continuing through what is generally conceived of as the initial Peiligang agricultural period through to the Yangshao.

A three pronged approach to the study of the archaeobotanical record was implemented here. Macrobotanical study, assessment of use-related residues and a comparative reference database of economic and non-economic plants were compiled. Residues from artefacts were analysed to add information to what is known about subsistence before, during and after the ‘origins of agriculture’ Peiligang period. These artefacts included *mopan* and *mobang* grinding implements and denticulate stone sickles characteristic of the Peiligang. This is the first residue examination of Peiligang stone sickles to date. This analysis of grinding implements builds on several recent studies of starch residues, including those by Li Liu and colleagues (2010b; 2010c).

A range of comparative plant reference samples were collected, prepared and examined for this thesis. These included macrobotanical samples as well as microfossil references of starch, phytoliths and bordered pits (see Chapter 7). The quality of identification and hence the conclusions drawn from this research rely on the plant references used in archaeobotanical identification. Therefore much time was spent in collecting and cataloging plant references for comparison with ancient plant material.

The implications of the study findings presented in this thesis for understanding the Late Palaeolithic, Peiligang and Yangshao period in the study region within North China are presented here and discussed in the context of current knowledge and debates on the timing and appearance of millet agriculture. In this chapter I will briefly summarise what is known about the agricultural transition in North China prior to the 21st century as an arbitrary division. Then I will discuss the changes in our understanding of agriculture in

ancient North China based on a number of recent studies and the data presented in this thesis. Results and data from this thesis will be discussed chronologically, from the Late Palaeolithic through the Peiligang and Yangshao periods.

11.1 20th Century View of the Agricultural Transition in North China

Our understanding of the agricultural transition in North China has changed dramatically in recent times. Changes in data collection and research focus have led to a clearer understanding of the type and timing of crop domestication and use. Prior to the 21st century, very little was known about the ‘agricultural transition’ in North China. In the fourth edition of ‘The Archaeology of Ancient China’ K. C. Chang (1986) was not able to identify plant remains from a transitional period between the nomadic Late Palaeolithic microlithic cultures and allegedly sedentary Peiligang agricultural societies. Although faunal remains were reported from numerous sites, plant remains were typically not visible and had not been recovered from Palaeolithic sites. Speculation regarding Late Palaeolithic plant use suggested that tubers and nuts were commonly utilised, but there was no hard evidence (Chang, K. C., 1986: 79).

No plant remains were reported from sites such as Nanzhuangtou and Hutouliang (Guo & Li, 2002) possibly because flotation was not commonly utilised at the time these sites were excavated. Although Lu’s thesis (1999) examined the transitional period between foragers and agriculturalists, she mainly focused on domesticated cereals rather than uncovering evidence for different forms of subsistence. The Peiligang and related cultures are commonly held to be the initial agricultural sites in China (Chang, K. C., 1986: 87). However plant remains transitional between wild and domestic taxa that should precede agricultural societies were not identified until Li Liu and colleagues (2002-2004: 82) recovered four grains of *Setaria* sp. grasses intermediately sized between domesticated and wild taxa.

Two types of artefacts which are typologically Peiligang were examined for residues in this study: grinding *mopan* and *mobang* and denticulate stone sickles. Grinding stones and sickles were usually interpreted as cereal processing implements and were thought to have been used for grinding or dehusking millet cereals. Denticulate sickles were thought to have been used for harvesting or reaping millet grains (Chang, K. C., 1986: 91-93). Given the lack of flotation and residue research during the 1970s and 1980s, when many of these

early agricultural sites were excavated, it was a reasonable hypothesis at that time. However, recent residue research outlined in Chapter 9 has shown that acorns were at least equal or more important as a staple food than millet cereals. Furthermore, it has now been demonstrated that acorns were also ground on Peiligang *mopan* and *mobang* for food (Liu, Li, et al., 2010c; Tao, et al., 2011). In addition stone sickle surfaces yielded grass and eudicot residues (Chapter 10). Consequently, it appears that stone grinding implements and sickles were multifunctional artefacts.

The implications of these results will be discussed with regard to North China subsistence during the Late Palaeolithic, Peiligang and Yangshao periods. The significance of plant remains from these time periods will be discussed in light of the transition to agriculture during the Peiligang and Yangshao periods.

11.2 Late Palaeolithic Plant Food Subsistence in North China

Foods utilised in a region relate directly to the environmental background. An environmentally deterministic understanding of agricultural origins would relate subsistence change directly to climatic and environmental concerns. However such a model is not proposed here. Models of agricultural origins that relate to multiple factors including environmental effects and internal social dynamics are currently in favour. The origins of North Chinese agriculture were examined in light of the new data and new ideas, as well as the theories, presented in this thesis.

11.2.1 Environmental backdrop to research sites and time period

The cold and dry Late Palaeolithic post-glacial steppe environment gradually transformed into a more temperate region by the early Holocene around 11,000 cal BP (Bettinger, et al., 2007: 85). The mid-Holocene hypsithermal occurred sometime between c. 9,900 – 4,500 cal BP in China (Barton, L., et al., 2009) and this corresponds roughly to the Peiligang and Yangshao periods in North China. Pollen profiles from the Yellow River basin suggest that grasses decreased while broad-leaved forest taxa increased between 12,000–9,800 cal BP (Yi, et al., 2003). At Jiahu broad-leaved and tree taxa increased during the period prior to c.9,000 cal. BP to make up 20 percent of the pollen profile (Henansheng, 1999: 809).

11.2.2 Palaeolithic flotation samples

It is difficult to investigate the transition to agriculture without an understanding of the nature of society and subsistence in the pre-agricultural period. Despite numerous

discussions in the literature concerning the origins of agriculture in North China, one of the only known systematic studies of Palaeolithic seed remains occurring before agriculture in North China is presented here. Chenopods were present in ‘pre-Dadiwan’ layers at Dadiwan in the Upper Yellow River Valley (Ji, 2009), but the date of this layer or implications thereof, were not discussed.

Flotation samples from two localities at the Shizitan site, situated along the Qingshui-Wei river valley in Shanxi Province, North China, were examined. Locality S14 dates to 20,700-20,000 cal BP (this thesis, lab number BA01158) and locality S9 dates between c. 13,800-8,500 cal BP (Xia, Z., et al., 2002). This latter locality provided evidence for the earliest known examples of cf. *Setaria* seeds collected from cultural layers in North China. Small numbers of grass seeds were recovered from 225 litres of floated sediment and included specimens similar to *Setaria* sp. grasses. Research on grinding implement residues (Liu, Li, et al., 2011) suggested that additional foods at Shizitan included beans, yams and acorns.

11.2.2.1 INDIGENOUS DOMESTICATION OF MILLET TRIBE GRASS SEEDS

It appears that the forerunner of Neolithic seed based subsistence were present at Shizitan between c. 13,800-8,500 cal BP. Two *Setaria* type and two cf. *Setaria* sp. seeds as well as one *Echinochloa* sp. seed, were recovered from the upper layers of Shizitan locality S9. In addition, three other Paniceae tribe and two other Poaceae grass seeds were recovered from both the upper and lower layers of this site. Seeds of *Setaria* sp. were present throughout the Neolithic and into the Erlitou early state period in many North Chinese flotation samples and included both wild and domesticated specimens (Bestel, 2006; Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007; see also this thesis, Chapter 8). Barnyard grass or *Echinochloa* sp., also in the millet tribe, was also sporadically present (Lee, G.-A., et al., 2007).

Crawford (2005: 80) observed that no archaeological sequence of seeds from wild to domesticated had been recovered for either foxtail or broomcorn millet crops. However, evidence for indigenous development of agriculture requires pre-domestication usage of the taxa that were eventually domesticated (Bettinger, et al., 2007: 83). The Shizitan seed remains provided the first reliable macrobotanical evidence for pre-domestication usage of millet in North China and hence also the first macrobotanical evidence for indigenous domestication of millet in North China.

Wild barnyard grass seeds are common in the late Early Jomon (*c.* 4,000 – 3,500 BC) at the Hamanasuno site in Hokkaido, Japan (Crawford, 2005: 80). One thousand to fifteen hundred years later towards the end of the Middle Jomon (*c.* 2,500 BC) Crawford noted seeds indistinguishable from cultivated barnyard millet at the nearby Usujiri B site (Crawford, 2005: 80). A domestication event occurring over 1,000-1,500 years is neither a particularly long, nor a particularly short event. Hillman and Davies (1990) attempted to replicate conditions of domestication in wild wheats and barley. They found that a process simulating the domestication of wheat could occur in approximately 200 years or perhaps 20 to 30 years given the right conditions. However, computer simulation modelling of genetic changes suggests a prolonged or protracted domestication process (Allaby, et al., 2008). This concurs with recent suggestions by Fuller and colleagues (Fuller, 2007; Fuller, et al., 2009) regarding a prolonged or protracted model of rice domestication in South China.

Fuller and colleagues suggest that rice reached full domestication at the Tianluoshan site in South China by 6,900 – 6,600 cal BP (Fuller, et al., 2009). This suggestion was based on an increase in the number of non-shattering spikelet bases which corresponded to an increase in the percentage of rice at the site across this three hundred year period. However, rice spikelet bases are less commonly preserved at non-waterlogged sites such as Jiahu where an increase in seed size is more commonly used as an indication of domesticated status (Zhao, Z. & J. Zhang, 2009; Zhao, Z. 2011). Rice has been gathered or cultivated for many thousands of years and was used as a plant temper in pottery at the Shangshan site (Jiang, L. & Li Liu, 2006), which has been dated to around 10,000 cal BP (Jiang, L. & Li Liu, 2006: 356). Rice appears to have been used for several millennia prior to the occurrence of non-wild type rachillae at sites such as Tianluoshan. A non-shattering rice rachis was also present at Shangshan (Zheng, Z. & Jiang, 2007) and was used with morphological data to suggest that rice use at Shangshan may signal the emergence of the rice domestication process (Jiang, L. & Li, Liu, 2006; Zhao, Z., 2011). The location of Jiahu outside the area of the distribution of wild rice also led Z. Zhao (2011: S296) to suggest that rice use at Shangshan may signal the start of the rice domestication process. He suggests that the earliest clearly domesticated rice in China comes from Jiahu and dates to between 9,000 – 7,800 cal BP (Henansheng, 1999: 515).

In summary, Z. Zhao (2011: S299) and also Fuller and colleagues (2009) appear to agree that domestication of rice was a gradual process that began with intensive and long-term

rice cultivation. However, it appears that both Z. Zhao and Fuller and colleagues use different definitions of cultivation and domestication to support early or late arguments for the importance of rice. Fuller and colleagues suggest that that rice domestication ‘culminated’ with morphologically evident changes in rice rachillae after *c.* 6,500 cal BP (2009: 1609). Z. Zhao (2011) suggests that this process had begun by 8,000-7,700 cal BP as indicated by domesticated type rice spikelet bases at Kuahuqiao (Liu, Li, et al., 2007a; Zheng, Y., et al., 2005). Z. Zhao (2011) suggests that domesticated rice at Jiahu is indicative of an ‘early stage’ in the initial transition to rice agriculture and one that continued with cultivation across several millennia. It seems that Z. Zhao refers to the initial stages of a lengthy transitional process while Fuller and colleagues refer to the later stages of the same process for definitive evidence of morphological change.

Until now, there has not been enough evidence to make suggestions about the length of time required for domestication syndrome traits to occur in North Chinese millets. However, with evidence of grass seed usage prior to *c.* 13,000 cal BP at Shizitan and cf. *Setaria* type millet grasses present in later layers of the site, it is likely that a prolonged period of grass seed usage and experimentation took place prior to eventual domestication during the Peiligang. This is comparable to models for the Near East, which suggest that domesticated wheat and barley took millennia to become domesticated (Tanno & Wilcox, 2006: 1886; Weiss, et al., 2006).

An issue related to the length of time required for crop domestication is the question regarding the speed of the spread of the domesticated crop (Jones, 2004; see also discussion in Zhao, Z., 2011 regarding the uptake of rice agriculture). Less than 1,000 years after the initial occurrence of domesticated millet in China over twenty sites with millet remains were present west of the Black Sea (Jones & X. Liu, 2009: 731). Due to difficulties with recording and identifying early records of millet (see Hunt, et al., 2008) it remains uncertain exactly whether these records refer to broomcorn or foxtail millet. However this is an extremely rapid transition from semi-sedentary or sedentary foraging to what were probably initially low-level food producing societies (Smith, B. D., 2001).

D. J. Cohen (1998) initially suggested that broomcorn millet was domesticated in central Asia but this claim has not reappeared in his more recent publication (2011). The earliest known domesticated broomcorn millet in central Asia dates between 4,410-4,140 cal BP (Frachetti, et al., 2010). Polymorphisms in genetic data at both ribosomal and

mitochondrial genetic loci suggest that East Asia is the centre of origin of foxtail millet (Fukunaga, et al., 2002; 2006; Fukunaga & Kato, 2003). However, genetic data from an international collection of foxtail millet suggest an independent domestication of foxtail millet races in Afghanistan and north-western Pakistan (Fukunaga, et al., 2006). Other proposed centres of origin for foxtail millet include Taiwan and the Philippines in tropical East Asia, although Fukunaga and colleagues (2006) note that the ribosomal markers have a complex evolution meaning that this proposed centre of origin is only tentative. Broomcorn millet was probably domesticated in China (Hunt, et al., 2011) although an independent domestication event in Eastern Europe is also not ruled out by genetic data.

As eventual cereal domestication suggests, during the Late Palaeolithic ancient people were experimenting with a range of grasses. The macrobotanical grass seed remains, including non-Paniceae tribe grasses, present at the S9 Shizitan site dated between 13,800 – 8,500 cal BP (Xia, Z., et al., 2002) also attest to this. This evidence is consistent with pre-domestication usage of grass seeds, although not necessarily with pre-domestication grass cultivation. Residue analysis of two grinding *mopan* and *mobang* implements from the upper layers of the same site also yielded similar evidence for experimental grass use (Liu, Li, et al., 2011). Starch remains recovered from these grinding implements were consistent with two distinct grass sub-families, the panicoid and the pooid grasses. Millets are included in the panicoid subfamily and some millets (broomcorn millet and foxtail millet) first appear as domesticated taxa in China during the Peiligang period, although wild millets were present at Shizitan (Chapter 8). Li Liu and colleagues (2011: 3530) note difficulties in identifying panicoid starch grains to species or even genus level. However they also note the similarity of a large cluster of starch grains (n=58) within a cell wall to small grained grasses in the Paniceae tribe (Liu, Li, et al., 2011: 3528-3529). Other panicoid grass starch from the Shizitan implements exhibits similarities to both Andropogoneae and Paniceae tribe modern reference samples.

In addition to panicoid starch grains, pooid starch grains were present on the Shizitan grinding artefacts. The pooid subfamily includes several tribes as well as the archaeologically well-known Triticeae (wheat and related taxa) tribe. A total of 27 starch grains identified as Triticeae taxa were recovered from Shizitan grinding implements, each exhibiting the large and rounded morphology characteristic of this tribe. These are similar to modern *Agropyron* and *Elymus* sp. reference taxa, both of which are common in North China today. Wild pooid tribe grasses do occur in Neolithic China, including at Jiahu

during the Peiligang period (Zhao, Z. & J. Zhang, 2009) and at Liangchengzhen during the Longshan period (Crawford, et al., 2005). Domesticated wheat is thought to have been introduced to North China sometime around 4,500 cal BP (Zhao, Z., 2009: 5). Given the evidence for use of ground Triticeae tribe taxa in the late Palaeolithic,, , it appears that ancient people may have known how to use and grind Triticeae cereal grains prior to the introduction of wheat. The knowledge of wild Triticeae, including how to grind it and prepare it for food, may have enhanced the ease of introduction of related domesticated Triticeae when wheat was introduced. . More research on wild Chinese Triticeae grasses is needed to determine the exact genera of the Triticeae tribe starch grains at Tieshenggou and the exact ways in which they were prepared for consumption.

11.2.2.2 PALAEOLITHIC USE OF CHENOPODS

Chenopod remains occur in North Chinese sites across the Neolithic and into the early state periods (see Lee, G.-A. & Bestel, 2007; Lee, G.-A., et al., 2007; Zhao, Z. & J. Zhang, 2009). Chenopod or amaranth seeds were recovered from both the Shizitan S9 and S14 localities (Chapter 8). *Chenopodium* sp. represent one of the early domesticates in the Americas, with B. D. Smith (2006) suggesting wild cultivation of chenopods by 8,500 cal BP. Chenopod remains are known from ‘pre-Dadiwan’ layers at the Dadiwan site (Ji, 2009) however Ji did not provide ‘pre-Dadiwan’ dating information. Crawford (2005: table 5.1) lists chenopods as an example of a managed or domesticated plant in East Asia.

Lee, G.-A., et al. (2007: 1090) suggest that the different size and shape of chenopods represented in Yiluo Region samples from the Yangshao period onwards, suggests that different species are involved. Certain specimens exhibit a truncated margin similar to some thin-testa domesticated varieties from the Americas. Certain chenopods may also have been used as kindling or as a fuel for starting a fire rather than as a food source. In modern times chenopods are used for this purpose in northern Shaanxi (Liu, Li, 2011, Pers. Comm.). This would explain their constant presence as charred seeds from ash pits in the archaeobotanical record and may explain an absence of selection for thin-walled seed specimens in certain taxa. Other amaranth or chenopod taxa, however, may have been cultivated if not domesticated in Neolithic China (Lee, et al., 2007: 1090) although further research is needed to determine this.

11.2.3 Broad Spectrum Revolution

The broad spectrum revolution (BSR) (Flannery, 1969) predicts a significant increase in low ranked resources including plant foods prior to agriculture. However, resource stress-based models of dietary adaptation including optimal foraging theory do not always fit emerging scenarios of agricultural adoption in resource rich areas (see Zeder, 2012: 242). In addition, resource ranking is itself a contentious issue. For example, a resource in one location and to one group of people may be highly ranked, but to other people with different technology or in a different environment, the same resource may rank much lower.

Plants that Bettinger and colleagues (1997) have described as low ranked were identified at Shizitan and include grass seeds from two grass subfamilies as well as acorn starch. The longevity of grass seed use in Palaeolithic China is uncertain, although no grasses were observed at the 20,700-20,000 cal. BP site of S14. Only 5 seeds were recovered from S14 (including three chenopods), probably due to the small bulk sediment sample size that was available for flotation.

Bettinger and colleagues (1997) have also described acorns as a low-ranked resource, and it has been hypothesized that the presence of low-ranked resources such as acorns at Shizitan in North China, may signal the beginning of the BSR (Liu, Li, et al., 2011). Substantial evidence for the BSR in the Late Palaeolithic was identified by Weiss and colleagues (2004a,b) at the c. 23,000 cal BP Ohalo II site in Israel. This waterlogged site preserved over 90,000 plant remains including a number of small grained grasses (Weiss, et al., 2004a). It appears that the Ohalo II inhabitants experimented with a range of wild grasses prior to domesticating wheat tribe taxa in the early Holocene (Weiss, et al., 2004a). Macrobotanical evidence for small grained grasses disappeared from the archaeological record in this region after wheat and barley domestication (Weiss, et al., 2004a). Experimentation with a wide range of grasses prior to domestication of a narrow number of species may also have occurred in North China although the sample size of macrobotanical seed remains recovered from China and presented in this thesis is much less than that recovered from Ohalo II.

A major concern with the application of the BSR theory, which was initially conceived in response to perceived changes in the Near East (Flannery, 1969) is that plant-related subsistence practices prior to the introduction of grasses is unknown in North China. The BSR requires that the subsistence base be broadened to allow experimentation with grasses

and other low-ranked resources such as acorns. Evidence for the consumption of both is certainly present at Shizitan. It is possible that the apparent broadening of the resource base during the Late Palaeolithic at Shizitan was not a broadening at all, but simply a continuation of a relatively stable and long-established subsistence pattern that included low levels of grass and nut consumption. More research is needed to determine when initial grass and acorn subsistence really took place before it may be determined that the BSR is applicable to North China in the Late Palaeolithic.

11.2.4 Palaeolithic residue samples from grinding implements

In Asia, starch grains on grinding implements from Kagoshima prefecture in southern Kyushu, Japan, were contextually dated to 30,000 BP, but Shibutani (2009) was not able to identify the species to taxon. Despite earlier theories that grinding artefacts in China were an agricultural adaptation (see Liu et al. 2002-2004: 81-82) they are present in the Late Paleolithic cultures of North China (Lu, T. L. D., 1999: 38). Grinding slabs are associated with the Xiachuan culture which is thought by some to represent the forerunner of Neolithic farming cultures of the middle Yellow River region (see also Lu, T. L. D., 1999: 38; Wu, S. W., 1994). Grinding slabs were also used for ochre grinding at Shizitan and exemplify late Palaeolithic grinding technology (Shanxisheng, 1989). In addition to grasses, the Shizitan grinding slabs also preserved starch grains from acorns, yams and beans (Liu, Li, et al. 2011). The Shizitan site is currently the earliest taxonomically identified pre-Neolithic evidence for plant food processing in Asia.

11.2.4.1 ACORNS

Starch and use-wear analysis on two *mopan* and associated *mobang* from the early Holocene layer IV at Shizitan suggest that acorns were an important part of the diet at that site (Liu, Li, et al. 2011). The pollen of *Quercus* sp. was intermittently present at the site throughout its 35,000 year period (Xia, Z., et al., 2002: figure 1). It is possible that fluctuations in this food source caused less-frequently utilised foods such as grasses to become more important during the early Neolithic (see Fuller and Qin, 2010).

The identification of acorns as an important staple food source in Chinese Holocene communities is supported by residue analyses of grinding artefacts in North China (Liu, Li, et al., 2010b; Yang, X. Y., et al., 2009a), north-east China (Tao, et al., 2011), the central plains region (Liu, Li, et al., 2010c; Tao, et al., 2011; Zhang, Y., et al., 2011) and in South China (Liu, Li, et al., 2010a).

Bettinger and colleagues (1997) have developed an optimal foraging model of acorn processing based on ethnographic evidence from modern Californian groups where acorns were an important if not a staple, dietary resource. For some Californian hunter gatherers, acorn field processing was minimal and confined mainly to drying acorns (Bettinger, et al., 1997). Acorns used by Paiute and Yosemite Valley Indians were then ground and leached to remove toxins prior to human consumption (Ortiz, 1991). Nutshells were then discarded, frequently into a fireplace. In some Indian sites this practice resulted in numerous charred acorn and nut shells (Yarnell & Black, 1985: 97). Given the absence of discussion in the Chinese literature regarding the use of acorns in ancient times (although recent starch research on early Neolithic grinding implements typically identifies acorn starch), this model will be compared briefly to the study region.

Numerous acorns or nutshells are typically not reported for Peiligang sites (although see Jiahu report (Zhao, Z. & J. Zhang, 2009)). This may be due to a research focus on domesticated crops and to the lack of flotation carried out on Chinese sites (see Zhao, Z., 2004). However in the study area of Henan and Shanxi Provinces in North China, where flotation was carried out for this research, identifiable acorn or other nutshells were not recovered from the light fraction of the flotation samples. A single fragment of probably Rosaceae nutshell was recovered from a Yangshao period flotation sample (Chapter 8). This suggests that certain stages or steps in the acorn processing methods used in modern or ethnographic California and in the study region of North China in the Late Palaeolithic and Peiligang periods may be different. There appears to be different amounts of acorn and nut shell recovered from the archaeological records in the USA and China. This may indicate different methods of processing acorns in the different continents. It is possible that Palaeolithic people de-husked the shells away from the living or cooking area or simply disposed of the shells somewhere not in a fire. They may also have had acorn collecting and processing camps away from the main village areas (Liu, Li, in press). Such processing would explain the presence of acorn starch and a lack of charred macrobotanical nutshells. The model proposed by Bettinger and colleagues (1997) of bringing acorns to a central place for de-shelling, processing and grinding prior to discard and eventual deposition in the archaeological record does not fit with the North China evidence presented in this thesis.

11.2.5 Optimal foraging theory and other ecological models

Optimal foraging theory as applied to Late Palaeolithic and early Neolithic North China might suggest that the gradual change in staple plant foods over time was related to resource ranking. Low-ranked resources such as acorns were gradually replaced by grass seeds, the latter taking less time to prepare for consumption though they are still ranked relatively low on a caloric return scale. However, according to Kelly (1995) acorns ranked higher than grasses in terms of the resource return rate, with acorns returning 1488 kcal/hr while grass seeds only returned 575 kcal/hr.

In North China, acorns may have been processed differently to Californian acorns. Acorns may have been a relatively high ranked plant resource in California, but in some parts of China are now a famine food eaten only when there is nothing else to eat. This different plant resource ranking between China and California may be due to dissimilar acorn preparations methods. If oaks decreased due to changing climatic conditions and further travel was required to gather acorns, this would account for a change in the ranking of this resource. The lack of acorn nutshells in some North Chinese archaeological sites, when acorns are clearly processed, may appear different to Californian archaeological evidence for acorn usage. Acorn nutmeat and nutshells are common in archaeology sites in California (Bettinger, et al., 1997) and other parts of the United States (Yarnell & Black, 1985). However, the macrobotanical remains of acorns are rare to non-existent in some archaeological sites in North China such as in the Yiluo Basin, but in other sites such as Jiahu acorns are common (Zhao, Z., & J. Zhang, 2009). In addition, the lack of flotation at sites such as Egou and Shigu may lead to an apparent absence of acorns that is unfounded.

A drawback to the application of optimal foraging theory to the current study is that only plant food subsistence was examined in detail here. The higher-ranked dietary choices of meat and animal products were not addressed, although details regarding the type of meat consumed may be garnered from the 'laundry lists' of animal species present in some field reports (IACASS, 1984; Kaifeng Diqu, 1979; Shanxisheng, 1989; Guojia, 2004; Shizitan Kaogudui, 2010). Archaeological evidence from North China to support Bettinger's 'central place theory' derived from Californian Indian acorn processing (1997) has not been recovered.

11.2.5.1 YAMS AND BEANS

Yams and beans are components of the Late Palaeolithic diet in North China (Liu, Li, et al., 2011). At the current time, little is known of the processing methods, particularly how grinding implements were used in the preparation of these foods. Some beans (soybeans) are prepared extensively to make foods such as tofu but yams and beans may typically be eaten either raw or with minimal preparation. Until more information is obtained on processing methods it is difficult to evaluate the low proportions of starch from these taxa in grinding artefacts residue samples.

11.3 Peiligang and Yangshao Subsistence: Yiluo Samples

The Peiligang culture lasted from c. 9,000 – 7,000 cal. BP in central China. It is similar to several other cultures that were present at the same time, including the Cishan culture. This led K. C. Chang (1986: 88) to describe this cluster of cultures as the ‘Peiligang and related cultures’. Peiligang sites in the Wuluo region of the Yiluo Basin were typically small and egalitarian (Liu, Li, 2004: 74). Based on the small sizes and thin cultural deposits in the Wuluo Region of the Yiluo Basin, Li, Liu and colleagues (2002-2004: 82) have suggested that these were a semi-sedentary population. This is consistent with other low-level food producing societies. The increased sedentism, ash pits and standardised grinding implements of the Peiligang period may indicate a shift in subsistence that should be evident from plant food remains recovered from the archaeological record (Bettinger, et al., 1997: 897). This may indicate a shift away from the broad spectrum revolution, proposed by Flannery (1969a), towards an increased use of grasses.

Henan Province sites with macrobotanical remains included Tieshenggou, where carbonised fruit kernels from pits were recovered (Fu, 1980; IACASS, 1986; Gongyishi, 1992; Kaifeng Diqu, 1980). The flotation of two bulk sediment samples from an ash pit at Tieshenggou produced only limited charcoal fragments and no identifiable macro-remains (chapter 8). In fact, seed remains were rare in Peiligang sites with only 2 out of 7 sites examined preserving evidence for seed taxa. This may suggest that the transition to a cereal based subsistence strategy had not yet occurred by the Late Peiligang in the Yiluo study region of North China.

The site of Wuluo Xipo yielded carbonised remains of four small millet grains, which were intermediate between wild and domesticated foxtail millet (Liu, Li, et al., 2002-2004: 82). Lee and colleagues (2007) identified two foxtail millet grains and two wild foxtail grass

seeds from the Yiluo Basin site of Wuluo Xipo, as well as a single manna grass or panic grass specimen. The same team also recovered two foxtail millet grains from the Peiligang Fudian Dong site (Lee, G.-A., et al., 2007). In summary, there are less than 15 identified domesticated seeds dating to the Peiligang period from the Yiluo Region. Fragments of tubers or roots were recovered from the Peiligang Wuluo Xipo site, however these were not taxonomically identifiable (Chapter 8). The earliest domesticated seed remains from the Yiluo study region came from the site of Fudian Dong (Chapter 8). The seeds were from archaeological horizons dated on flotation charcoal to 7,504 – 7,412 cal BP (NZA 33139) suggesting that the Peiligang period started later in this region than at places such as Jiahu. There is a paucity of domesticated seeds in the Peiligang period from the Yiluo Region. This corresponds to the lack of recovered seeds by Lu and colleagues (2009b) from the Cishan ash pits. Research on ten samples from seven sites in the Yiluo region recovered only 18 seeds from 90.5 litres of sediment. Five of these seeds (less than 30 percent) were from domesticated species. Only two of the Peiligang period sites examined produced seed remains at all. This is consistent with research on several Yiluo region sites by G.-A. Lee and colleagues (2007) where only small numbers of seeds and domesticates were found from the Peiligang period. Similar sample sizes from the Yangshao period produced much greater numbers of seeds: 782 seeds from 42 litres of sediment. Of these only 93 seeds or less than 12 percent, were domesticated. Many of these seeds were *Digitaria* with some *Echinochloa* sp taxa. These two taxa were also present at Jiahu but were not domesticated (Zhao, Z., & J. Zhang, 2009), although it is possible that they were cultivated. This is consistent with B. D. Smith's 'middle ground' between hunter-gatherers and agriculturalists (2001). Crawford (2011) has suggested that the middle to late Jomon of Japan, with a heavy reliance on nuts and small numbers of domesticated crops, fit the conceptual 'middle ground.' It is possible that the Peiligang in China, rather than being conceptualised as an agricultural society with a heavy reliance on millet cereals, actually practiced a plant subsistence strategy that was similar to the Jomon model.

At Xinglonggou in north-east China directly dated domesticated millet grains are approximately contemporary with domesticated millet from Fudian Dong. However, the number of millet seeds at this site is far greater than those recorded in the Yiluo region during the Peiligang: 1,400 charred broomcorn millet grains and about 60 grains of foxtail millet (Zhao, Z., 2011: S301). This is partly due to a larger bulk sediment sample size at Xinglonggou. Domesticated millets make up nearly 50 percent of the charred Xinglonggou seeds, which compares favourably to the five domesticates from 18 seeds in the Yiluo

Peiligang samples. Xinglonggou millet seeds were located across the site, with domesticated seeds occurring in only about five percent of the 1,200 soil samples collected and processed (Zhao, Z., 2011: S301). It can be concluded that the ubiquity of domesticated millet across the site was very low.

The small sample size may be a reason for the small numbers of seeds in the Peiligang samples. In addition, a lack of seed-based subsistence in the research area may be a significant factor. Site size and the number of individual sites increased across the Neolithic in the Yiluo region (Liu, Li, et al., 2002-2004).

Other possible explanations for the small number of macrobotanical seed remains in the Peiligang period relate to site formation processes. If people were not eating seeds and were not utilising a subsistence regime heavily invested towards grasses, it is unlikely that there would be many seed remains in the archaeobotanical record. However, evidence from the Late Palaeolithic site of Shizitan may indicate that some grasses were present in anthropogenic habitats around sites and were preserved through charring in cultural layers of Late Palaeolithic horizons (Chapter 8). Thus grasses, along with lithic debris, grinding artefacts and bone food remains, were preserved as cultural artefacts from the Late Palaeolithic (Guijia 2004; Shizitan Kaogudui 2010). Additional evidence in the form of starch residue analyses (Liu, Li, et al., 2011) from the site suggest that a range of foods including acorns and yams comprised the non-seed or vegetative part of the diet.

11.3.1 Peiligang Starch Residues

Several recent studies have examined starch residues from grinding implements in North China (Liu, Li, et al., 2010b; 2010c; Yang, X. Y., et al., 2009a). To date a number of different plant families have been identified from ancient residues in North China, including the bean family (Fabaceae), the oak family (Fagaceae), yams and other underground storage organs (Dioscoreaceae/ Cucurbitaceae) and millet (Poaceae) (Liu, Li, et al., 2010b; 2010c; Tao, et al., 2011; Yang, X. Y., et al., 2009a). Peiligang starch taxa are broadly consistent with the taxa identified in the Late Palaeolithic Shizitan starch residues (Liu, Li, et al., 2011) suggesting a general continuation of the wide-ranging subsistence strategy.

11.3.1.1 STARCH FROM GRINDING IMPLEMENTS AT EGOU AND SHIGU

Analysis of grinding implements from the Peiligang site produced evidence of a range of taxa including *Quercus* sp. acorns, yams and beans (Zhang, Y., et al., 2011). A published analysis of grinding artefact residues from Peiligang Egou and Shigu sites reported several different types of starch. This suggested that Peiligang *mopan* grinding tools were multi-functional (Liu, Li, et al., 2010c). The main plant foods processed included *Quercus* sp. acorns, with some yam, beans and millet grains (Liu, Li, et al., 2010c). Acorns and yams are known to have been a component of subsistence activities at the Jiahu site from the Peiligang period (Zhao, Z., & J. Zhang, 2009), however this was the first evidence of these plants at Egou and Shigu.

11.3.1.2 STARCH FROM GRINDING IMPLEMENTS AT TIESHENGGOU

Mopan and *mobang* grinding implements from the Peiligang Tieshenggou site were examined for starch and other residue remains (see Chapter 9). Over 1,230 starch grains were recovered from six artefacts. These were classified into ten morphological types with approximately 40% unknown or unidentified starch grains. Grass starch grains from both the panicoid and pooid subfamilies were identified and tentatively assigned to cf. *Andropogoneae* and cf. *Triticeae* tribe levels respectively. Each of these grass types constituted approximately 30 percent of starch in the total assemblage. In addition, two types of acorn starch from both *Quercus* and *Lithocarpus* spp. were present, accounting for almost 15 percent of starch in total. The identification of *Lithocarpus* sp. starch on Tieshenggou grinding implements may reflect a warmer, wetter climate in the Peiligang period, more suitable for this sub-tropical genus.

Small amounts of starch from underground storage organs such as yams or tubers (tentatively identified as cf. *Dioscoreaceae*/ *Cucurbitaceae* tubers) and bean starch (cf. *Phaseoleae* tribe) were also present at Tieshenggou. Almost 10 percent of starch granules were small, round and indeterminate granules that may represent several taxa including small millet or panicoid grass starch, as well as possible transient starch or starch from several other taxa. A student's t-test suggested that they were statistically similar to broomcorn millet starch grains ($t = -0.12$, $df = 1$, $p < 0.05$) but not to any other taxa in the reference collection. However, there is considerable overlap between small grained grass starch sizes and this result should not be taken as evidence of broomcorn millet starch in the assemblage until further research on modern reference data has been completed. It was

not possible to confirm the presence of millet starch granules with certainty in the Tieshenggou assemblage.

Many wild *Paniceae* tribe grass seeds are also present in the Yangshao flots. These are difficult to separate out and identify (King, n.d.). Nevertheless, several different types are clearly evident. At the site of Wuluo Xipo a possible *Glyceria-Panicum* grass seed was recovered (Lee, G.-A., et al., 2007: table 1 page 1089). The genus *Panicum* is variable in form and some *Panicum* sp. seeds are indistinguishable from *Glyceria* sp. seeds so they were categorised together (Lee, G.-A., et al., 2007).

Grasses of *Glyceria* sp. are pooid grasses not panicoid grasses. This means that this specimen is not in the *Paniceae* tribe within the Panicoid subfamily of grasses, but in the *Meliceae* tribe of the Pooid subfamily. Some grasses in the Pooid subfamily, namely *Bromeae* and *Triticeae*, typically have easily distinguishable large and round types of starch grain diagnostic of these two tribes (Clayton & Renvoize, 1986: 143-144; see also chapter 7 section 2.3). These types of starch grains have been identified in the microfossil record on grinding artefacts from various sites across North China during the late Palaeolithic (Liu, Li, et al., 2011) and Peiligang period (Liu, Li, et al., 2010c; Yang, X. Y., et al., 2009a). More research is needed to determine the identity of these and other small grass seed taxa and whether they are represented as a Pooid starch grain taxa on grinding implements from the Peiligang and Late Palaeolithic periods.

11.3.2 Starch from other early Neolithic Grinding Artefacts in China

Residue and use-wear analyses on a grinding slab and handstone from the Donghulin site near Beijing in North China suggested that processing acorns was a major task for grinding implements (Liu, Li, et al., 2010b). Tao and colleagues (2011) determined that north-eastern grinding implements from Baiyingchan were used to process *Quercus* sp. acorns. Similar research on Shangshan grinding implements from Zhejiang Province, South China, identified both *Lithocarpus* sp. and *Quercus* sp. starch, suggesting a focus on acorn, rather than rice processing (Liu, Li, et al., 2010).

11.3.3 Peiligang Phytolith Residues: Jiahu subsistence

Jiahu (9,000-7,000 cal BP) is a Peiligang culture site with characteristic denticulate stone sickles and pottery (Henansheng, 1999). The Peiligang emerges at a later time in other parts of Henan Province such as the Yiluo study region. A radiocarbon date on charcoal

from the Fudian Dong site places the Peiligang period here at *c.* 7,504-7,412 cal BP (lab code NZA 33139).

The Jiahu site has some of the oldest clearly cultivated rice in China (Chen, B. & Q. Jiang 1997). Z. Zhao (2011) and J. Zhang (Zhao, Z., & J. Zhang, 2009) suggest that these seeds are domesticated based on morphological features. Fuller and colleagues disagree (Fuller, et al., 2007; 2008; 2009). Despite extensive flotation at the Jiahu site, no *Panicum* sp. or *Setaria* sp. seeds were identified (Zhao, Z., & J. Zhang, 2009). A number of panicoid grass seeds were recovered including *Digitaria* sp., *Echinochloa* sp. seeds and unidentified Panicoideae. A small number of Pooid grasses were also found.

At Jiahu, *Quercus* sp. acorns and *Carya cathayensis* hickory nuts were identified (Zhao, Z., & J. Zhang, 2009). Tubers included lotus roots (*Nelumbo nucifera*) and water caltrop (*Trapa* sp.). Although foxnuts (*Euryale ferox*) were not recorded at the site (Zhao, Z., & J. Zhang, 2009) unidentified tubers and seeds were present. Foxnuts are known from several South Chinese sites including Tianluoshan during the Hemudu culture period (Fuller, et al., 2009: 1607).

11.3.3.1 STONE SICKLES

Some phytoliths were recovered from a sample of Peiligang stone sickles from the Egou, Shigu and Jiahu sites. No useful remains were recovered from Egou however three bilobes were recovered from the Shigu site sickles. They may be consistent with millet harvesting although more research is needed to verify this. Some evidence for the management or cultivation of panicoid grasses may be provided by bilobe phytolith residues on the Shigu stone sickles. The sickle residue evidence is limited and taxonomically non-specific. Although broomcorn and foxtail millet crops were being cultivated (as their domesticated status in the Peiligang period suggests), no archaeological evidence of a crop field or single function reaping and harvesting tool has yet been recovered.

Several fan-shaped phytoliths were recovered from the Jiahu site sickles, although they are not all consistent with *Oryza* sp. fan-shaped phytoliths. Other phytolith types recovered from Jiahu sickles included a eudicotyledonous leaf hair base in association with a fan-shaped phytolith. This may suggest that the sickles were used to process plants other than monocotyledonous grasses.

In addition to phytoliths, small clusters of starch grains were present on some of the Jiahu sickles (Chapter 10). It was thought that these starch grains may have been small, transient starch grains, which were probably produced in oak leaves during photosynthesis. However the rounded clusters of small granules are also consistent with starch from *Euryale ferox* (foxnut) seeds. More research is needed to verify the exact identification of these starch grains and the exact use of these sickles. At this stage a multi-functional use appears most likely.

Some evidence for the management or cultivation of panicoid grasses may be provided by bilobe phytolith residues on the Shigu stone sickles. The sickle residue evidence is limited and taxonomically non-specific. Although broomcorn and foxtail millet crops were being cultivated (as their domesticated status in the Peiligang period suggests), no archaeological evidence of a crop field or single function reaping and harvesting tool has yet been recovered.

This research represents the first residue analyses on stone knives or sickles from the Peiligang period in North China. Research from the Egou, Shigu and Jiahu stone sickles presented in this thesis (chapter 10; Bestel, et al., 2011; Fullagar, et al., in press) thus preserves the first evidence for the use of these Peiligang artefacts. The tools may have been multi-functional as they yielded evidence for grass as well as eudicotyledonous phytoliths. However, analysis of modern experimental residues shows that eudicot residues can be accidentally incorporated into grass-cutting sickles (Chapter 10). The presence of eudicot residues on Jiahu sickles may indicate that the sickles were utilised in an ecologically patchy environment where grass and other eudicot plants were present. If rice was being harvested (and the residues do not preclude this possibility) the rice may not have been a large, pure stand, but was mixed with other plants. These other plants may have fallen onto the rice crop leading to eudicot phytolith residues on the sickle. In addition, the residues may relate to a range of other tasks occurring at different times, which were preserved in one assemblage as sickle residues.

11.3.4 When Did 'Agriculture' Initially Occur in North China?

Despite suggestions in the literature to the effect that the Peiligang was the initial agricultural period in North China (Chang, K. C., 1986: 91-92) there are few domesticated cereals present in the current archaeobotanical record from the Yiluo region to substantiate this. If one takes a 50 percent reliance on domesticates as a benchmark of agriculture (see

Zvelebil, 1996: 325) then neither the Peiligang nor the Yangshao periods could be considered agricultural (given the seed numbers presented in this research). However, the question of agriculture is more complex than this (see Chapter 2 for debates and discussion). Pottery, animal domestication and sedentism, which are often regarded as hallmarks of the Neolithic Revolution (Childe, 1936), are evident at this time, but extensive evidence for plant cultivation does not appear to be present. This is especially so when one takes into account the fact that grinding artefacts, previously taken as proxy evidence of millet cereal grinding in North China (Liu, Li, et al., 2002-2004: 81-82) appear to have been used predominantly to grind acorns (Liu, Li, et al., 2010c; Zhang, Y., et al., 2011). The 'sickles' thought to have been used to harvest cereals may also be multifunctional (Bestel, et al., 2011; see also chapter 10). As Crawford (2008) has noted, the middle to late Jomon of Japan were low-level food producers with small numbers of domesticates present in their diet and he finds they defy classification as either hunter-gatherer or agricultural. Instead, Crawford suggests the Jomon occupy a 'middle ground' between these two extremes. It is likely that the small numbers of domesticates present in Peiligang sites in North China indicate low-level food production and the beginnings of agriculture. It seems that in the Peiligang period domesticated cereals may not have been the staple or main source of food in the diet, although it is difficult to directly compare preserved macrobotanical cereal remains with acorn starch residues. A far more extensive reliance on grasses (over 95 percent of seed remains were grasses) and the disappearance of acorn stone grinding implements seems to occur in the Yangshao period.

During the Late Palaeolithic period at Shizitan, 10 out of 28 seeds (35 percent) were grasses and none were domesticated. During the Peiligang period five out of 18 seeds (28 percent) were domesticated seeds and 11 out of 18 (61 percent) were grasses. The number of grasses present in samples increased during the Yangshao to over 95 percent but domesticates decreased to only 12 percent of total seeds recovered. Even when potentially cultivated taxa including *Digitaria* sp. seeds (101 seeds) and *Glycine* sp. seeds (2 seeds) are added to the numbers of domesticates from the Yangshao period to create a domesticated or cultivated category, the percentage of such taxa only increases to 20% percent of total seeds. This is still a lower proportion of domesticated seeds than in the Peiligang period. It may reflect continued or ongoing experimentation with a range of different grasses. The increased proportion of grasses in the Yangshao to over 95 percent may suggest the use of grasses that were not domesticated as part of the diet. The assemblage may also reflect weed seeds that represent the uningested or discarded part of the crop and different food

and seed processing methods may also contribute to the unexpected decrease in percentage seed domesticates during the Yangshao.

Extensive examples of charred grain and/or storage pits dating to the Peiligang period have not been found in recent research in the Yiluo region. Previous research (Lee, G.-A., et al., 2007) examined the remains of flotation samples taken from 13 litres of sediment from two Peiligang culture sites, Fudian Dong and Wuluo Xipo. A total of seven seeds were recovered in G.-A. Lee and colleagues' (2007) research, including two foxtail millet seeds from Fudian Dong and two foxtail millet seeds from Wuluo Xipo. In addition, the Wuluo Xipo site also produced three wild grass seeds including two green foxtail grass seeds and one panic/ manna grass seed. A previous study from Wuluo Xipo reported the recovery of four seeds intermediate between wild and domesticated taxa (Liu, Li, et al., 2002-2004: 82).

Over 50 percent of the seven seeds recovered from Peiligang samples in G.-A. Lee and colleagues' (2007) study were domesticates. It is difficult to say anything significant about subsistence in the Peiligang based on a sample size of seven seeds. Taking preservation and taphonomic factors into account, the low seed numbers may suggest that subsistence was not heavily reliant upon cereal seed staples.

11.3.5 Alternative Subsistence Strategies

It seems possible that the Peiligang diet in the Yiluo area and in my study region was based only minimally on seeds and cereals and more on leafy plant parts (vegetables and fruits), nuts (including acorns and walnuts) and tubers (Chapter 9). A tuber or root fragment was present in the Wuluo Xipo flotation sample examined. Such plant remains may not preserve well in the macrobotanical record (Samuel, 2001: 360), or if they are preserved may be difficult to identify. Despite the lack of flotation several Peiligang or related period sites have revealed macroscopic remains of nuts including hackberry (*Celtis* sp.), walnuts (*Juglans* sp.) and acorns (*Quercus* sp.) (Liu, Li, et al., 2010c). Flotation at the Jiahu site revealed considerable quantities of acorn and tuber remains (Zhao, Z. & J. Zhang, 2009).

Based on the lack of cultigens at six of the seven Peiligang sites analysed, it is hypothesized here that some of the smaller Peiligang sites may represent resource focused nut collection subsistence strategies, rather than cereal growing or 'agricultural' communities. To examine this hypothesis, residues from grinding artefacts at one of these

sites, Tieshenggou, were analysed (see Chapter 9). The starch resources ground on the artefacts appear to have included grasses (panicoid and pooid) and acorns, including both *Lithocarpus* and *Quercus* spp. It seems these implements were not used for de-husking cereals as grass husk phytoliths were not preserved on these artefacts. These findings concur with those from A. Wilson (2010), who has suggested that usewear, including that resembling grass grinding, is present on the Tieshenggou grinding implements..

The site of Fudian Dong may represent an alternative subsistence strategy to the other Peiligang sites analysed. Fudian Dong subsistence strategies are possibly based on a wider range of seed resources including domesticated grasses and cereals. This may be due to the type of site and the local environment: Fudian Dong was the only one of the seven sites analysed that was located in the lowland region of a river valley, rather than in hilly or mountainous areas. However, any inferences are based on a relatively small sample size and larger flotation samples and more research are needed to confirm this.

G.-A. Lee and Bestel (2007) have suggested that the increased seed numbers noted in the Yangshao and later periods are indicative of increased population size. These observations are consistent with the study of settlement patterns by Qiao (2007) and by Li Liu and colleagues (2002-2004) which indicate Neolithic population growth in the Yiluo Region from the Peiligang and Yangshao periods onwards. Increased population size may have put pressure on local resources leading to subsistence change (e.g., Cohen, M. N., 1977) although it is more likely that multiple factors were involved (Zeder and B. D. Smith, 2009).

11.3.6 Was the Peiligang period an agricultural society?

The term 'agriculture' is typically applied to societies with a cereal based staple food source (Vrydaghs & Denham, 2007). The identification of acorns as a major food source has raised questions about the role of staples in the Peiligang diet and other early Neolithic diets by Li Liu and colleagues (2010a; 2010b; 2010b). Although acorns are known from Peiligang sites such as Jiahu (Zhao, Z., & J. Zhang, 2009), they do not appear to preserve well as macrobotanical remains in the Yiluo region. In some Californian sites acorns were staples that were ground and leached prior to consumption (e.g., Ortiz, 1991). Acorns also occur regularly in carbonised plant assemblages in California. This may reflect differences in the chain of processing (gathering, storing, de-husking, grinding and leaching) between the two continents.

It is not currently possible to quantify and compare macrobotanically preserved seeds with microfossil starch remains, as hundreds of starch grains may only represent a single seed. In addition, single seeds may only represent a single plant. Hence it is difficult to say whether millet grasses (preserved in an identifiable manner in the study region only as charred macrobotanical remains) or other panicoid or pooid grasses preserved as less specifically identifiable starch grains, were more important dietary components. It is not possible to quantify whether acorns constituted more of the diet than grass seeds. Although the evidence of acorns and other nuts from Jiahu suggests that some groups stored resources at this time, it is unclear whether enough food was stored to last for a full year. Other unanswered questions relate to whether the Tieshenggou site was a specialised or seasonal acorn-collecting camp, given the numerous grinding stones used to process acorns and large amounts of diagnostic acorn starch identified on grinding implements. It may have been a sedentary community using stored resources such as acorns, beans, yams and possibly grains. More research is needed to determine the portions of each type of plant to Palaeolithic, Peiligang and Yangshao diet and this is especially difficult to calculate when different types of plant remains (macrobotanical and microbotanical) are involved.

There are many definitions of agriculture in use today, with different definitions prevalent in different academic disciplines (Chapter 2). Researchers who work in different regions of the world and in different time periods also disagree about the exact meaning of agriculture (Denham & Haberle, 2008; Harris, 2007). The term is highly value-laden and in some cases a source of nationalistic pride. For instance, the people of Kuk swamp in Papua New Guinea were sedentary and socially complex banana producers by around 10,000 cal BP (Denham, 2007; Denham, et al., 2003). Denham and colleagues (2003; 2007) have defined this as agriculture. However, the value-laden term 'agriculture' has led to Papua New Guinea being overlooked in the debates about early plant food producing or 'agricultural' communities until recently (Denham, 2007). Another example of a complex sedentary community that is typically not described as 'agricultural' would include some Californian Indians. Californian Indians from several tribes relied heavily on acorns and salmon as their staple foods (George-Moore, 2010; McCorriston, 1994; Ortiz, 1991). Ethnographic records suggest that acorns were stored and then ground, leached and eaten as acorn mush all year round (George-Moore, 2010). This 'balanophagy' is typically not held in the same esteem as cereal-based agriculture (although see Bellwood, 2005: 13). Given the lack of evidence for grass seed resources in the study area during the Peiligang period it is unlikely that this region fits the typical definition of an 'agricultural' community focused on cereals.

However, some may argue that the sedentism, high degree of social complexity and low-level food production indicated by small numbers of domesticates does indeed allow the Peiligang to be included under a definition of agriculture, albeit one expanded from previous constricted versions of the definition.

Increased evidence for the presence of cereal seeds begins in the Yangshao period, where only 35 out of a total 782 seeds recovered are *not* grasses. That is, over 95 percent of the seeds recovered were grasses. This makes it more likely that the Yangshao rather than the Peiligang period represents the first society with subsistence based heavily around domesticated millets and non-domesticated grass seeds in the Yiluo region.

Domesticated cereal seeds recovered as part of this study only comprise 12 percent of the total seeds during the Yangshao period, although over 95 percent of the seeds recovered are grasses. If Zvelebil's (1996: 325) suggestion of 50 percent domesticated cereal seeds is an indicator of agriculture, this would suggest that the sites researched are not yet agricultural. However, the seeds recovered by G.-A. Lee and colleagues (2007: table 1) suggest that over 70 percent of Yangshao period seeds from 8 sites were domesticated (n=559, including 405 domesticated cereal seeds). It is possible that small sample sizes examined here have caused this discrepancy between the two studies. An additional complicating factor is the possibility that numerous morphologically wild *Digitaria* sp. seeds noted in my research were in fact cultivated and eaten at this time. However, *Digitaria* sp. has never been morphologically domesticated in China despite cultivation elsewhere (Hilu and de Wet, 1976).

11.4 Conclusions

A number of conclusions can be made regarding the data presented in this thesis and the points outlined above. These conclusions will be discussed below, including methodological conclusions relating to the use of several different archaeobotanical methods of analysis. The implications of the research and data presented for understanding the origins of agriculture in North China will be reiterated. A key question raised in Chapter 1 relates to broadening our understanding of plant exploitation during the initial agricultural period in the North China study region. The role of cereal cultivation and usage of wild resources including acorns requires re-assessment..

11.4.1 Methodological conclusions

The examination of several types of archaeobotanical remains provides a robust foundation from which interpretations of ancient Chinese subsistence can be made. This is one of the first dissertations to use several types or scales of macrobotanical data (macro-identified seeds and micro-identified starch and phytoliths) to study Chinese archaeology. Starch residue analyses have facilitated the identification of acorns as a major food source, with yams and beans also present in the diet. Several subfamilies of grasses were exploited and ground in Late Palaeolithic North China but only panicoid grasses were eventually domesticated.

Typically, archaeobotanical analyses that focus only on macrobotanical seed remains cannot assess the non-cereal part of the diet and as a result have been unable to identify or assess uncooked plant foods and plant parts that are less resistant to decay. Previous research on the origins of agriculture and the Peiligang overlooked the use of acorns and yams as food sources in the region. Recent exceptions include starch and use-wear analyses by Li, Liu and colleagues (2010a; 2010b; 2010c). The use of relatively recently developed research techniques, including starch and microfossil analyses, complements earlier macrobotanical research.

11.4.2 Implications for understanding the origins of agriculture in North China

The research results presented here for the Yiluo and Henan province region of North China do not support the notion that the Peiligang subsistence base was a seed crop (millet) staple diet. These results are consistent with new interpretations of the Peiligang period. Z. Zhao recently suggested that the Peiligang was the formative period for millet agriculture in North China, but that millet farming at this time was ‘supplementary’ to hunting and gathering (Zhao, Z., 2011: S304).

Subsistence strategies and relative contributions of acorns, beans and yams in the diet appear similar in both the Late Palaeolithic and Peiligang periods. Acorns were present in the form of starch grains at Shizitan (see Liu, Li, et al., 2011), Egou (see Liu, Li, et al., 2010c) and Tieshenggou (chapter 9). Acorns appear to be an important source of food for both Late Palaeolithic and Peiligang peoples, but were not detected at Yangshao period sites. Unfortunately, grinding artefacts from the Yangshao period were not available for analysis and this reflects the absence of grinding implements recovered from this period (Chang, K. C., 1986: 91-93). It is unclear whether acorns were in use during the Yangshao,

although the absence of grinding artefacts and increased millets may suggest they were less common at this time. It is possible that methods of acorn preparation may have evolved during the Yangshao period which are not readily recognised or preserved.

The presence of numerous ash pits indicates the Peiligang period in the Yiluo study region was at least partly sedentary (Cohen, D. J., 2011). The thin cultural deposits in the Wuluo Region of the Yiluo Basin attest to the presence of small, possibly seasonal sites (Liu, Li, et al., 2002-2004: 81). However, subsistence was not based on millet cereals, rather, plant exploitation was multi-faceted, with possibly seasonal exploitation of acorns and grasses. As in the late Palaeolithic period, underground storage organs and beans were also exploited to varying degrees.

11.4.3 Role of cereal cultivation in North China study region?

As described in background literature (Chapter 2 and 3), Peiligang period society does not appear to exhibit social stratification, with most grave goods being relatively egalitarian (Liu, Li, et al., 2002-2004; 80-84; Underhill, 1997). The Peiligang period in the Yiluo region lacks a settlement hierarchy (Liu, Li, et al., 2002-2004; 80-84) and site sizes are relatively small with only thin cultural deposits (Liu, Li, et al., 2002-2004: 82-83). Sedentism may have been present (Cohen, D. J., 2011) or at least partly present (Liu, Li, et al., 2002-2004; 80-84) although ash pits and hearths, considered to be domestic features that indicate sedentism, were present at Nanzhuangtou (*c.* 10,500-9,700 cal BP) and Hutouliang (*c.* 11,000-9,000 cal BP) outside of the Yiluo study region (Guo and J. Li, 2002). Macrobotanical evidence for plant domestication has not been recovered from these sites.

A high level of plant domestication is not a necessary pre-requisite for a sedentary agricultural society (e.g., Crawford, 2008; Denham, 2007). Flannery (1969a: 80) noted that the high yield from dense stands of wild grains in certain regions of the Levant probably facilitated a sedentary existence. Similarly, while Californian Indian groups were complex and sedentary (Lightfoot & Parrish, 2009: 15-19) they had a resource base that was heavily reliant on acorns, which are considered by Bettinger and colleagues (1997) to be a lower ranked resource. The Peiligang period in the Yiluo Region yields preserved evidence for minor domesticated cereals (5 out of 18 seeds, or 28 percent of seeds were domesticated). This may have been an important step in the transition to more intensive agriculture as seen in the Yangshao period.

In the Yangshao period domesticated cereals made less than 12 percent (93 seeds out of 782 recovered) of the total seed subsistence. However, approximately 95 percent of seeds at Yangshao sites are grasses, and this may indicate possible cultivation of *Digitaria* and *Echinochloa* spp. taxa. The change in diet from a higher ranked resource (acorns) to a lower ranked resource (grasses) (cf. Kelly, 1995) cannot be understood in terms of resource ranking alone. It appears that optimal foraging theory may not be applicable to the data presented in this thesis. Other factors must be invoked, including perhaps a decline in oak trees in the region (Fuller and Qin, 2010) or perhaps food preference (Smith, M. L., 2006) to account for this dietary change. Further research is needed to understand the decline of acorns and increased grass seed use during the Peiligang and Yangshao periods.

The large, standardized implements used to grind acorns and the high percentages of acorn starch on Peiligang grinding artefacts when compared with other wild taxa (Liu, Li, et al., 2011) suggest that Peiligang society was based more heavily around acorns and wild resources such as grasses than domesticated millet cereal seeds. For example, both *Triticeae* and cf. *Andropogoneae* tribe grasses at this time are considered to have been wild, not domesticated, taxa. The absence of large amounts of other plant remains such as seeds in the macrobotanical record also attest to a lower importance of domesticated grasses than previously expected. It seems that the beginnings of agriculture may be referred to the Peiligang period with the presence of small numbers of domesticated millet seeds. However, emerging social complexity does not appear to be heavily reliant on domesticated cereals, and has far more wild resources than domesticated ones as the subsistence base. This is true whether domesticated to wild taxa are compared in terms of macrobotanical data, or in terms of starch (30% wild seeds and 14% wild acorns, with no absolutely diagnostic domesticated starch taxa present) and other microfossils such as phytoliths on sickles. Social complexity may also pre-date plant domestication in North China although further research at sites such as Nanzhuangtou and Hutouliang are required.

Thus the role of cereal cultivation in the study region appears to begin during the late paleolithic, then expand, as domestication evidence suggestion, in the Peiligang. However it appears that during the Peiligang cereal cultivation plays only a minimal role in subsistence, with other foods such as acorns, yams and wild grasses also important. In the Yangshao period grass seed and cereal usage appear to dramatically increase but still wild grasses were more important than domesticated taxa.

11.4.4 Summary

The first macrobotanical evidence for millet tribe grasses in North China comes from the Late Palaeolithic Shizitan site where carbonised grains of cf. *Setaria* sp. grass seeds were recovered. Use-related starch grains identified from implements at the site indicate that acorns were a staple food with wild yams, grasses, and beans also utilised. Some experimentation with wild panicoid and poooid grasses may have occurred and this is evident as residues from Tieshenggou grinding implements. The small numbers of domesticated cereals from the Peiligang period may indicate that broomcorn millet may have been more important than foxtail millet although the sample size is very small (3 broomcorn millet grains and 2 foxtail millet grains were present at Fudian Dong). A student's t-test on small and round non-diagnostic grains suggests that the sizes of such grains were significantly similar to broomcorn millet starch. They were not significantly similar to foxtail millet or the other wild Paniceae tribe taxa tested. However there is considerable overlap in the size range of small grained grass starch and these results should be interpreted with caution.

Small numbers of bilobate phytoliths from sickles used at the Shigu site may suggest the use of denticulate stone sickles to harvest grasses as well as to perform other tasks. Archaeobotanical evidence from stone sickles used at Jiahu neither precludes nor indicates use as rice harvesting implements. Jiahu sickles preserve a range of grass and eudicot residues which may indicate multifunctionality. The small numbers of phytoliths preserved do not allow definitive statements about their use to be made.

Domesticated cereals and seed taxa in general, are rare in the Peiligang period (only 18 seeds were recovered from 7 sites). However, domesticates decrease to 93 grains (12 percent of all seed taxa) in the Yangshao period. This is probably due in part to the population increase in the area at this time (Liu, Li, et al., 2002-2004). Although the raw numbers of domesticates increased in the Yangshao period, the percentage of domesticated taxa decreased at this time. It is possible that some of the morphologically wild grass seeds present in Yangshao period sites were in fact being cultivated.

Evidence of plant subsistence from the Peiligang does not provide substantive evidence of an agricultural society with millet cereals as food staples. The substantial use of acorns as suggested from starch grain residues on grinding artefacts attests to the use of what were probably phenotypically wild plants; little evidence is present for acorn cultivation or

management. The small numbers of domesticated cereals in the Peiligang and a heavy reliance on wild plants is consistent with B. D. Smith's (2001) idea of a 'middle ground' between hunter-gatherer and agricultural society.

Chapter 12: Appendices

Appendix 1 Complete List of All Samples Used in Thesis

Sample No.	Type of Sample	Site Name (English)	Site Name (Chinese)	No. Residue Samples	Feature Number	Age	Litres Soil Floated
FLOT 1	flotation	Bucun	布村		H2	L. YS	11
FLOT 2	flotation	Bucun	布村		H1	L. YS	11
FLOT 6	flotation	Bei ying	北营		LP layer	L. PLG	6.5
FLOT 8	flotation	Didong	堤东		H1	YS	15
FLOT 9	flotation	Didong	堤东		H2	YS	10
FLOT 13	flotation	Fudian E	府店东		H1	L. PLG	10
FLOT 14	flotation	Fudian E	府店东		H1	L. PLG	10
FLOT 34	flotation	Liujianhe shuiku	浏涧河水库		LY1	L. PLG	9
FLOT 35	flotation	Liujianhe shuiku	浏涧河水库		LY1	L. PLG	7
FLOT 48	flotation	Tianpocun	天坡村		H1	YS	8
FLOT 49	flotation	Tieshenggou	铁生沟		H1	L. PLG	9
FLOT 50	flotation	Tieshenggou	铁生沟		H1	L. PLG	9
FLOT 55	flotation	Wuluo xipo	坞罗西坡		LP layer	L. PLG	8
FLOT 65–b	flotation	Yulinzhuan g	羽林庄		H1	L. YS	6
FLOT 65–a	flotation	Xishiqiao	西石桥		LP layer	L. PLG	12
FLOT 66	flotation	Zhaocheng SW	赵城西北		H1	L. YS	8
FLOT 67/ 68	flotation	Zhuge shuiku N	诸葛水库北		H1	L. PLG	10
SK001	sickle	Shigu	石固	3	AT65(E):6	PLG	
SK002	sickle	Shigu	石固	2	survey 1979 area B:7	PLG	
SK003	sickle	Shigu	石固	4	AT33:H122:1	PLG	
SK004	sickle	Shigu	石固	1	ShiguB T1H1:1	PLG	
SK005	sickle	Egou	莪沟	2	M47:2	PLG	
SK006	sickle	Egou	莪沟	1	T4:1	PLG	
SK007	sickle	Jiahu	贾湖	2	WJT109[3B]:25	PLG	
SK008	sickle	Jiahu	贾湖	1	T12[3]:2	PLG	

Sample No.	Type of Sample	Site Name (English)	Site Name (Chinese)	No. Residue Samples	Feature Number	Age	Litres Soil Floated
SK009	sickle	Jiahu	贾湖	2	M356:4	PLG	
SK010	sickle	Jiahu	贾湖	2	T105[3]:5	PLG	
SK011	sickle	Jiahu	贾湖	1	WJT120[30]:7	PLG	
SK012	sickle	Jiahu	贾湖	1	T8H20:3	PLG	
SK013	sickle	Jiahu	贾湖	1	T109[3B]:36	PLG	
SK014	sickle	Jiahu	贾湖	1	34M414:1	PLG	
SK015	sickle	Jiahu	贾湖	1	T101H106:1	PLG	
SK016	sickle	Jiahu	贾湖	1	T11H25:5	PLG	
SK017	sickle	Jiahu	贾湖	1	T33[3]:1	PLG	
SK018	sickle	Jiahu	贾湖	1	T12H57	PLG	
SK019	sickle	Jiahu	贾湖	1	T23[3]:3	PLG	
SK020	sickle	Jiahu	贾湖	1	T16[3]:5	PLG	
SK021	sickle	Jiahu	贾湖	1	H101:1	PLG	
SK022	sickle	Jiahu	贾湖	1	T6[1]:13	PLG	
SK023	sickle	Jiahu	贾湖	1	T109[3B]:23	PLG	
GS1	mopan	Tieshenggou	铁生沟	5	0085–0079	PLG	
GS2	mopan	Tieshenggou	铁生沟	7	0086–0074	PLG	
GS3	mopan	Tieshenggou	铁生沟	1	0146–23	PLG	
GS4	mopan	Tieshenggou	铁生沟	1	0146–9	PLG	
GS5	mopan	Tieshenggou	铁生沟	2	0146–21	PLG	
GS6	mopan	Tieshenggou	铁生沟	2	0146–19	PLG	
GS7	mopan	Tieshenggou	铁生沟	2	0146–16	PLG	
GS8	mopan	Tieshenggou	铁生沟	2	0146–20	PLG	
GS9	mopan	Tieshenggou	铁生沟	2	0146–14	PLG	
GS10	mopan	Tieshenggou	铁生沟	1	0146–18	PLG	
GS11	mopan	Tieshenggou	铁生沟	0	0146–5	PLG	

Sample No.	Type of Sample	Site Name (English)	Site Name (Chinese)	No. Residue Samples	Feature Number	Age	Litres Soil Floated
GS12	mopan	Tieshenggou	铁生沟	0	0146-13	PLG	
GS13	mopan	Tieshenggou	铁生沟	0	0146-28	PLG	
GS14	mopan	Tieshenggou	铁生沟	0	0146-29	PLG	
GS15	mopan	Tieshenggou	铁生沟	0	0146-8	PLG	
GS16	mopan	Tieshenggou	铁生沟	0	0146-6	PLG	
GS17	mopan	Tieshenggou	铁生沟	0	0146-18	PLG	
GS18	mopan	Tieshenggou	铁生沟	0	0146-4	PLG	
GS19	mopan	Tieshenggou	铁生沟	0	0146-3	PLG	
GS20	mopan	Tieshenggou	铁生沟	0	0146-24	PLG	
GS21	mopan	Tieshenggou	铁生沟	0	0146-1	PLG	
GS22	mopan	Tieshenggou	铁生沟	0	0146-26	PLG	
GS23	mopan	Tieshenggou	铁生沟	0	0146-30	PLG	
GS24	mopan	Tieshenggou	铁生沟	0	0146-2	PLG	
GS25	mopan	Tieshenggou	铁生沟	0	0146-17	PLG	
GS26	mopan	Tieshenggou	铁生沟	3	0084-0072	PLG	
GS27	mopan	Tieshenggou	铁生沟	3	0083-0071	PLG	
GS28	mopan	Shigu	石固	2	215	PLG	
GS29	mopan	Shigu	石固	3	AT6z M86:2	PLG	
GS30	mopan	Egou	莪沟	1	T17 M36:1	PLG	
GS31	mopan	Egou	莪沟	2	T4 M26	PLG	
GS32	mopan	Egou	莪沟	2	TP1 M68:1	PLG	
GS33	mopan	Shigu	石固	2	AT6z M67	PLG	
GS34	mopan	Egou	莪沟	3	M57:1	PLG	

Sample No.	Type of Sample	Site Name (English)	Site Name (Chinese)	No. Residue Samples	Feature Number	Age	Litres Soil Floated
GS35	mopan	Egou	莪沟	2	M57	PLG	
GS36	mopan	Egou	莪沟	3	M57	PLG	
R1	mobang	Tieshenggou	铁生沟	1	0146-0184	PLG	
R2	mobang	Tieshenggou	铁生沟	1	0146-0184	PLG	
R3	mobang	Tieshenggou	铁生沟	3	0146-	PLG	
R4	mobang	Tieshenggou	铁生沟	2	0146-11	PLG	
R5	mobang	Tieshenggou	铁生沟	2	0146-22	PLG	
R6	mobang	Tieshenggou	铁生沟	1	0146-13	PLG	
R7	mobang	Tieshenggou	铁生沟	1	0146-	PLG	
R8	mobang	Tieshenggou	铁生沟	1	0146-	PLG	
R9	mobang	Tieshenggou	铁生沟	1	0146-	PLG	
R10	mobang	Tieshenggou	铁生沟	1	0146-	PLG	
R11	mobang	Tieshenggou	铁生沟	0	0083-0071	PLG	
R12	mobang	Tieshenggou	铁生沟	0	0146-25	PLG	
R13	mobang	Tieshenggou	铁生沟	0	0146-31	PLG	
R14	mobang	Tieshenggou	铁生沟	0	0146-32	PLG	
R15	mobang	Tieshenggou	铁生沟	3	0146-33	PLG	
R16	mobang	Tieshenggou	铁生沟	0	0146-34	PLG	
R17	mobang	Tieshenggou	铁生沟	0	0146-35	PLG	
R18	mobang	Tieshenggou	铁生沟	3	0146-36	PLG	
R19	mobang	Tieshenggou	铁生沟	0	0146-37	PLG	

Sample No.	Type of Sample	Site Name (English)	Site Name (Chinese)	No. Residue Samples	Feature Number	Age	Litres Soil Floated
R20	mobang	Tieshenggou	铁生沟	2	0146–38	PLG	
R21	mobang	Tieshenggou	铁生沟	0	0146–39	PLG	
R22	mobang	Tieshenggou	铁生沟	2	0146–40	PLG	
R23	mobang	Egou	莪沟	2	M40:6	PLG	
R24	mobang	Shigu	石固	1	AT6z M86:3	PLG	
R25	mobang	Egou	莪沟	1	M55:6	PLG	
R26	mobang	Egou	莪沟	3	M36	PLG	
R27	mobang	Egou	莪沟	2	T4 M26:2	PLG	
R28	mobang	Egou	莪沟	1	H36:1	PLG	
R29	mobang	Egou	莪沟	3	T10:2	PLG	
R30	mobang	Egou	莪沟	1	H39:3	PLG	
R31	mobang	Egou	莪沟	1		PLG	
R32	mobang	Shigu	石固	2		PLG	
R33	mobang	Shigu	石固	1	275	PLG	
F1	mopan	Tieshenggou	铁生沟	1	1046–41	PLG	

Appendix 2 Summary of Palaeolithic, Peiligang and Yangshao Samples Used in Thesis

English Site Name	Chinese Site Name	Feature	Age	Flot Samples	Grinding Implements	Stone Sickles
Bucun	布村	H2	L. YS	1x flot		
Bucun	布村	H1	L. YS	1x flot		
Beiyang	北 营	LY	L. PLG	1x flot		
Beizhai SE	北寨东南	H1	L. YS	1x flot		
Didong	堤东	H1	YS	1x flot		
Didong	堤东	H2	YS	1x flot		
Egou	莪沟	various	PLG		6x grinding slabs, 8x rollers	2x sickles
Fudian Dong	府店东	H1	L. PLG	2x flot		
Jiahu	贾湖	Various	PLG			17x sickles

English Site Name	Chinese Site Name	Feature	Age	Flot Samples	Grinding Implements	Stone Sickles
Longgudui	龙骨堆	H1	YS	1x flot		
Liujianhe shuiku	浏涧河水库	LY1	L. PLG	2x flot		
Shigu	石固	Various	PLG		3x grinding slabs, 3x rollers	4x sickles
Shizitan	柿子滩	S9, S14	Palaeolithic	12 flots		
Tianpocun	天坡村	H1	YS or L. YS	1x flot		
Tieshenggou	铁生沟	H1	L. PLG	2x flot	27x grinding slabs; 22x rollers	
Wuluo xipo	坞罗西坡	LY	L. PLG	1x flot		
Xishiqiao	西石桥		L. PLG	1x flot		
Yulinzhuang	羽林庄	H1	L.YS or YS	1x flot		
Zhuge shuiku N	逐各水库 北	H1	L. PLG	1x flot		

H = ash pit

LY = layer

PLG = Peiligang

L. PLG = Late Peiligang

YS = Yangshao

L. YS = Late Yangshao

Appendix 3 Dual Starch/ Phytolith Extraction Protocol – Stanford Archaeobotany Lab
(After Rosen [unpub protocol] and Field [unpub protocol (from Lisa Kealhofer unpub protocol)])

Sedimentation/Gravity Settling of Sediment

Weigh out 800mg of sediment. If sample requires deflocculation to reduce clay allow to sit in 5 percent calgon overnight or for 24 hours. After deflocculation remove calgon and continue with gravity settling sedimentation process. Fill 1000 ml beaker to 800 ml (8 cm line) and insert dry sediment sample. Stir well and allow to settle for one hour. Discard water with silt but do not discard settled sample. Re-fill beaker to 8 cm line and stir sediment well. Allow to sit for one hour and discard. Repeat as many times as necessary. This will remove silts from sediment sample. After decanting process, allow sample to dry below 40 degrees C. Weigh dried sample to allow quantification of microfossils present.

Carbonate Removal

Sediment is treated with either 10 percent HCL (10 percent hydrochloric acid) or 6 percent H₂O₂ (6 percent hydrogen peroxide) to get rid of any pedogenic carbonates. Transfer 5ml of 6 percent H₂O₂ to each 15ml centrifuge tube containing sediment. Vortex

or shake sample and watch for any reaction. After reaction and to remove H₂O₂, spin tubes at 1500 rpm for 5 minutes then remove supernatant before repeating procedure if necessary.

Preparing Samples for Heavy Liquid Separation

If samples are wet then fill to top with filtered or distilled water and spin at 1500rpm for 5 minutes. Pour off water and retain sample as a small pellet at base of tube. If samples are composed of dry sediment or have been dried overnight in an oven this step is not necessary.

Heavy Liquid Separation

Sodium polytungstate (SPT) mixed to a specific gravity of 2.4 is used in a heavy density separation. Fill each tube to the same amount with SPT so that they balance in the centrifuge. If less than 2ml of water is remaining in a wet sample 15ml tube this is usually between 4–5ml SPT. If the sample being processed was dry approx 3ml SPT may be used per sample. Vortex and then spin samples at 1000 rpm for 15 minutes. Pipette off top 1–2 mm layer containing starch and phytoliths into new, labelled centrifuge tube. This new tube contains the sample to be retained, rinsed and mounted. Repeat heavy liquid step to maximise sample collection if desired. Recycle SPT.

Rinse SPT from Sample

Fill centrifuge tubes containing sample to top with water. Spin at 1500 rpm for 5 minutes then discard supernatant and repeat until all SPT is out of the sample.

Acetone Rinse to Remove Water

To remove water from sample and make mounting the sample easier, 100 percent acetone is used to rinse the sample. Fill tube with 100 percent acetone and spin at 1500 rpm for 5 minutes. Repeat if necessary. Mount slide.

Appendix 4 Sample Dates Presented in Thesis

Site	Details	Lab Number	Date cal BP	Date BP	Details of Date	Reference
Shizitan	Locality 14		39,100–9,400		Geological (TL)	Xia et al., 2002
Shizitan	Locality 14	BA01158	20,700–20,000	17,210 ±290	Burnt bone	This thesis, Chapter 8
Shizitan	Locality 9		13,800–8,500		9x AMS ¹⁴ C dates	Xia et al., 2002
Shizitan	Locality 9 Stratum IV		12,700–11,600	10,558–10,079		Shi and Song, 2010
Shizitan	Locality 9	BA02053	9,700–9,000	8340 ±130	Charcoal (AMS ¹⁴ C)	Shizitan kaogudui 2010: 16.
Fudian Dong	H1	NZA 33139	7,504–7,412		Charcoal from flot sample (AMS ¹⁴ C)	This thesis, Chapter 8

Appendix 5 Inventory of All Flotation Samples Collected from Shizitan Site

Locality	Flot Number	Depth Below Surface (cm)	Age cal BP	No. Seeds	Soil Floated (kg)	Notes
Locality S9	Flot 1	Soil from under shell ornament	12,756–12,393	7	3–4	Associated with grinding stones
Locality S9	Flot 2	405	13,210–12,985	4	15	
Locality S9	Flot 3	405		3	15	
Locality S9	Flot 4	431		0	15	
Locality S9	Flot 5	431		0	15	
Locality S9	Flot 6	443	13,239–13,043	0	15	
Locality S9	Flot 7	443		0	15	
Locality S9	Flot 8	393	13,890–13,670	3	15	
Locality S9	Flot 9	393		0	15	
Locality S9	Flot 13			0	0.5	Floated LTU
Locality S9	Flot 14			0	0.5	Floated LTU
Locality S9	Flot 15			0	20	
Locality S9	Flot 16			0	20	
Locality S9	Flot 17			3	20	
Locality S9	Flot 18			0	20	
Locality S9	Flot 19			8	20	
Total Locality S9				28	225	
Locality S14	Flot 10			0	15	
Locality S14	Flot 11			0	15	
Locality S14	Flot 12			5	15	
Total Locality S14				5	45	
Total S9 and S14				33	270	

Appendix 6 Flotation Samples from the Yiluo Region in Thesis

Site Name (English)	Site Name (Chinese)	Site Number	Total No. Samples from Site	Feature Number	Age	Litres Soil Floated
Beiyang	北营	07-44	1	LP layer	L. PLG	6.5
Bucun	布村	07-204	2	H2	L. YS	13
Bucun	布村	07-204	2	H1	L. YS	11
Didong	堤东	07-52	2	H1	YS	15
Didong	堤东	07-52	2	H2	YS	10
Fudian E	府店东	07-124	2	H1	L. PLG	10
Fudian E	府店东	07-124	2	H1	L. PLG	10
Liujianheshuiku	浏涧河水库	07-187	2	Layer 1	L. PLG	9
Liujianheshuiku	浏涧河水库	07-187	2	Layer 1	L. PLG	7
Tianpocun	屯寨西南	07-49	1	H1	YS	8
Tieshenggou	天坡村	07-29	2	H1	L. PLG	9
Tieshenggou	铁生沟	07-29	2	H1	L. PLG	9
Wuluoxipo	坞罗西坡	07-42	1	LP layer	L. PLG	8
Xishiqiao	西石桥	01-010	1		L. PLG	12
Yulinzhuang	羽林庄	07-50	1	H1	L. YS	6
Zhugesuiku N	逐各水库 北	07-052	1	H1	L. PLG	10

Appendix 7 Domesticated Seed Sizes for Foxtail and Broomcorn Millet Specimens

Site	Flot	Seed	No. Measurable Seeds	Length (µm)	Width (µm)	Thickness (µm)
Bucun	Flot 1	Broomcorn millet	3	1410.34	1168.67	1503.52
				1562.88	1583.58	1613.66
				1462.24	1218.84	1284.97
		Foxtail millet	48	1315.16	1131.34	906.28
				1238.93	1070.25	871.3
				1345.41	1188.63	954.21
				1304.27	1034.95	770.12
				1358.21	1133.44	1065.32
				1239.3	1055.4	880.16
				1346.57	1032.03	927.07
				1311.88	1003.54	944.08
				1505.94	1282.26	994.54
				1406.15	1189.37	1048.16
				1379.23	1010.31	1086.07
				1311.46	1217.82	1134.05
				1037.11	892.26	342.65
				922.4	806.38	567.68
				939.88	891.65	443.93
				1074.82	976.94	341.91
				1100.61	907.13	457.2
				1267.37	1079.93	465.65
				1050.53	1039.65	392.88
				1219.27	1035.41	482.37
				1435.64	1134.05	394.36
				1114.04	1043.25	422.65
				1259.07	1029.81	402.27
				1198.03	1262.85	520.92
				1287.28	985.15	915.96
				1258.4	1183.43	705.91
				1169.59	1051.48	1163.38
				1309.87	1175.03	1090.23
				1271.01	1306.8	927.21

Site	Flot	Seed	No. Measurable Seeds	Length (μm)	Width (μm)	Thickness (μm)
				1219.17	1015.15	772.29
				1188.25	1019.48	812.12
				1269.04	1121.61	1209.79
				1332.43	1210.97	661.09
				1202.1	1088.43	907.29
				1325.35	1401.42	941.75
				1402.05	1245.77	952.05
				971.47	858.49	983.95
				1417.07	1301.94	896.71
				1034.67	1053.35	699.77
				1426.17	1199.49	1087.36
				1374.18	1056.21	884.31
				1163.88	916.5	838.45
				1217.66	943.14	782.74
				1497.98	1233.46	1173.64
				1339.28	1386.23	1335.21
				1282.33	1168.58	833.39
				1207.19	919.42	825.32
				1483.51	1276	603.09
Didong	Flot 8	Foxtail millet	1	1654.1	1153.93	695.25
Yulinzhuang	Flot 68	Foxtail millet	10	1391.65	1158.46	1242.57
				1292.54	1124.03	1041.3
				1002.4	997.8	1113.96
				1142.8	1143.61	1138.66
				1151.97	1065.75	1158.93
				1138.79	1109.67	966.16
				1085.53	962.55	1193.11
				1160.78	1150.32	1013.16
				1148.37	1015.04	1273.9
				1202.52	1203.47	1009.95
				1099.56		928.29
						755.5
Fudian E	Flot 13–14	Foxtail millet	1	1393.91	1154.23	1185.12

Site	Flot	Seed	No. Measurable Seeds	Length (µm)	Width (µm)	Thickness (µm)
		Broomcorn millet	1	1610.0	1600.0	1252.07

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