

**Early Evidence of Maize (*Zea mays* ssp. *mays*) and Beans (*Phaseolus vulgaris*) on the
Northern Plains: An Examination of Avonlea Cultural Materials (AD 300-1100)**

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ABSTRACT

The goal of this thesis is to reconstruct the plant component of paleodiet for the Avonlea complex (AD 300 – 1100 BP), an early ceramic-producing culture on the Northern Plains. Avonlea peoples have been assumed by archaeologists to subsist exclusively off of wild plant and animal (bison) resources. However, elsewhere on the Great Plains, this time period witnessed a dramatic increase in the use of domesticated plants such as maize, beans, and squash. In addition to identifying consumption of wild plants, this thesis will examine the extent to which these cultigens were incorporated into Avonlea diet.

The plant component of Avonlea palaeodiet is reconstructed through analysis of starch and phytoliths from carbonized and non-carbonized food residue. This sample set included 21 ceramic vessels, 7 stone artifacts, and 3 soil samples obtained from eight Avonlea sites located in Manitoba and Saskatchewan. In addition to archaeological food residues, starch assemblages from 45 modern plant specimens were also examined to enable identification of previously unidentifiable wild and domesticated plant taxa.

My results indicate domesticated plant use at all of the eight sites examined. The overwhelming evidence for cultigens at these sites indicates that Avonlea groups were actively involved in the acquisition of domesticated plants, which led to the widespread dispersal of maize (*Zea mays* ssp. *mays*) and bean (*Phaseolus vulgaris*) by at least AD 660 and 710. In addition to domesticated plants, wild rice and other wild plants were identified, indicating that Avonlea peoples collected and consumed a wide diversity of plants.

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CHAPTER 1

INTRODUCTION

1.1 Cultural Historical Context

Human use of plants in North America has been recognized as early as the Palaeo-Indian period. Throughout much of the less temperate parts of North America wild plants and animals were the basis of subsistence, until new food production systems involving plant domestication and crop growing gradually developed and spread. Although it is generally accepted that maize and other domesticated plants first become widespread in many areas of the Eastern Woodlands, Central Plains, and the American Southwest by AD 800 to 1200 (Adair and Drass 2011; Hart *et al.* 2002; Smith and Cowan 2003; Smith 1992c), very little is known on how this dispersal occurred. The Northern Plains are no exception to this, since very little is known regarding plant use in general. It is thought that hunting and gathering of wild foods remained dominant until the widespread dispersal of domesticated crops into the Central Plains and Eastern Woodlands around AD 800 to 1000.

Although indigenous horticulture had already been established in many areas of the Central Plains and Eastern Woodlands, the diffusion of maize horticulture appears to have been the catalyst for significant cultural change for many societies throughout the eastern and Central Plains. This can be seen in the development of Plains Village economies in the Central Plains and Missouri River Valley where sedentary village life developed based upon a bison/farming

subsistence strategy. This involved horticulture while also focused on the procurement of bison (Ahler 2007; Bowers 1948; Tiffany 2007; Wilson 1917).

A largely unresolved issue revolves around addressing the geographic extent of maize cultivation, and whether it had any impact upon Northern Plains people who were thought to have continued employing a mobile lifestyle based upon hunting and gathering. If groups in this northern periphery area were including maize in their diet, it has been hypothesized to occur in small amounts (Boyd and Surette 2010). Therefore, the limited availability of maize may result in such domesticated plants being missed through conventional archaeological techniques. Subsequently, when considering groups who consumed low amounts of domesticated plants, archaeologists may require different tactics when trying to identify the presence of domesticated plants.

The inclusion of maize, and other domesticated plants, into the diet of foraging groups represents a key shift in subsistence (Ahler 2007; Fritz 2011; Adair and Drass 2011; Schneider 2002; Smith and Cowan 2003; Tiffany 2007). The ability to recognize this shift requires the archaeologist to employ different analytical methods, such as plant microfossil analysis. Past archaeological research has shown that the timing and distribution of domesticated plants is far more dispersed and complex than originally thought (Boyd and Surette 2010). While maize and other domesticated plants appear to be widespread around AD 800 to 1200 (Adair and Drass 2011; Smith and Cowan 2003) in many areas of the Americas, the appearance of these cultigens remains uncertain in the Northern Plains. Therefore, examination of cultural materials from the Avonlea complex (AD 300 to 1100) provided the opportunity to study the dispersal of these cultigens within North America.

The main objective of this research is to provide insight into the palaeodiet of Avonlea peoples, and whether or not this involved domesticated plants. This will be completed through the analysis of plant microfossils from food residue on Avonlea ceramics, stone tools, and soil samples. A total of 21 ceramic vessels, 7 stone artifacts, and 3 soil samples were analyzed from 8 Avonlea sites across the Northern Plains. The analysis of multiple Avonlea contexts allowed for a more holistic view of plant use including preparation, cooking, and disposal of plant materials. In order to complete this objective, starch grains from modern edible plants were collected, processed and analyzed to enable microscopic identification of wild and domesticated plants. Ultimately, the identification and interpretation of domesticated plants, will aid in the understanding of the timing, dispersal, and development of maize in North America.

The Avonlea complex appears on the Northern Plains from AD 300 to 1100 (Morlan 1988) and encompassed much of the Plains and Aspen Parklands of Southwestern Manitoba, Central and Southern Saskatchewan, and southern Alberta, and parts of Montana and North Dakota (Meyer and Walde 2009) (Fig. 1.1). The Avonlea complex occurs at the same time that domesticated plants are estimated to become widespread in the Central Plains and Eastern Woodlands, making this tradition a prime candidate for analysis.



Fig. 1.1 Distribution of the Avonlea Complex (AD 300-1100) within Canada and the Northern United States (adapted from www.map-of-canada.org).

The Avonlea complex is defined by widespread use of multiple forms of ceramics (Meyer and Walde 2009) and small finely-made projectile points (Kehoe 1973). Early viewed as specialized bison hunters (Kehoe 1973), recent evidence points to a broader subsistence strategy focused on seasonally abundant resources (Meyer and Walde 2009; Smith and Walker 1988). Very little evidence of plant use is known, although use of wild plant species has been suggested (Adair 2003). A great deal is known about faunal materials recovered from Avonlea sites, however, very little is actually known about the role of plants within the Avonlea complex. This may be due to limited plant recovery and analysis due to conventional archaeological excavation and collection strategies. However, recent analytical approaches have shown the value of plant microfossils in interpreting palaeodiet.

1.2 Methods

In this thesis, microscopic techniques are used to identify plant starch and phytoliths in archaeological residue and soils from Avonlea sites. Starch grains are produced by plants as a means to store energy (Gott *et al.* 2006). These energy reserves are one of the main reasons humans target plants. Phytoliths are composed of inorganic silica deposits and are produced and deposited within plant cells during the uptake of water and minerals from soils (Piperno 2006). Variations in morphology and size have been used to differentiate both starch (Lentfer 2009a, 2009b) and phytoliths (Pearsall *et al.* 2003) among plant taxa. These microfossils preserve well, as starch grains have been recovered in contexts dating to 105,000 BP (Mercador 2009) and phytoliths have been recovered from coprolites dating to 80 mya (Prasad *et al.* 2005). Recent studies have shown that plant microfossils, such as phytoliths and starch grains, can be employed to identify key economic plants (Holst *et al.* 2007; Pearsall *et al.* 2003; Piperno 1988, 2006; Piperno *et al.* 2009), can provide interpretations of plant preparation strategies (Barton 2007; Messner and Schindler 2010), and be well preserved in a wide variety of archaeological contexts (Boyd *et al.* 2006, 2008; Boyd and Surette 2010; Haslam 2004; Horrocks *et al.* 2008; Kononenko *et al.* 2010; Lamb and Loy 2005; Mercador 2009;). Employing starch and phytolith analysis greatly improves the visibility of plants in the archaeological record. For example, recent research by Boyd and Surette (2010) that addresses organic residue on Laurel pottery has shed light on the dispersal of maize into the Boreal Forest. This research also indicated the presence of maize in Sub-Arctic sites much earlier (AD 500) than originally anticipated. These results ‘open the door’ for future research into groups, contemporaneous with Laurel residing on the Northern Plains, such as the Avonlea complex.

Plant microfossils can be recovered from multiple behavioral contexts, including carbonized food residue (Boyd and Surette 2010; Boyd *et al.* 2006, 2008; Staller and Thompson 2002; Surette 2008; Hart *et al.* 2004; Zarrillo 2008). Carbonized food residues, which are composed of carbonized food remains, can be found adhering to the surfaces of ceramic cooking vessels. This characteristic of carbonized food residues makes this form of analysis suitable for elucidating the diet of ceramic-producing groups. Within this carbonized matrix, plant microfossils may be recovered and identified. This matrix can also be radiocarbon dated, providing direct insight into the timing of particular plants within archaeological traditions. Although carbonized food residue analysis provides subtle insight into paleodietary investigations, limited ceramic recovery and poor preservation of plant microfossils can constrain insight.

Another source of archaeological plant microfossils can be observed by examination of residues adhering to stone tools (Barton 2007; Duncan *et al.* 2009; Lamb and Loy 2005; Lui *et al.* 2010; Mercador 2009; Perry *et al.* 2007; Piperno *et al.* 2009; Zarrillo and Kooyman 2006). Similar to carbonized food residue, plant microfossils may become ‘trapped’ in micro-fissures on the surface of stone tools and thus, preserve them (Barton 2007). The condition of the plant microfossils removed from the stone tool may also yield valuable information. Signs of gelatinization and wear may provide indications on how these plants were prepared (i.e. grinding or cooking) (Messner and Schindler 2010). This form of research provides valuable insight into plant preparation strategies and provides verifications of identifications made through carbonized food residue analysis.

Archaeological soil samples represent another source of plant microfossils (Balme and Beck 2002; Boyd 2002; Horrocks *et al.* 2008; Horrocks and Rechtman 2009; Horrocks and Nunn

2007; Li *et al.* 2010). When plants are deposited in the soil, enzyme activity breaks down the majority of the remaining organic materials (Haslam 2004). However, although the enzymes breakdown the organic materials, inorganic plant microfossils such as phytoliths often remain unaltered in the soil. When carbonized food residue, stone tool analysis, and soil analysis are collectively used to identify plant microfossils from a single research question, a more holistic view of plant use by past groups may be obtained.

1.3 Samples

Plant microfossil analysis requires starch and phytolith comparative keys with which to compare the archaeological recoveries to taxonomically known specimens. Few studies have been completed addressing the micro-botanical identification of edible plants from the Northern Plains (Zarrillo and Kooyman 2006). This required collection and identification of a range of wild and domestic plants, processing them for starch grains, identification and subsequent organization of starch grain types based on morphology and size. In total 45 plant taxa were obtained and 300 individual starch grains were counted for each plant specimen. These plants were chosen based on ethnographic and historical records of plant use in the region (e.g., Shay 1980), as well their ability to produce starch grains. Domesticated plants, including beans and squash, were of special interest because identification of these key economic plants based solely on the starch grains they produce has not previously been accomplished.

Once the comparative starch key was assembled, Avonlea cultural materials from eight Avonlea sites were obtained from the Manitoba Heritage Resource Branch (MHRB), Royal

Saskatchewan Museum (RSM), and Western Heritage Services (WHS). Avonlea sites examined included the Miniota (EaMg-12), Broadview (EbMp-6), Lebret (EeMw-25, 26), Avonlea site (EaNq-1), Garratt (EcNj-7), Remembrance (EjNq-19), Sjovold (EaNs-4), and Gull Lake (EaOd-1). These sites represented a wide spatial distribution of Avonlea sites from Western Manitoba to Southwestern Saskatchewan and as far north as Northcentral Saskatchewan. The archaeological specimens were processed to extract possible micro-botanical remains, microscopically examined, and the recovered grains were then identified using the comparative collection.

CHAPTER 2

ENVIRONMENTAL SETTING

2.1 Climate

The climate of the Great Plains is greatly affected by three air masses: Pacific warm-dry air, Arctic cold-dry air, and moist tropical air from the Gulf of Mexico (Bryson 1966). Past environmental conditions of the Northern Plains can be inferred from fossil diatom research by Laird *et al.* (1996). Analysis of lake sediments from Moon Lake, North Dakota, yielded evidence of environmental fluctuations on the Great Plains. This included a shift from wet deciduous environments to dry prairie environment around 7300 BP followed by a period of low moisture from 7300 to 4700 BP. This period of low moisture was supplanted by an interval of increased moisture from 4700 to 2200 BP, with fluctuating moisture levels occurring between 2200 BP to present times (Laird *et al.* 1996). These data were then compared to other studies completed on lakes in Manitoba, Saskatchewan, and Alberta, which also reveals these trends, albeit with subtle variations between sites (Laird *et al.* 1996).

Modern climatic conditions in Northern Plains region also vary between locations. However, these variations are slight and climate conditions at sites such as the Miniota site are common throughout this Plains region. Landals (1995:13) describes this area as having a "...dry, sub-humid continental climate, with short warm summers and long cold winters." This climatic trend is similar to that described near the Lebret site. The climate for this area has also been

described as a Dry-Warm climate supporting a Mixed-Grass Prairie/Aspen Parkland transitional environment (Kendrew and Currie 1955).

2.2. Physical Geography

The Avonlea complex is distributed within the Northern Plains, which is a subdivision of the Interior Plains region. Vincent and Klassen (1989: 99) identify this area as “The Interior Plains area of Canada encompassing the region between the Canadian Shield and the western Cordillera.” The Northern Plains can be subdivided into three regions: the Manitoba Plain, Saskatchewan Plain, and the Alberta Plain (Bostock 1970). Most of the sites examined in this thesis are located within the Saskatchewan Plains (Fig. 2.1). Major features of this region include the Manitoba escarpment in the eastern region and the Missouri Coteau, located in the western region (Dyck and Morlan 1997). The topography of this region is defined by subsurface bedrock and other topographical features created by glacial activity (Scott 1971; Klassen 1989). Many of these features, such as the Qu’Appelle Valley formed approximately 14,000 years ago in the form of a melt-water spillway draining from the Laurentide Ice Sheet, which eventually drained into glacial Lake Agassiz (Klassen 1989).

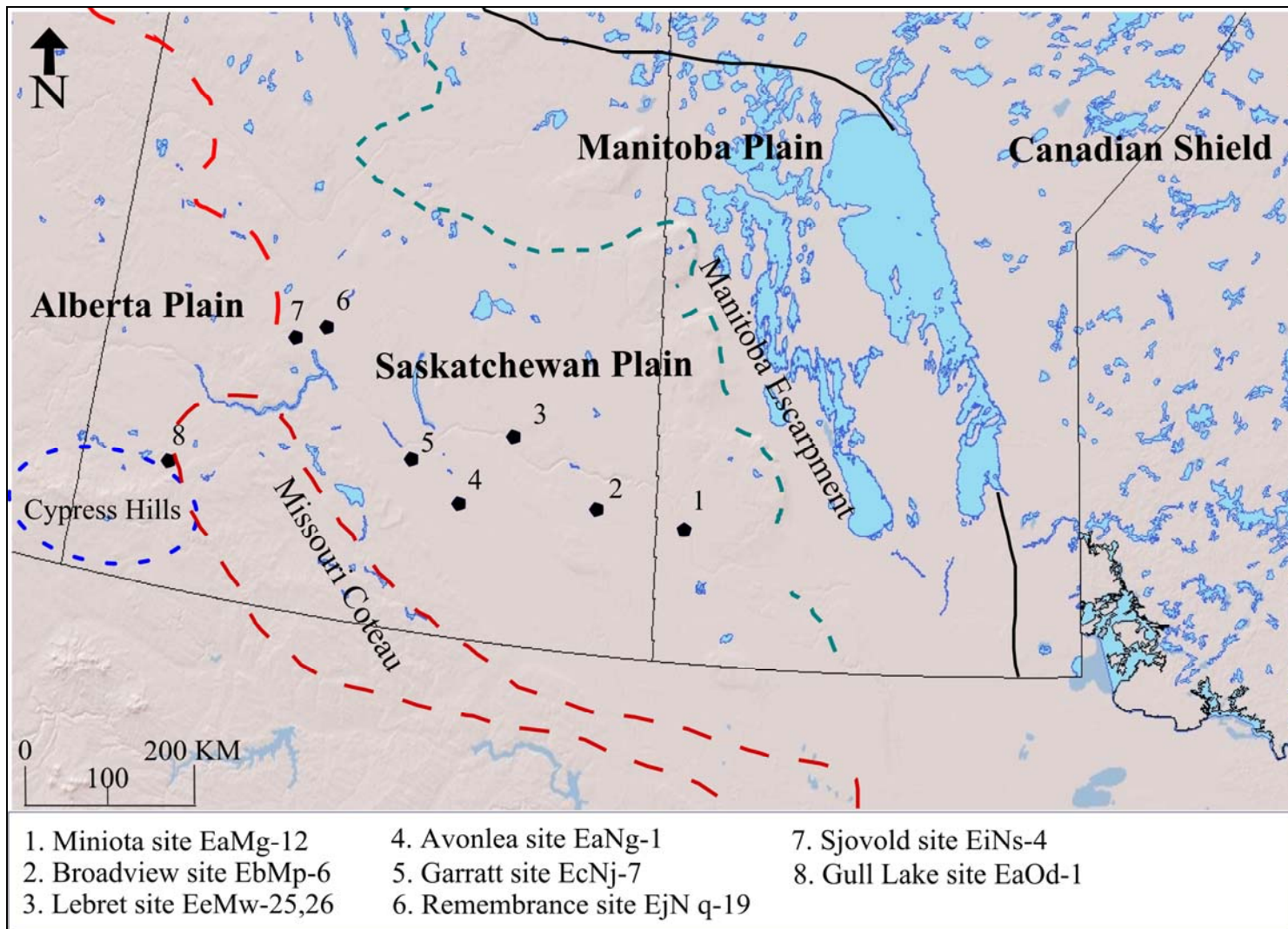


Fig. 2.1 Physical geographical zones of the Northern Plains. Numbers indicate Avonlea sites examined in this thesis.

2.3 Modern Vegetation

This area of the Northern Plains contains two main ecological zones: Aspen Parklands (temperate deciduous forests) and open plains (prairie) (Fig. 2.2). The Aspen Parklands typically appear in the northern edge of the Northern Plains and represent a transitional zone between plains and Boreal forest environments (Nicholson 1988). Aspen parkland environments may also be located around the margins of zones with persistent surface water such as rivers, valleys, and lakes. The open plains are marked by tall and short grass prairie and located in the Southern portions of the Northern Plains. This grassland environment is present in the Southwestern corner of Manitoba, Southern portions of Saskatchewan, and the Southeastern corner of Alberta.

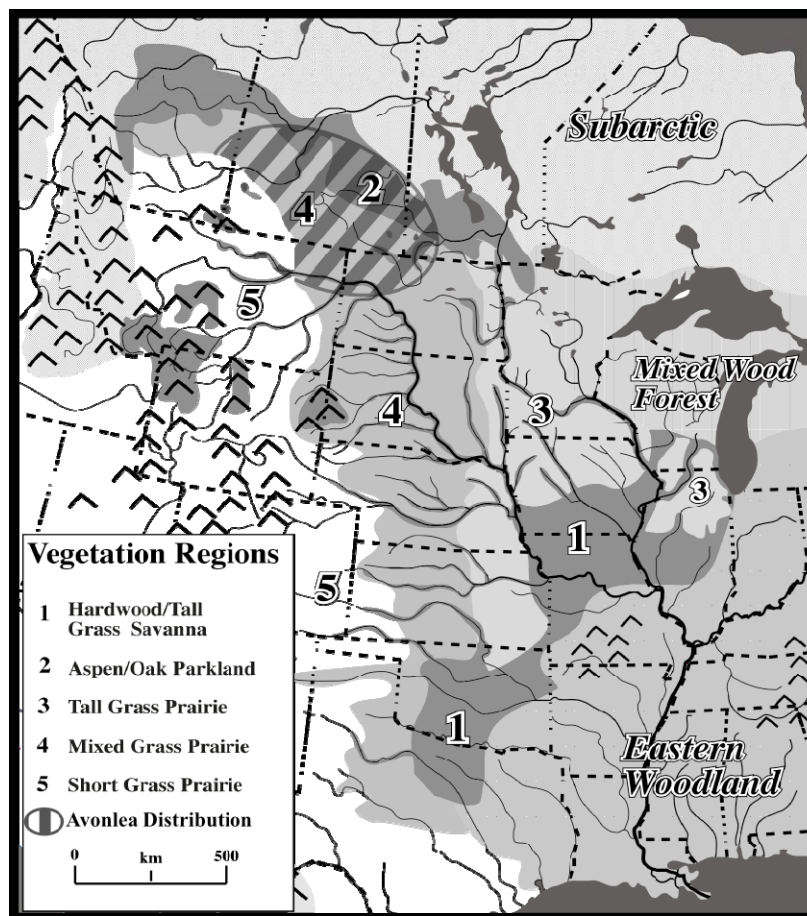


Fig. 2.2 Ecological zones of North America. Note the circled area which identifies the spatial distribution of the Avonlea complex (Adapted from Hamilton 2007)

2.4 Floral Species

Forested species in the Aspen Parklands include aspen (*Populus tremuloides*), Manitoba maple (*Acer negundo*), bur oak (*Quercus macrocarpa*), green ash (*Fraxinus pennsylvanica*), and elm (*Ulmus americana*). While shrubs in the Aspen Parklands include snowberry (*Symphoricarpos* sp.), wild rose (*Rosa acicularis*), and wolf willow (*Elaeagnus commutata*). Other berry producing shrubs include choke-cherry (*Prunus*

virginiana), pin-cherry (*Prunus pensylvanica*), buffalo berry (*Sheperdia* sp.), and Saskatoon (*Amelanchier alnifolia*). The plants listed above are found near many Avonlea sites including the Miniota and Broadview sites (Landals 1995), the Lebret site (Smith 1986), the Garratt site (Morgan 1978), Sjovold site (Dyck and Morlan 1997), and the Remembrance site (Norris 2009). Many of these sites are located in the vicinity of rivers, which provides ready access to a high diversity of ecological resources. This is evident at the Sjovold site where Dyck and Morlan (1997) propose that, depending on the size of the Aspen Parkland in the past, the Sjovold area may have been seen as a favorable habitation area by past groups traveling across the Northern plains.

The flora of the open plains consists of Mixed-Grass prairie (Table 2.1). These grasses include speargrass (*Stipa* sp.), wheatgrass (*Agropyron* sp.), and June grass (*Koeleria macrantha*). Common shrubs include berry producing varieties such as saskatoon, choke-cherry, wild rose, and snowberry (Harris *et al.* 1983). Tuber producing plants such as Indian breadroot (*Psoralea esculenta*) are also located in this ecoregion. Presently, this area is used for agriculture including production of cereal crops and hay. Many Avonlea sites are located within this environmental setting including the Avonlea (Klimko 1985a) and Gull Lake (Kehoe 1973) sites.

Table 2.1: The dominant species of grasses found on the North American Great Plains (Fredlund and Tieszen 1994).

Scientific Name	Common Name	Subfamily	Tribe
<i>Poa pratensis</i>	Kentucky bluegrass	Pooideae	Poeae
<i>Festuca spp.</i>	Fescue	Pooideae	Poeae
<i>Koeleria pyramidata</i>	Junegrass	Pooideae	Aveneae
<i>Phalarisi arundinaceae</i>	Reed canary grass	Pooideae	Aveneae
<i>Agropyron smithii</i>	Western wheatgrass	Pooideae	Triticanae
<i>Elymus Canadensis</i>	Canada wild rye	Pooideae	Triticanae
<i>Hordeum jubatum</i>	Foxtail barley	Pooideae	Triticanae
<i>Stipa comata</i>	Needle-and-thread	Arundinoideae	Stipeae
<i>Stipa viridulal</i>	Porcupine-grass	Arundinoideae	Stipeae
<i>Aristida spp.</i>	Three-awn	Arundinoideae	Aristideae
<i>Danthonia spicata</i>	Poverty oakgrass	Arundinoideae	Danthonieae
<i>Panicum capillare</i>	Switch grass	Panicoideae	Paniceae
<i>Andropogon gerardii</i>	Big bluestem	Panicoideae	Andropogoneae
<i>Andropogon scoparius</i>	Little bluestem	Panicoideae	Andropogoneae
<i>Sorghastrum nutans</i>	Indian grass	Panicoideae	Andropogoneae
<i>Bouteloua spp.</i>	Grama grass	Chloridoideae	Chloiridoid
<i>Buchloe dactyloides</i>	Buffalo grass	Chloridoideae	Chloiridoid
<i>Muhlenbergia cuspidate</i>	Plains muhly	Chloridoideae	Chloiridoid

2.5 Faunal Species

The Aspen Parklands are home to a wide variety of fauna. Large herbivores such as bison (*Bison bison*), mule deer (*Odocoileus hemionus*), moose (*Alces alces*), and elk (*Cervus canadensis*) would have been present as well as smaller mammals such as beaver (*Castor canadensis*), muskrat (*Ondatra zibethicus*), and porcupine (*Erethizon dorsatum*). Carnivores such as wolves (*Canis lupus*), coyotes (*Canis latrans*), bears (*Ursus americanus*), and foxes (*Vulpes vulpes*) would also be present. Many species of migratory and non-migratory birds as well as numerous fish species also would have inhabited this region. Many of these faunal species have been found at numerous Avonlea sites

including the Miniota and Broadview sites (Landals 1995), the Lebret site (Smith 1986), the Garratt site (Morgan 1978), Sjovold site (Dyck and Morlan 1997), and the Remembrance site (Norris 2009).

Animals inhabiting the open plains consisted of large mammals such as bison, mule deer, and antelope (*Antilocapra americana*) in addition to small fur bearing mammals. Fish species such as northern pike (*Esox lucius*), perch (*Perca* sp.), and walleye (*Sander vitreus*) were also present. These species are noted to have been present at the Avonlea (Klimko 1985a) and Gull Lake (Kehoe 1973) sites.

CHAPTER 3

ARCHAEOLOGICAL BACKGROUND (11,050 BP – 300 AD)

3.1 Cultural Systematics and Taxonomy

Three major regional divisions of North America include: the Great Plains, the Eastern Woodlands, and the Sub-Arctic (Fig. 3.1). Within these divisions, archaeologists have distinguished and defined cultural histories that are often regarded as separate entities based on stylistic attributes of material culture (e.g., projectile points and ceramics), site interpretations (e.g., wild rice jigging pits), and archaeological features (e.g., burial mounds) (Fig. 3.2). These separations in cultural identities become increasingly complex through time, especially near the Woodland Period, where the spread of knowledge and influence extends to multiple culture regions. This has led to speculations that groups, such as Avonlea, were heavily influenced by groups residing in the Eastern Woodland and/or Sub-Arctic (Meyer and Walde 2009; Morgan 1978; Norris 2007). Subsequently, my research is fundamentally tied to the permeability of these ‘barriers’ regarding not specifically the flow of cultural groups, but rather ideas, influence, and trade goods between each division. Therefore, the descriptions of archaeological background literature will span these key regions, and include important Sub-Arctic groups (e.g., Laurel), Eastern Woodland groups (e.g., Hopewell), and Great Plains groups (Plains Village Tradition) relative to my research topic. These traditions will be discussed in chronological order.

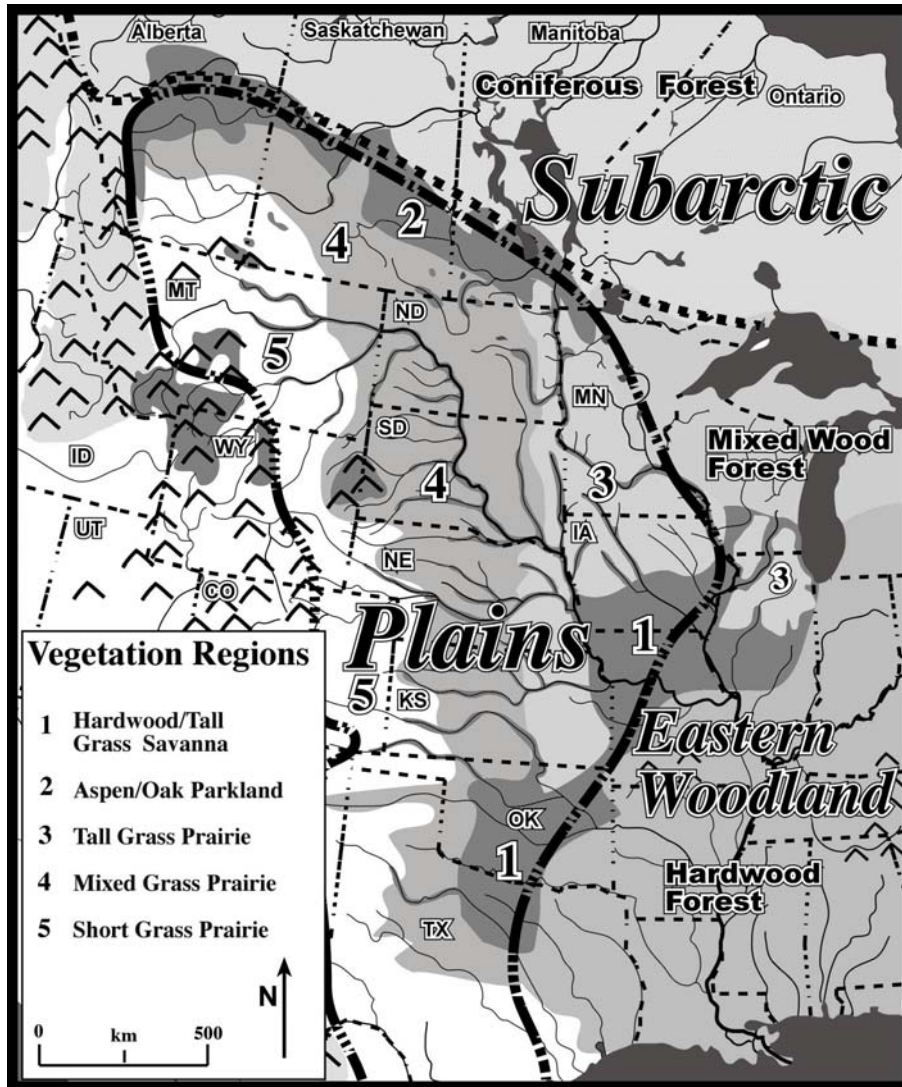


Fig. 3.1 Map depicting the geographic locations of the Eastern Sub-Arctic, Plains, and Eastern Woodlands (from Hamilton *et al.* 2011).

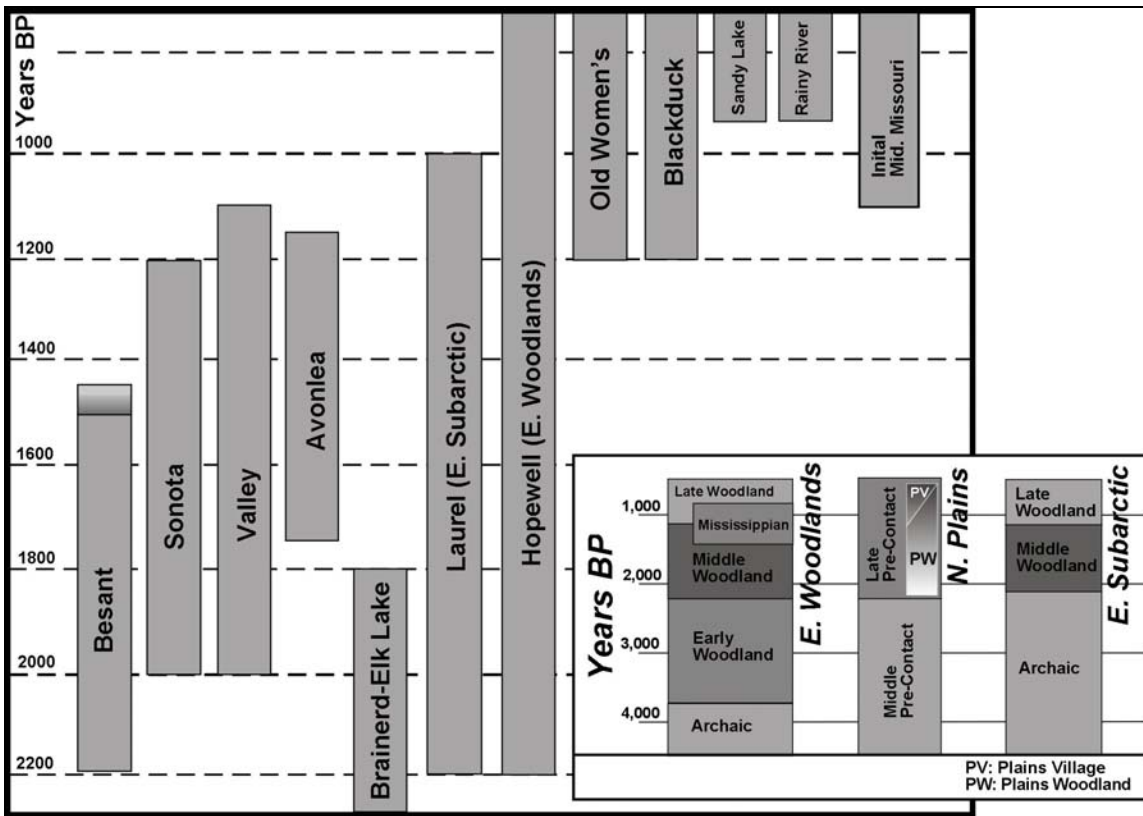


Fig. 3.2 Comparison of Northern Plains, Sub-Arctic, and Eastern Woodland culture sequences (from Hamilton *et al.* 2011).

3.2 The Paleo-Indian Tradition (11,050 BP to 8,600 BP)

Identification of the first peoples to occupy the Northern Plains and the timing of this colonization is difficult to determine. A dynamic early post-glacial environment, extreme seasonality, and the presence of glacial lakes limit the archaeological sites that may be discovered. It is generally accepted that the first people to inhabit the Northern Plains produced the distinctive Clovis assemblage. While Clovis complex sites have been excavated in the United States, evidence of this tradition is scarce with few published excavations on the Northern Plains, some publications are from research at the Wally's

Beach site (DhPg-8) (Kooyman *et al.* 2006) in Alberta and Long Creek site (DgMr-1) in Saskatchewan (Wettlaufer 1960).

In Saskatchewan and Manitoba, Clovis finds are mostly generated from surface collections. Thus, interpretations of Clovis land-use in Manitoba and Saskatchewan are difficult and usually based on archaeological finds to the south. Based on excavations of Clovis sites in the United States it was originally hypothesized that the Clovis people were highly mobile big-game hunters. Alternatively, analysis of Clovis sites by Grayson and Meltzer (2002) indicates that out of 76 Clovis sites analyzed, evidence for a big-game subsistence strategy was only found in 14 sites. The presence of other sources of faunal remains may indicate a more generalized hunter-gatherer subsistence strategy.

The location and timing of the Folsom tradition (10,900 to 10,200 BP) on the Northern Plains is also difficult to identify for reasons similar to that for Clovis. The Folsom tradition likely derived from the Clovis tradition and is defined by spear-points that contain a large flute extending down the length of the point. Similar to Clovis, archaeological evidence for the Folsom tradition in Saskatchewan and Manitoba is also limited to surface recoveries.

Although there is a paucity of evidence for Folsom on the Northern Plains, increased archaeological evidence for this tradition has been identified in the United States. Camp sites (Forbis and Sperry 1952), kill-sites (Frison and Stanford 1982), hunting stands (Hofman and Ingbar 1988), and quarries (Howard 1988) have been identified. While Bement (1997) favors a subsistence strategy for Folsom based on utilization of natural traps for bison procurement, at the MacHaffie (Forbis and Sperry 1952) and Lindenmeier (Roberts 1935) sites a more varied subsistence diet can be seen as

indicated by diverse faunal remains. A focus on bison procurement continues on to the Agate Basin, Hell Gap, and the Scottsbluff-Eden phases of the Plano tradition. Frison (1991) emphasizes the importance of bison procurement for the Plano tradition, while Husted (1969) and Bamforth (1991) propose a more generalist diet with Kornfeld *et al.* (1999) suggesting a varied diet breadth across the region.

A general trend is visible during the early prehistoric period involving subsistence strategies. This trend involves evidence towards both specialized big-game hunting and generalized subsistence occurring within both the Llano and Plano traditions. It is likely that this may be the result of scarce archaeological data from the Paleo-Indian period greatly limiting the available evidence for interpretations. It may also be possible that large mammal remains recovered at archaeological sites from this time period may simply be creating a bias due to their increased probability of preservation.

3.3 The Archaic Tradition (7,500 to 1,500 BP)

Beginning approximately 10,000 BP, the Hypsithermal climatic interval occurred and continued into the Archaic cultural period (Peck 2011). This trend resulted in conditions that were warmer and drier than existing conditions on the Northern Plains (Vance *et al.* 1995). However, although the middle Holocene was warmer and drier, it is important to note that this climate trend was time-transgressive, and its impact likely varied from place to place (Williams *et al.* 2010). Some have suggested that the lack of archaeological sites dating to this period on the Great Plains may have been a result of

arid environmental conditions, but Reeves (1973) argued that this lack of evidence is due to archaeological sampling and not increased aridity. In addition to Reeves (1973), Mandel (2008) hypothesizes that erosion or other geomorphic processes may have decreased the visibility of these sites. Hurt (1966) hypothesized that Archaic sites likely occurred in close association with reliable water sources, a trend that continued throughout the Woodland period. Around 4,000 BP the Hypsithermal was followed by a period of cool and moist temperatures with little drought (Vance 1991).

The Archaic Period marks an increase in archaeological complexity on the Northern Plains with variations and similarities between cultural materials through time. Within this period traditions such as Mummy Cave (7,500 to 5,500 BP); Gowen (5,900 to 5,200 BP); Oxbow (4,500 to 4,100 BP); McKean (4,200 to 3,500 BP); Pelican Lake (3,600 to 2,800 BP); and Besant (2,100 to 1,500 BP) occupied areas of the Northern Plains. The Archaic tradition is marked by a general increase in archaeological sites and archaeological features such as hearths, boiling pits, burials, and living structures (Peck 2011). A common theme during this period is a subsistence strategy focused on bison procurement supplemented by other faunal resources.

3.4 The Woodland Tradition (2,000 BP to Precontact)

Near the end of the Archaic tradition, the first influences or populations arrive from the Middle Missouri area. This influence ushers in the Woodland Period onto the

Northern Plains, marked by the first appearance of pottery and bow and arrow technology in the region (Hamilton *et al.* 2011).

The Besant tradition occurs during a time of immense change on the Northern Plains. Influence or even population movements from the Middle Missouri brings about the first evidence of pottery on the Northern Plains as well as an increased use in exotic resources such as Knife River flint (Neuman 1975). Diagnostic artifacts of the Besant tradition include side-notched atlatl points and conoidal pottery with vertical or horizontally corded surface impressions, bosses, and punctates (Reeves 1983; Wettlaufer 1955). A subset of the Besant tradition has been identified as the Samantha phase where smaller transitional atlatl to arrow-head projectile points were produced (Kehoe and Kehoe 1968). Besant burial structures were also similar to Middle Missouri, which consisted of log-covered pits beneath mounds (Reeves 1983).

Besant sites are widespread throughout the Northern Plains (Reeves 1983). Reeves (1983) indicates that during expansion of Besant from the north-eastern plains to the north-western plains, groups were displaced further west. Reeves (1983) suggests that Besant ties to Hopewellian Interaction Sphere gave Besant groups a competitive advantage over resident groups.

However, Neuman (1975) and Syms (1977) have identified similar artifacts from North and South Dakota as a separate sub-phase known as Sonota. While Dyck (1983) argues that with exception to small variations in point style and burial structure, Sonota is quite similar to Besant. These similarities have been indicated by some researchers as not enough difference to merit separate affiliations between Besant and Sonota. On the other

hand Byrne (1973) infers that Besant originated in the Boreal Forest of Manitoba and that the development of pottery and burial structures was a local development rather than southern influence. Although a lot of speculations have been made regarding the origins of the Besant phase, archaeological research has presented information on the past life-ways of the Besant.

Peck (2011) notes that Besant subsistence was heavily focused on bison procurement. In his review of Besant sites in Alberta, Peck (2011) notes a dominance of bison with very small amounts of other game. Furthermore, Peck (2011) interprets Besant as a separate identity from Sonota based on variations in projectile points, utilization of local rather than exotic materials, and overall artifact assemblages (Peck 2011). Peck (2011) attributes the disappearance of Besant from the archaeological record as a result of Sonota expansion from the southeast. Peck adds, "...clear replacement of all aspects of Besant material culture by Sonota material culture suggests a movement of people out of the Middle Missouri, replacing the Besant people occupying southern Alberta (Peck 2011: 331)." The reason for this population shift has been attributed to population or economic pressures relating to the Hopewellian Interaction Sphere (Peck 2011).

Although this theory has merit, the manifestation of Sonota attributes in the Northern Plains may also be the result of influence rather than a movement of people. As knowledge regarding Sonota materials and demand for exotic lithics increased, an exchange or abandonment of cultural traits may also be possible. The idea that the Woodland cultures remained in a particular area and merely adapted through time is seldom discussed in archaeological literature and is ignored in favor of explanations involving movement and displacement of people. Regardless of cultural origins or the

eventual demise of this culture from the archaeological record, Besant typically is located stratigraphically beneath the next culture group that occupied the Northern Plains: the Avonlea complex (AD 300-1100). Before a description of the Avonlea complex is presented, the Eastern Sub-Arctic Laurel tradition should be discussed. This cultural manifestation is crucial to the understanding of the Avonlea complex due to the similarity in chronology and archaeological evidence that has been discovered indicating interactions between Laurel and Avonlea.

3.4.1 Laurel Complex

The emergence of the Laurel complex is estimated to have occurred in the southern Eastern Sub-Arctic Boreal Forest as early as 300 B.C. (Spiedal 1989), or 500 B.C. in the Boundary Waters area (Dawson 1981; Rajnovich 1980). This complex persisted until approximately AD 800 (Wright 1967) to AD 1200 (Reid and Rajnovich 1991) (see Fig. 3.2). The Laurel complex is estimated to have expanded into the Boreal Forest regions of Manitoba around AD 100 (Dawson 1981; Rajnovich 1980). The earliest Laurel sites are located in the southern borders of the Laurel complex while more recent sites are located further north (Mason 1981) (Figure 3.3). This distribution area of the Laurel complex has been traced as far west as central Saskatchewan (Meyer and Epp 1990), as far north as the Hudson Bay Lowlands (Rapp Jr. *et al.* 1995), central Quebec to the west (Dawson 1983b; Mason 1981), and as far south as central Minnesota (Meyer and Hamilton 1994; Rapp Jr. *et al.* 1995) (Fig.3.1).

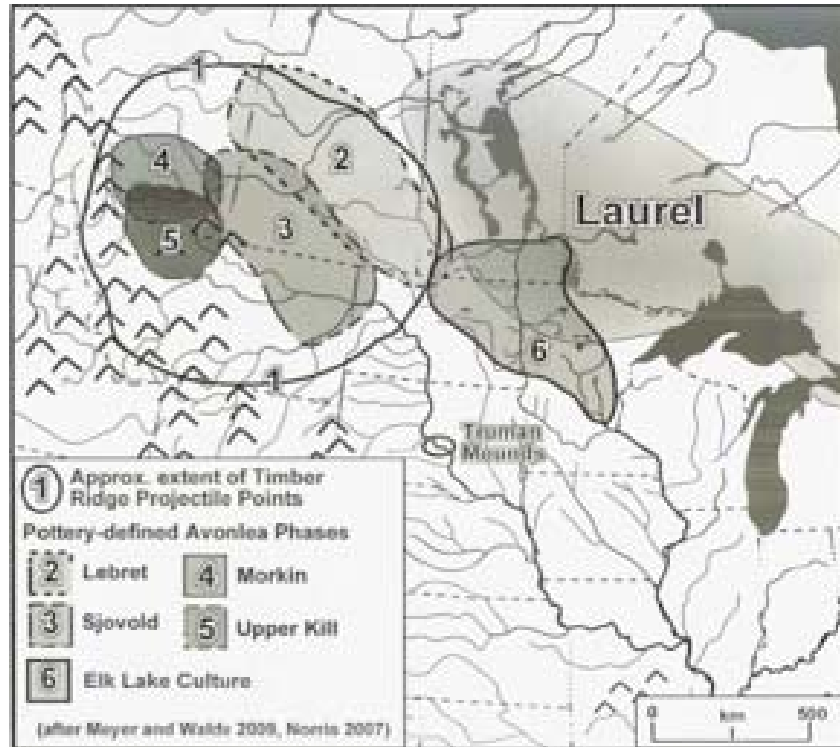


Fig. 3.3. Distribution of Avonlea, Laurel, and Elk Lake tradition (From Meyer and Walde 2009; Norris 2007; Hamilton *et al.* 2011).

The origins of pottery into the Laurel complex may be the result of adoption of pottery by Shield Archaic peoples (Hamilton 1981; Syms 1977), or perhaps as the result of cultural influence from the Saugeen and Point Peninsula traditions in Southern Ontario. Another possibility is Hopewellian influence from the south, through the Malmo culture of Northern Minnesota (Dawson 1983c). Others view the adoption of pottery as a result of increased exploitation of resources, including wild rice (Gibbon and Caine 1980). These vessels are produced by coiling (Budak 1985) and are typically decorated with pseudo-scalloping, incising, and dentate and linear stamping (Anfinson 1979; Meyer and Hamilton 1994; Rapp Jr. *et al.* 1995).

In contrast to Avonlea, subsistence practices of the Laurel complex are more difficult to interpret due to poor preservation of faunal remains in the Boreal Forest. Regardless, many theories have been produced regarding the subsistence strategies of Laurel peoples. Hamilton (2007) suggests that the archaeological materials recovered from Laurel sites indicate a broad-spectrum hunting and gathering subsistence strategy. Furthermore, this would involve the completion of a seasonal round based upon gathering resources during times of seasonal abundance. Wild rice has been suggested as a primary motivator in the dispersal of Laurel groups northwards into the Boreal Forest (Buchner 1979). According to Surette (2008), evidence of wild rice phytoliths within Laurel carbonized food residue indicates the use of this economic plant. Surette (2008) also identified maize from carbonized food residue of two Laurel ceramics. Further evidence of this southern cultigen was identified by Boyd and Surette (2010).

Signs of external Eastern Woodland ‘Hopewellian’ influence have been identified in the Laurel complex in the form of burial mounds and exotic grave goods (Dawson 1983a). This ceremonial tradition has been hypothesized by Wright (1995) to have occurred in Laurel cultures as a result of Malmo Hopewellian Influence.

Interpretations of archaeological recoveries have been made regarding interaction between Laurel and Avonlea (Meyer and Walde 2009). This evidence has been noted at archaeological sites such as Gravel Pit site (FhNa-61) (Meyer *et al.* 1988), where the presence of both Avonlea and Laurel ceramics have been uncovered. This has been identified as interaction between Laurel and Avonlea groups, in the form of trade. These sites containing both Laurel and Avonlea materials in close association are located in the Aspen Parklands, directly south of the Boreal Forest. This trade is likely to have occurred

sometime during the seasonal round, such as the late fall, when both groups inhabited the Aspen Parklands. Further evidence has been identified at the Miniota site in the form of groundstone celts sharing similarities with celts produced by Laurel groups recovered from Avonlea cultural layers (Landals 1995).

CHAPTER 4

THE AVONLEA COMPLEX (AD 300-1100)

The Avonlea complex is defined by the use of small, finely made, projectile points in conjunction with several types of ceramic wares. The following paragraphs reviews the distribution of this complex, its origins, material culture, archaeological sites analyzed in this thesis, and its eventual disappearance.

4.1 Distribution

Based on evaluation of Avonlea radiocarbon dates, Morlan (1988) suggests a temporal range for Avonlea between AD 300 to 1100 with a majority of sites occurring from AD 600 to 1000. The geographic distribution for the Avonlea complex is widespread throughout the Northern Plains. This distribution extends from the southwest corner of Manitoba westward to the edge of the Rocky Mountains in British Columbia. Southernmost Avonlea sites are located in southern Montana while the northern most sites are situated in the southern Boreal Forest of central Saskatchewan (see Fig. 3.3). More specifically, on the Canadian side of the Northern Plains, the majority of the Avonlea sites in Alberta are found in the southeastern plains with fewer sites found in the west (Peck and Hudeck-Cuffe 2003; Reeves 1983; Vickers 1986). In Saskatchewan, Avonlea materials have been documented on the Plains (Dyck and Morlan 1997; Klimko 1985a), Aspen Parklands (Landals 1995; Norris 2007; Smith and Walker 1988), and near

the southern edge of the Boreal Forest (Meyer *et al.* 1988). Avonlea materials in Manitoba are limited to the southwest corner of the province (Fig. 4.1)

Conventional wisdom is that the Avonlea complex appears on the Northern Plains during a period of abundant and dependable resources (Vance 1991). However, through an analysis of sediments from Moon Lake, North Dakota, Laird *et al.* (1996) reported episodes of extreme drought between 200-370 AD, 700-850 AD, and 1000-1200 AD. This suggests more complex and dynamic environmental conditions existed while the Avonlea peoples occupied the Northern Plains.

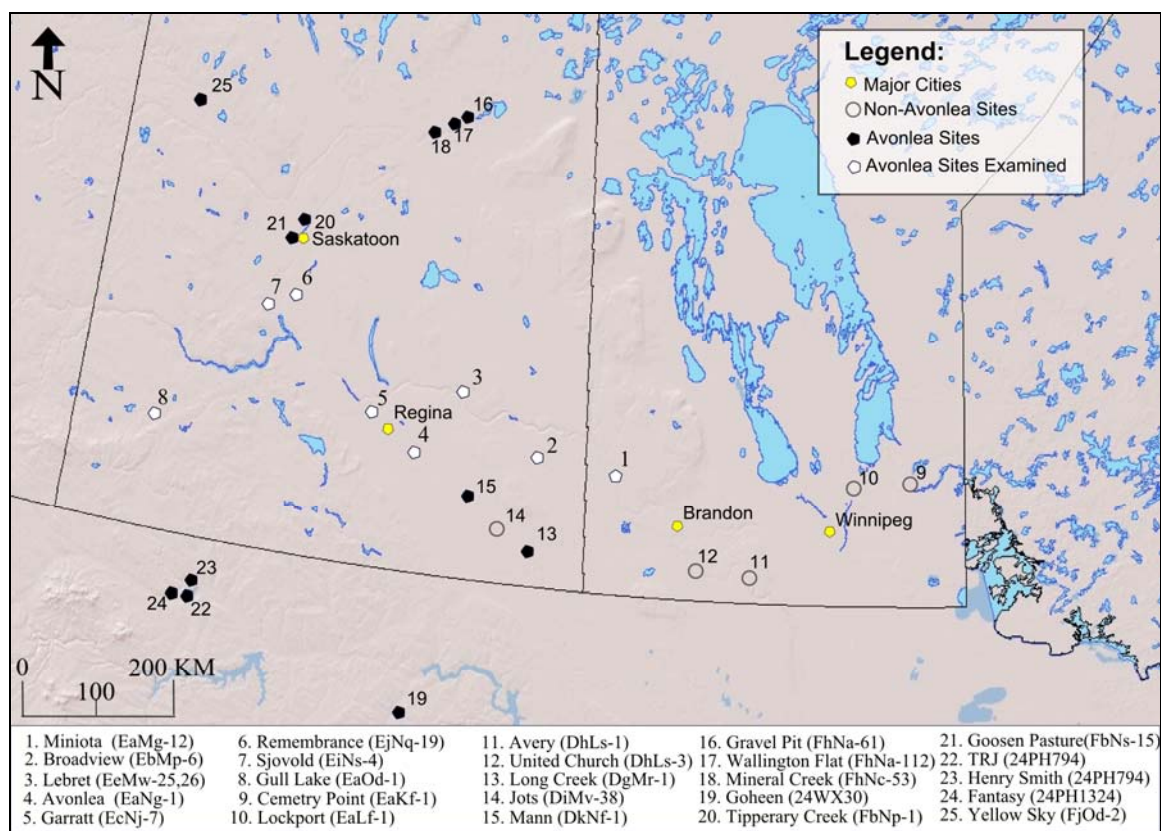


Fig. 4.1 Distribution of major ceramic bearing Avonlea Sites on the Northern Plains (from Meyer and Walde 2009).

The Avonlea complex was named after archaeological materials recovered at the Avonlea Type site (EaN_g-1), near Avonlea, Saskatchewan. Although excavations at this site began in the 1950's, the first usage of this term was by Mayer-Oakes (1960) in the description of similar projectile points recovered at the Long Creek site (DgMr-1), which is also located in southern Saskatchewan (see Fig. 4.1).

4.2 Origins

There have been numerous theories concerning the origins of the Avonlea complex. These theories range from intrusive groups adapting to previously uninhabited areas of the plains (Davis 1966; Kehoe 1966), an *in situ* development of Avonlea technology (Reeves 1983), to a population movement or cultural influence from the south and the east (Landals *et al.* 2004; Meyer and Walde 2009; Morgan 1978; Norris 2007).

4.2.1 Athapaskan Caribou Hunters of the Northern Boreal Forest?

One theory for the origins of the Avonlea complex involves northern Athapaskan caribou hunters who moved onto the Northern Plains and adapted their hunting skills for the procurement of bison (Davis 1966; Kehoe 1966). These caribou hunters are thought to have caused the displacement of Besant peoples who inhabited the Northern Plains prior to the arrival of the Avonlea complex (Kehoe 1966). The general consensus from

Kehoe (1966) was that these northern hunters already held knowledge of communal hunting and merely adapted this technique for bison. Difficulties in this theory have appeared due to new evidence that suggested that communal bison drives were present on the plains prior to the Avonlea complex (Brink 2008). Another problem with this theory is the lack of cultural materials in the northern Boreal Forest exhibiting traits that would suggest a pre-Avonlea tradition (Peck 2011).

4.2.2 Avonlea as an *In Situ* Development

Another theory concerning the origins of the Avonlea complex was developed by Reeves (1983) and involves an *in situ* development of Avonlea on the Northern Plains. The '*in situ* model' (Reeves 1983) suggests that the Avonlea developed out of the Pelican Lake complex and that were previously occupying in the plains area. In this instance the progenitor of the Avonlea complex originated in the Northern Plains region and merely incorporated new technology into their material culture, such as bow and arrow from the west, and ceramics from the east and the west into their material culture. Byrne (1973) interprets the lack of pottery production by communal bison hunting groups in northern Montana and southern Alberta as the result of these groups adopting the bow and arrow while avoiding the use of ceramics. Adams (1977) supports this perspective while Morgan (1978) provides evidence to the contrary. While completing research at the Garratt site (EcNj-7), Morgan (1978) compared the Avonlea materials recovered at this site with cultures from the Eastern Woodlands and Minnesota. Morgan (1978) noted the presence of projectile points that were similar to diagnostic Avonlea points. Furthermore,

she argues that the presence of Samantha points indicates that the Avonlea complex coincides with the widespread transition to bow and arrow technology by plains groups (Morgan 1978).

4.2.3 Laurel: Ancestral to Avonlea?

Byrne (1973) argues that Eastern Sub-Arctic Laurel contributed to the origins of the Avonlea complex. This involves the adoption of similar pottery production techniques by Avonlea groups to that of Boreal Forest Laurel. Again Morgan (1978) indicates that in many cases, Laurel and Avonlea emerge at roughly the same time and there is no evidence of transitional wares that would likely have been initially produced by Avonlea groups. Morgan (1978) adds that a lack of Laurel ceramics recovered in association with net-impressed vessels in Minnesota and the high amounts of Knife River flint in some Avonlea sites indicates a more southerly connection. Morgan (1978) does, however, note similarities between Avonlea and Laurel material culture. The importance of net-impressed ceramics in association with Laurel wares was initially noted by Morgan (1978), and more recently by Meyer and Walde (2009). Through analysis of archaeological sites with both Avonlea and Laurel ceramics in association, it was determined that this connection is only found in the Aspen Parklands of Manitoba and Saskatchewan (Meyer and Walde 2009; Morgan 1978). It has been interpreted as a result of Avonlea and Laurel groups seasonally meeting in the sheltered Aspen Parklands in the fall/winter. This direct contact between Avonlea and Laurel groups likely is responsible for the association of these wares in the Aspen Parklands. Morgan (1978) further

indicates that acquisition of Laurel wares by Avonlea groups was likely the result of trade or inter-marriage.

4.2.4 An Upper Mississippi Valley Connection

Based upon her excavations at the Garratt site, Morgan (1978) argues that the Avonlea complex is developed as a result of displaced people moving from the upper Mississippi Valley into the Northern Plains between 1800 and 1750 BP. Cultural materials that were uncovered at Minnesota archaeological sites sharing similar attributes with the materials identified at the Garratt site (EcNj-7) supports this idea. Minnesota archaeological sites such as the Maplewood site (Watrall 1976), Gull Lake Dam site (21CA37) (Johnson 1971) and the Mountain Lake site (21CO1) (Bonney 1962) all contained net-impressed vessels that share similar traits with Avonlea ceramics recovered at the Garratt site (Morgan 1978). These similarities include vessels exhibiting a net-impressed surface, conoidal vessel form, rim and lip shape, and the use of decorative motifs (Morgan 1978). Not only have ceramics been recovered in Minnesota that share similarities with Avonlea, but similar projectile points have also been recovered. Morgan (1978) notes that points recovered from the Petuga site (Bleed 1969) and the Vineland Bay site appear to be slightly larger Avonlea points, while the points recovered from Vineland Bay were located in association with net-impressed ceramics.

While discussing the origins of Laurel groups, Syms (1977) addressed the rise of Hopewellian influence in the Upper Great lakes region. Mason (1970, 2002) identifies

Hopewellian influence as widespread, extending from the Hopewellian heartland areas located in Ohio and Illinois to northern Laurel cultures. This influence has been noted by Mason (1970; 2002) in inclusion of ceramics, mortuary practices, and settlement patterns by surrounding autonomous groups. Syms (1977) argues that, during the manifestation of the Hopewellian influence in the Upper Great Lakes region, groups north and west of this region were displaced causing a domino effect which resulted in groups expanding increasingly further north and west through time. Syms (1977) infers that the occurrence of Laurel around AD 200 to 800 in the Boreal Forest is the result of a displaced movement of people from the south. Furthermore, Morgan (1978) hypothesizes that the emergence of Laurel coincides with the emergence of Avonlea on the Northern Plains. Additional evidence is provided by Klimko (1985) who noted that when considering the geographic distribution of Avonlea sites the earlier sites are found in the southeast while later dates appear further west. Thus, this westward spread of Middle Woodland influence may led to the foundation of the Avonlea complex, as a regional expression of this influence.

4.2.5 Relationship with the Elk Lake Complex

The idea that Avonlea Net-impressed ware is related to Brainerd/Elk Lake ware is supported by Landals *et al.* (2004) (see Fig. 3.3). The Brainerd tradition in this study will be referred to as the Elk Lake complex following Hohman-Caine and Goltz (1995). Dating of Elk Lake ceramic residue by Hohman-Caine and Goltz (1995) resulted an early estimated date of 2800 to 2700 cal BP, suggesting that the Elk Lake complex may be

ancestral to Avonlea. However, Landals *et al.* (2004) emphasize the role of the Sonota phase as a factor for migration. While population pressures, resource stress, or technology are adequate push factors for migration, the relationship of Avonlea to Sonota may have held more importance (Landals *et al.* 2004). They propose that Sonota points recovered in Avonlea assemblages, coupled with high amounts of Knife River flint at the Miniota site (EaMg-12), Broadview site (EbMp-6), and Garratt site represent a connection with Sonota (Landals *et al.* 2004). Landals *et al.* (2004) noted that these materials were likely acquired by trade but it is difficult to identify what they would have traded. In this scenario, Avonlea may have followed Sonota onto the Northern Plains while remaining in the Aspen Parklands and further expanding to the west. With the disappearance of the Sonota complex from the archaeological record, Avonlea groups moved further south of such parklands (Landals *et al.* 2004). In addition, radiocarbon dates indicate that Avonlea was present first in Saskatchewan and Alberta prior to 1550 BP and by 1350 BP are present in Alberta but no longer in Manitoba and Saskatchewan (Landals *et al.* 2004).

More recent analysis of net-impressed pottery from the Avery site (DhLs-1), United Church site (DhLs-3), Lockport site (EaLf-1), and the Cemetery point site (EaKv-1) by Norris (2007) may indicate an association with the Elk Lake complex. Norris' (2007) analysis involved the examination of net-impressions found on Avonlea ceramics as well as a thorough examination of published literature on the Elk Lake complex. Norris (2007) suggests that net-impressed pottery, based on measurements of net-impressions, produced at these sites were likely Elk Lake and that the distribution of the Elk Lake complex is extended much further north than originally estimated. Norris

(2007) reiterates that the antiquity and similarity of Elk Lake with Avonlea wares represents an ancestral source for Avonlea. The distinguishing feature that Norris (2007) used to differentiate between Avonlea and Elk Lake was the visibility of the netting on the ceramics. This evidence is supported by background literature research, which led to the inference that out of the four types of surface expressions found in Elk Lake ceramics, three of these types are common in Avonlea (Norris 2007). Furthermore, Neuman (1975) indicates a vessel containing both net-impressed traits and parallel grooved traits recovered at the Gull Lake Dam site in Minnesota may represent a transitional Elk Lake/Avonlea vessel. In addition to Neuman (1975), Gonsoir (2003) notes that the presence of parallel grooved wares in association with net-impressed and horizontally-corded wares within an Elk Lake occupation at both the Lake Carlos Park Beach site (21DL2) and the Hockert site (21DL53) indicates affiliation with Avonlea. Norris (2007) also cites Morlan (1988), Morgan (1978), and Hohman-Caine and Gotz (1995) as suggesting that the appearance of both Brainerd ware and Avonlea wares occurs at similar times. This is further represented by ceramics at the Avery (DhLs-1) and United Church site (DhLs-3) and Norris (2007) indicates that these ceramics may indicate a transition between Elk Lake and Avonlea. An increase in ceramic varieties at the United Church site and the Avery site may indicate that these sites were occupied during an extended period of time possibly when groups gathered together during times of abundance (Norris 2007). In summary, Norris (2007) hypothesizes that Avonlea pottery styles represent a connection, influence, or cultural affiliation with southern Elk Lake groups.

4.2.6 Adoption of Bow and Arrow Technology

Rather than analyzing trends in Avonlea ceramics, Brumley and Dau (1988) studied lithic utilization patterns to determine cultural origins. Brumley and Dau (1988) infer straight-based Pelican Lake points extend into Avonlea times, while convex-based points do not. This led Brumley and Dau (1988) to further indicate that the development of the Avonlea complex was the result of external influence. They hypothesize that groups within the Avonlea complex held a significant advantage over groups without bow and arrow technology. They indicate that this technology may have been hidden from other groups and was socially regulated (Brumley and Dau 1988), suggesting a lack of cultural affiliation with surrounding indigenous groups. Additionally, when surrounding groups gained this technology, this may have caused a lessening of spiritual importance of bow and arrow technology and explains the later degeneration of Avonlea projectile points (Brumley and Dau 1988). It is important to note, however, the presence of bow and arrow technology by groups prior to Avonlea, such as Samantha, indicates a pre-existing knowledge of this 'new' technology.

4.3 Cultural Materials

Diagnostic projectile points for the Avonlea complex were first outlined by Kehoe (1973) through the analysis of materials recovered from the Gull Lake site (EaOd-1). Based on the 333 points recovered, Kehoe (1973) developed an Avonlea chronology that included the Gull Lake Classic, the Carmichael Wide-Eared, and the Timber Ridge Sharp-Eared varieties (Fig. 4.2). This chronology has been generally accepted with the Timber Ridge variety listed as the most predominant (Meyer and Walde 2009). The degradation of point forms throughout the Avonlea phase has also been noted (Peck 2011). This 'degradation' is apparent when comparing early finely made projectile points with cruder types made later. The reason for this trend is unknown. Other than projectile points, Reeves (1983) notes the presence of asymmetric bi-faces, diamond shaped bi-faces, pointed unifacial flakes, core and flake choppers, and excavated basin-shaped rock-filled hearths.



Fig.4.2 Avonlea projectile points recovered from the Miniota site.

Early examinations of Avonlea cultural materials led Kehoe (1966) to infer Avonlea as aceramic. However, subsequent archaeological excavations resulted in a tremendous amount of evidence suggests widespread use of ceramic wares (Meyer and Walde 2009). Recent analysis of Avonlea wares by Meyer and Walde (2009) resulted in the revision of Avonlea ceramic taxonomy to include four vessel types: Parallel Grooved, Net-Impressed, Shouldered wares, and Plain ware. These revisions are based on analysis of surface treatment, vessel shape, technique used to create the vessel, decoration, and paste characteristics used to develop a classification of Avonlea ceramic taxonomy (Meyer and Walde 2009).

The most common Avonlea ceramic type that is recovered at Avonlea sites is the net-impressed varieties (Meyer and Walde 2009). This form of Avonlea ware is typically conoidal in vessel form, contains net-impressed exterior surface, and may contain decorations such as punctates below the rim (Fig. 4.3). Net-impressed wares have been noted by Quigg (1988) to dominate the archaeological record both in the Aspen Parkland region of the Northern Plains, more specifically Manitoba, Saskatchewan, and Alberta. Examples of Avonlea sites containing net-impressed ceramics include the Miniota site (EaMg-12), Avery site (DhLs-1), United Church site (DhLs-3), Lockport site (EaLf-1), Long Creek site (DgMr-1), Broadview site (EbMp-6), Garratt site (EcNj-7), and the Lebret site (EeMs-25, 26).



Fig. 4.3. Net-impressed ceramics recovered from the Miniota site.

Based on their analysis of Avonlea ceramics, Meyer and Walde (2009) note that net-impressed Avonlea wares are quite similar in terms of paste and decoration across

Manitoba and Saskatchewan. Most of these vessels are conoidal with some having pointed bases (Meyer and Walde 2009). In addition, Meyer and Walde (2009) observed slight regional variation between Avonlea areas on the Northern Plains. The parklands of Manitoba and Saskatchewan, for example, generally yield net-impressed ceramics that are decorated with a single row of punctates below the rim (Meyer and Walde 2009). These similarities between sites have led Meyer and Walde (2009) to attribute the net-impressed ceramics of the parklands to the 'Lebret phase' (see Fig. 3.3). Meyer and Walde (2009) propose two possible sub-divisions found within the 'Lebret phase,' due to similarities in ceramic wares and lithics found at the Miniota and Broadview sites. Another sub-division may be found at the Garratt site, where complex motifs and decorations have been observed on net-impressed ceramics (Morgan 1978). Meyer and Walde (2009) acknowledge the complex decoration at the Garratt site but are unable to classify them as a separate phase until more sites containing similar wares are identified. In Alberta, variations in net-impressed vessels include using finger-pinch decorations. These more decorated vessels have been attributed to the 'Morkin phase' by Meyer and Walde (2009). Results from ceramic analysis of Net-impressed/Rock Lake ware by Meyer and Walde (2009) led the interpretation that Avonlea groups producing net-impressed ware were likely groups that followed bison to the parklands during winter months and then moved back out onto the plains in the summer.

It is important to note that in some instances, net-impressed (Avonlea) ceramics have also been recovered in association with Laurel wares. MacNeish (1958) observed this phenomenon at the Lockport site, although stratigraphic disturbance complicated his interpretation. Another site in Manitoba containing both Laurel and Avonlea wares is the

United Church site (DhLs-3) (MacNeish and Capes 1958). In Saskatchewan, the Gravel Pit site (FhNa-61) provided evidence of mixed Laurel and Avonlea wares (Meyer and Walde 2009). The Gravel Pit site is located on the northern edge of the Saskatchewan River close to the Boreal Forest. At this site, six vessels were uncovered, two of which were identified as coiled Laurel vessels (Meyer and Walde 2009). Similar net-impressed wares have also been recovered in non-Avonlea contexts from throughout the Eastern Woodlands and Minnesota (Meyer and Walde 2009). These similarities are noted in Elk Lake wares of Minnesota. It is important to note that some archaeological sites contain both parallel grooved and net-impressed wares (Morgan 1978), which may indicate geographic overlap (Walde *et al.* 1995).

Parallel-grooved ceramics have been observed by Johnson (1988) and Meyer and Walde (2009) as occurring less frequently in Avonlea sites. Johnson (1988) described these wares as exhibiting equidistant linear grooves over the entire exterior surface that may overlap. The term given to these wares was chosen based on similarities of these parallel grooved designs with wares from the Truman mounds (39BF224) in South Dakota. Avonlea parallel grooved vessels are conoidal with rounded, flattened, or decorated rims (Fig. 4.4). Decorated rims have been documented at the Avonlea site (Klimko 1985a) involving oblique cord-wrapped-tool impressions on the rim and punctates have been observed in parallel-grooved wares from the Riverland site (DIPc-4). Archaeological sites containing these wares includes the Morkin site (DIPk-2) (Byrne 1973), Avonlea site (EaNg-1) (Klimko 1985a; Klimko and Hanna 1988), Sjøvold site (EiNs-4) (Dyck and Morlan 1997), Henry Smith site (24PH794) (Quigg 1988), and Fantasy site (24PH1324) (Tratebas and Johnson 1988). Johnson (1988) interpreted the

small amount of parallel-grooved ceramics found within Avonlea contexts as either a result of outside influence, derived from an antecedent ceramic ware, or created as a novelty. The geographic distribution of these wares on the Northern Plains includes northeastern Montana, southeastern Alberta, and south/central Saskatchewan.

Archaeological sites containing these wares typically date from AD 400's to 800's (Meyer and Walde 2009). Meyer and Walde (2009) indicate that parallel-grooved ware is limited to the southern grassland areas of the Prairie Provinces and it is likely that the individuals producing these wares formed bands whose subsistence was connected to bison herd movements between Montana and southern Saskatchewan. The term 'Sjovold' phase was used by Meyer and Walde (2009) for parallel-grooved wares and associated sites within the Avonlea complex.



Fig. 4.4 Parallel grooved vessel recovered from the Sjovold site (EiNs-4).

A third type of Avonlea ceramic type has been identified in Avonlea contexts from northern Montana and southern Alberta (Quigg 1988a). Kehoe (1959) described these ceramics as globular/ovoid in vessel form, contain shoulders with out-curving rims, decorated with cord-wrapped paddle, and containing some decoration although undecorated vessels are more frequent. This type of ware was named 'Ethridge' by Wedel (1951) during excavations near the town of the same name in Montana. Quigg (1988a) notes that, while parallel grooved vessels do not continue into the Old Woman's phase, shouldered Ethridge wares do. Furthermore Walde, Meyer, and Unfreed (1995) observe that frequent occurrence of this style of ceramics in association with Old Woman's materials may suggest a connection between Avonlea and the Old Woman's phase. The areas containing Ethridge ware have been named the 'Upper Kill phase' of the Avonlea complex and is interpreted as groups inhabiting northern Montana and southern Alberta who were connected to bison moving from the Rocky Mountains to the Alberta grasslands (Meyer and Walde 2009).

The last and least known ceramic ware of the Avonlea complex is the plain/smooth ware. The plain/smooth ware is not commonly found in Avonlea sites. These wares consist of smooth wares commonly in the form of small bowls, and may contain some decoration. It has been argued that these ceramics may indicate interaction between Avonlea and Laurel cultures (Meyer and Walde 2009). However, excavations at the Garratt site (Morgan 1978) yielded smooth ceramics but were stylistically different from typical Laurel wares. These sherds lack signs of coiling, contain single-cord impressions, and exhibit incised lines beneath the lip (Morgan 1978). Therefore these

ceramics were identified as a separate entity from Laurel which is likely produced by coiling and does not exhibit the same decorations as described above (Morgan 1978).

4.4 Past Life-ways

Subsistence strategies employed during the Avonlea complex were originally thought to revolve around communal bison hunting (Klimko 1985a; Reeves 1970). However, recent evidence suggests a less specialized subsistence strategy involving a variety of seasonal faunal resources (Davis and Fischer 1988; Smith and Walker 1988). This broad-based subsistence strategy involved the hunting of both large and small game, with additional resources including fish and seasonal birds (Smith and Walker 1988). Bison likely remained an integral part of the overall diet, providing a dependable resource to supplement seasonal activities. This is especially true at large bison kill sites such as Head-Smashed-In (DkPj-1) and Gull Lake (EaOd-1) sites. The subsistence strategies observed by Peck (2011) at Avonlea sites in Alberta differ significantly where communal bison procurement was common. Furthermore, Peck (2011) states that bison hunting on the Northern Plains reached its pinnacle during the Avonlea phase. However, this trend may also represent a systematic bias in the archaeological record deriving from communal kill sites being a focal part of archaeological investigation. The discovery and analysis of more habitation sites in Alberta and elsewhere may shed some light on the diversity of subsistence strategies employed by Avonlea peoples.

Although a tremendous amount of information is known about the faunal resources targeted by Avonlea, very little is known about the role of plants in the diet of these, and other, ancient Plains societies. Information presented by Adair (2003) on plant use on the central and Northern Plains indicated the use of wild onion bulbs at several northwestern Avonlea sites based on macrofossil remains. Berries, tubers, and other edible parts of wild plants were likely gathered when available.

As with the role of plants in the Avonlea diet, little information is known about burial treatment and habitation patterns. At the Bethune site (EeNg-6), however, at least seven individuals were buried in flexed/semi-flexed/bundle positions (Dawson and Walker 1988). Associated cultural materials included a turtle carapace fragment, a deer metapodial stained with ochre, and bison bone fragments (Dawson and Walker 1988). Another burial found at the Carroll site (EkNv-2) contained a single individual identified as a 50 year old female who was placed in an elliptical pit in a sand dune beside the South Saskatchewan River (Walker 1984); associated materials included a foetal bison metacarpal. Peck (2011) hypothesizes that Avonlea burial likely involved the use of pits located directly below cairns. Although only a few examples of Avonlea burials have been recovered, these sites do provide some information regarding the spiritual importance of the natural environment.

Very little evidence of Avonlea habitation structures has been uncovered. Some archaeologists (Klimko 1985a; Landals 1995; Peck 2011; Reeves 1970) have suggested that Avonlea groups were highly mobile, leaving little behind in terms of habitation structures (e.g., tipi rings). The Miniota site, which is one of the sites analyzed in this thesis (see 4.5.1), provides a glimpse into the wintering activities of Avonlea groups. At

the centre of this wintering site was a large hearth that contained evidence of repeated use (Landals 1995). Observation of the vertical profile of this feature led to the identification of several instances where the hearth was excavated and then refilled by the site occupants. Baked clay and clinkers located in the hearth provide further evidence of extended use. The presence of this feature indicates that the Avonlea group inhabiting the Miniota site resided at this camp for quite some time. Evidence of a more mobile lifestyle was reported by Meyer and Walde (2009) through their analysis of Avonlea ceramics. For example, by analyzing similarities between wares, Meyer and Walde (2009) hypothesized that Avonlea groups, who created net-impressed wares, seasonally moved from the plains to the parklands in the winter following seasonally abundant resources.

4.5 Description of Avonlea Sites Examined in this Thesis

In total, archaeological materials from eight Avonlea sites from the Northern Plains were examined for this thesis. These sites included the Miniota site (EaMg-12), Broadview site (EbMp-6), Lebret site (EeMw-25, 26), Avonlea Type site (EaNq-1), Garratt site (EcNj-7), the Remembrance site (EjNq-19), the Sjovold site (EiNs-4), and the Gull Lake site (EaOd-1). A brief summary of each of these sites follows.

4.5.1 The Miniota Site, Manitoba

During the summer of 1992, archaeologists discovered cultural materials near the town of Miniota, MB (Fig. 4.5) while monitoring the extension of the Trans-Canada pipeline (TCPL) (Landals 1995). Archaeologists quickly identified evidence of human activity in the spoil piles created by the backhoes. E.J. McCullough identified a well-stratified cultural layer 120cm below surface. Heritage Resource Branch of Manitoba and TCPL negotiated the removal of archaeological materials from this area prior to the completion of the pipeline.

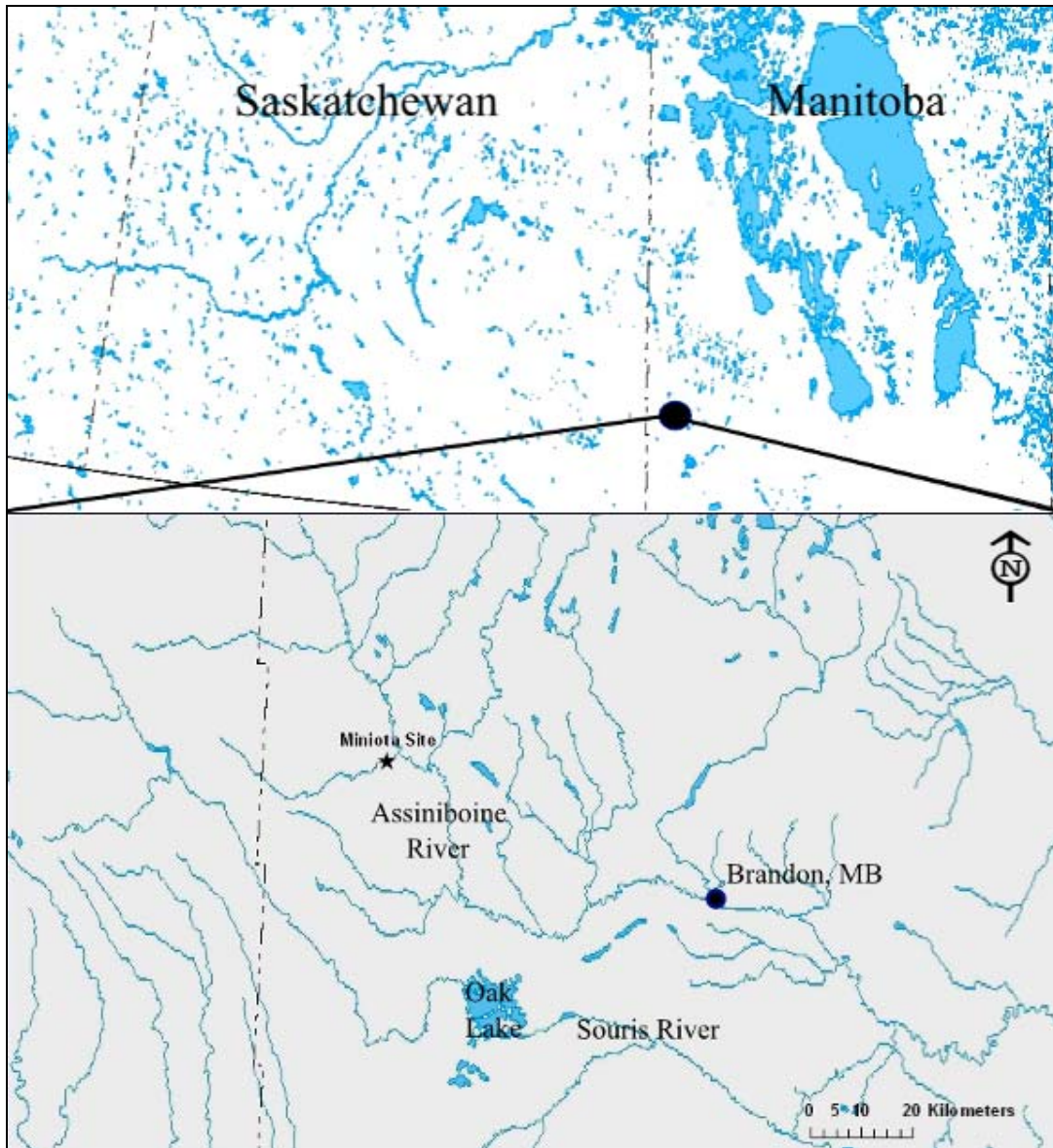


Fig. 4.5 Location of the Miniota site within the Assiniboine River Valley, Southwest Manitoba.

Radiocarbon dates were obtained by Landals (1995) on charcoal and bone samples from cultural levels. The charcoal sample yielded an earlier two σ date of AD 540 to 894 (1340 \pm 90 BP) (Beta 58908) while the bone yielded a more recent date of AD 893 to 1228 (970 \pm 90 BP) (Beta 58907) (Landals 1995). However, it is important to note this charcoal may have been from old wood. Regardless, these dates place the

Miniota site cultural materials in the middle to late phase of Avonlea cultural materials. More recently, bone collagen dates were obtained yielding earlier dates. These dates along with new AMS dates obtained on carbonized food residue will be more fully discussed later in this thesis (see Table 9.1).

Faunal remains at the Miniota site were numerous (32,788 specimens) and well preserved, and consisted of both modified and unmodified remains (Landals 1995). The majority of these are from bison (*Bison bison*) with other mammals such as canids and fur-bearing animals to a lesser degree. Fish scales were also recovered from this site providing a representation of aquatic species present at this site (Landals 1995). It is important to note that immature/foetal bison remains were discovered *in situ*. Immature bison remains provide an adequate indication of seasonality. Numerous modified bone artifacts were recovered including perforators, a pin, and a scapula ‘paddle.’

A high number of lithic artifacts were also recovered from the Miniota site. The majority of the stone tools are composed of Knife River flint (74%) (Landals 1995). The source area for Knife River flint is located near the Knife River in west-central North Dakota (Fig. 4.6). Several Avonlea projectile points were recovered at the Miniota site (see Fig. 4.2). Other stone artifacts that were recovered at the Miniota site included bifaces, knives, graters, endscrapers, and groundstone celts.

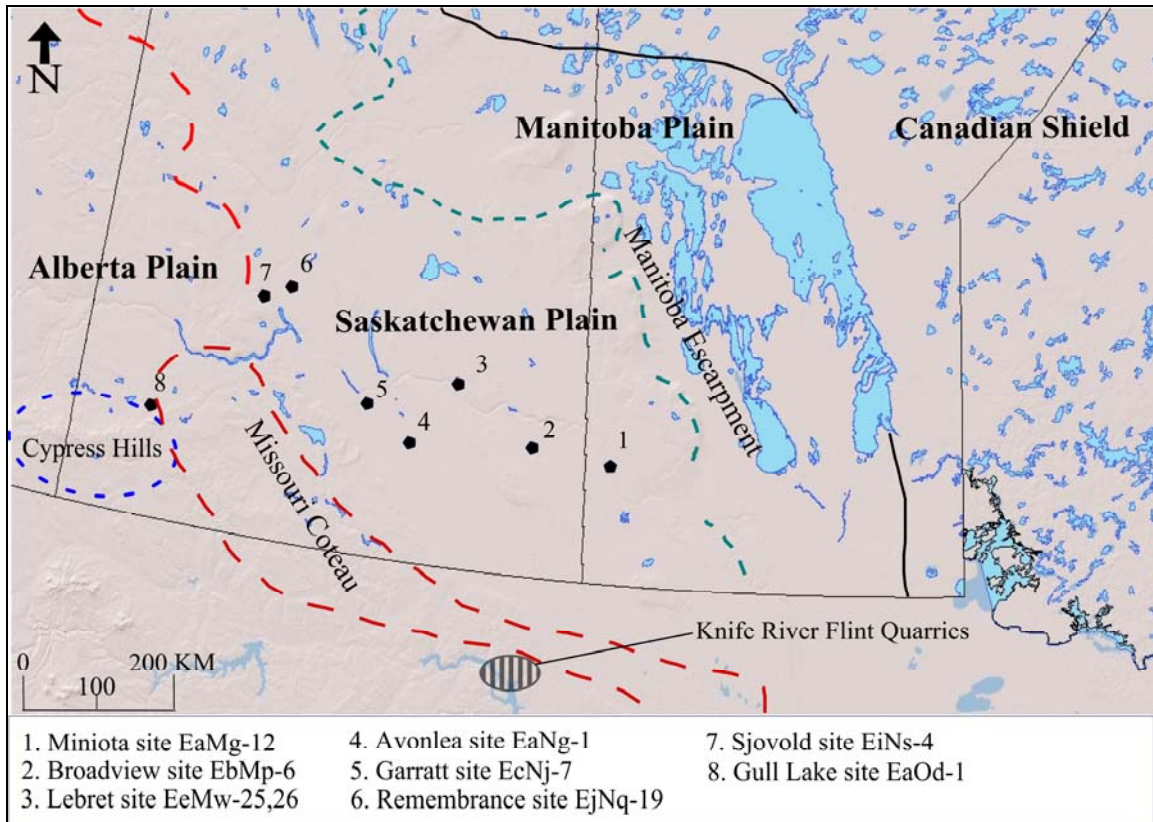


Fig. 4.6 Map of sites examined in this study in relation to important physiographic features and lithic resources.

The ceramics recovered from the Miniota site represent one of the largest assemblages of Avonlea ceramics yet recovered. These ceramics were net-impressed with decoration consisting of various styles of punctuates organized in horizontal rows. Among this assemblage is a partially complete vessel (see Fig. 3.4), called the ‘Miniota Vessel.’ This particular vessel is large (27.2 cm diameter), with an estimated holding capacity of 19 liters (Landals 1995). Landals (1995) also notes that there are at least three other vessels located at this site.

Several features were identified at the site, including a large-central hearth. This hearth exhibited a basin-shaped circular pattern and contained a 15 to 20-cm-thick layer

of fine white ash with numerous charcoal inclusions (Landals 1995). The sediment in the hearth was noted as 'greasy' during excavation, which Landals (1995) interpreted as the result of boiling of faunal remains. Within the hearth, several hardened fragments of baked clay were recovered, some of these clay fragments contained impressions of unidentifiable plants fragments (Landals 1995). Based on her observation of the vertical profile of the site, Landals (1995) interprets the inclusion of multiple basin-shaped hollows the result of repeated use. However, very few fragments of fire-cracked rock (FCR) were recovered. Another intriguing feature of this hearth is the presence of clinkers located within the hearth. Clinkers are created through the leaching of silica by wood during burning. Landals (1995) indicates that this is commonly found in hearths of long-term use areas in the Eastern Woodlands. Not only was a large hearth feature discovered, but possible midden features were also discovered. These middens contained large amounts of tiny carbonized faunal remains set within a greasy-ash layer (Landals 1995).

Through analysis of lithic materials Landals (1995) suggests the occupants of this site were able to acquire Knife River flint from other groups with access to southern areas or directly from the Knife River deposits. Another trade item that was recovered from the Miniota site was a dentalium fragment. Dentalium shells originate on the Western Coast of British Columbia and were widely traded across the plains (Landals 1995).

4.5.2 The Broadview site, Saskatchewan

Set within a deeply incised glacial spillway near Ekapo Lake (Fig. 4.7), southwestern Saskatchewan, the Broadview site yielded similar cultural materials in both type and frequency to the recoveries at the Miniota site (Landals 1995). Cultural materials were located approximately 20-30 cm below ground and in some areas were greatly disturbed. As with the Miniota site, much of the cultural layer was contained within a greasy-ash layer. Assessing the date of these materials was limited by a lack of remains eligible for dating. Landals (1995) reports that larger faunal remains were also highly fragmented at the Miniota site perhaps due to compression by heavy vehicles. Due to the highly fragmented remains, radiocarbon dates were not obtained.

As with the Miniota site, lithic materials at Broadview were primarily composed of Knife River flint (61% of total lithic assemblage) (Landals 1995). Net-Impressed ceramics and several bone tools recovered also contained similarities to materials recovered from the Miniota site. In total 912 ceramic fragments were recovered including both net-impressed and smooth ceramic wares (Landals 1995).

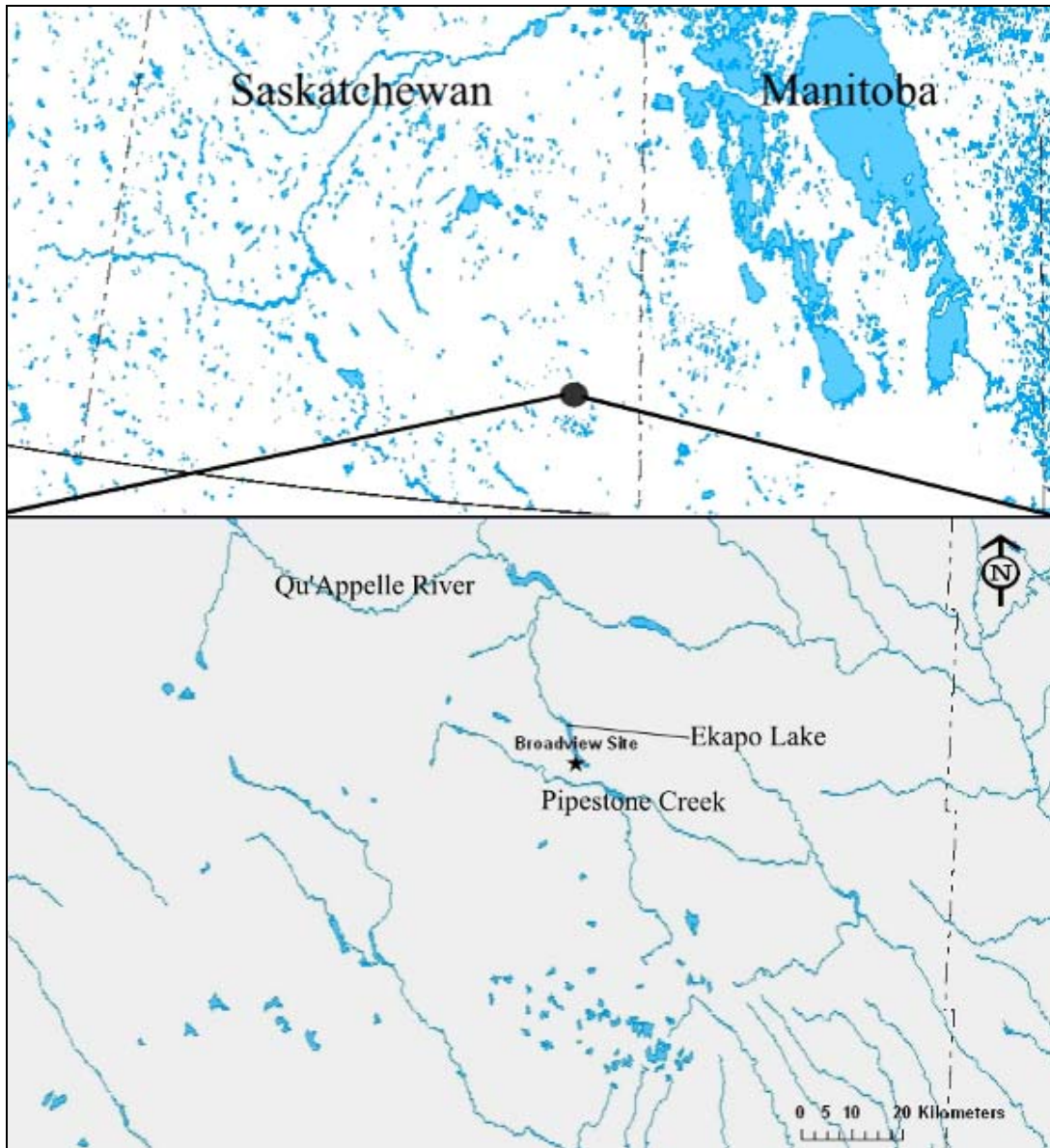


Fig. 4.7 Location of the Broadview site in Southeastern Saskatchewan.

4.5.3 The Lebret site, Saskatchewan

Located in the Qu'Appelle Valley in southeastern Saskatchewan (Fig. 4.8), the Lebret site is a multi-component Avonlea site. This site is situated on the southern valley bottoms of the Qu'Appelle River Valley between the Katepwa and Mission lakes. The

Qu'Appelle River flows through the Katepwa and Mission lakes and is immediately south of the Lebret site. Directly north of the Lebret site is the Lebret Marsh, this formed at the edge of a glacial alluvial fan which originates on the northern region of the Qu'Appelle Valley. The Qu'Appelle River flows eastward towards Manitoba eventually connecting with the Assiniboine River, 400 km east.

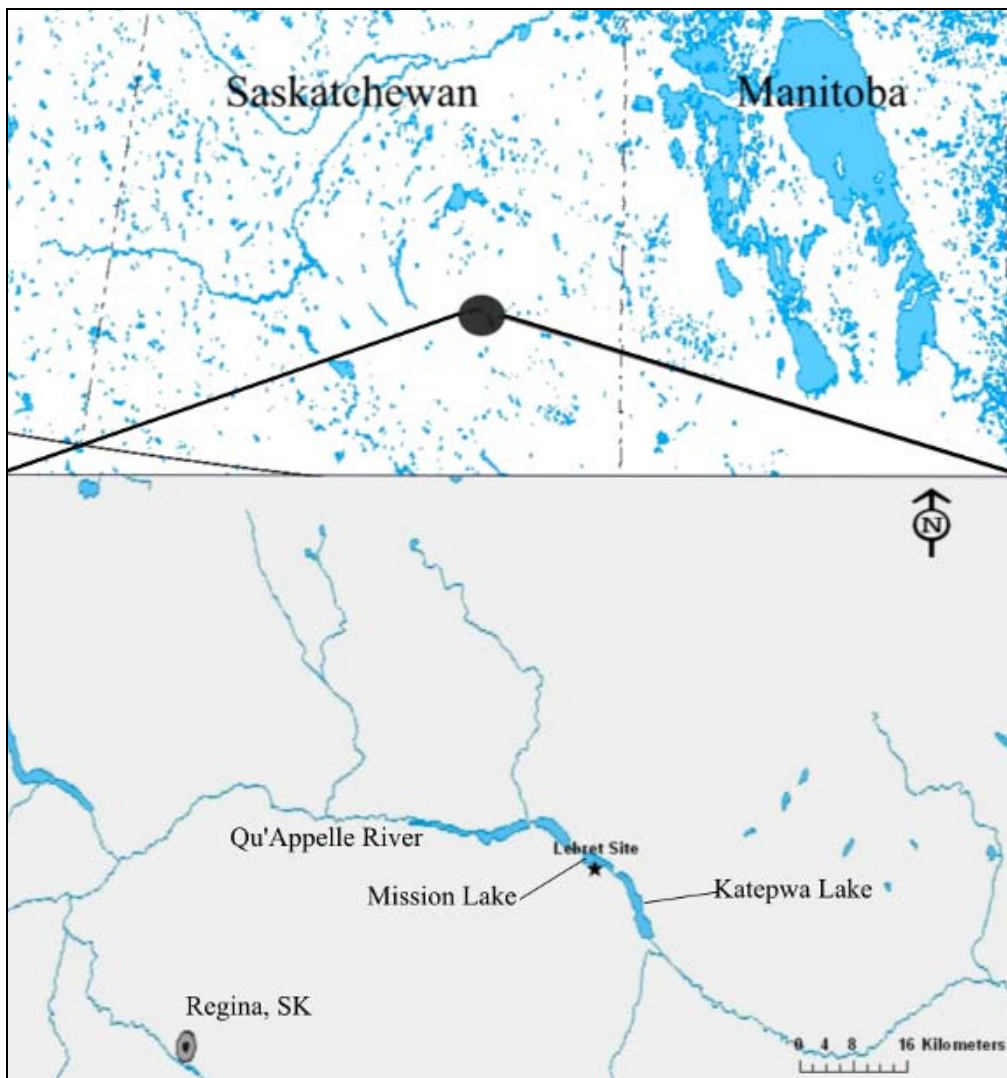


Fig. 4.8 Location of the Lebret site in the Qu'Appelle River Valley, SK.

Smith (1986) notes that during the late 1800's Cree peoples inhabiting the Qu'Appelle River Valley rarely camped near the mouth of a coulee valley that drained into the valley. This is likely due to the cold air draining past the coulee creating colder temperatures during summer nights. Residents who recently lived in the coulee mouth have noted several killing-frosts in July. Since the Lebret site is not located at the mouth of a valley coulee, this may have been a deciding factor for site selection by people of the past. As previously stated the Lebret site is located in the near vicinity of the Katepwa and Mission Lakes. This may also have had a moderating effect on temperatures throughout the year further increasing the desirability of this area for habitation.

There are five major microhabitats in the surrounding area of the Lebret site which include mixed-prairie uplands, wooded valley slopes and terraces, flood plains and marshlands, riverine, and lacustrine (Smith 1986). This variation in local habitat types greatly increases the amount of local resources available to individuals inhabiting this area, which is likely the primary reason for site selection. A wide variety of faunal resources are reflected in archaeological recoveries at the Lebret site, suggesting a broad-based seasonal subsistence strategy by the site occupants (Smith and Walker 1988).

Cultural materials recovered from the Lebret site represent multiple habitation periods beginning approximately 3,000 years cal ¹⁴C yrs BP to the historic period (Smith 1986). The longest occupation is from the Avonlea Complex that yielded four radiocarbon ages ranging from AD 325 to 690 (Smith 1986). Radiocarbon dates and cultural materials recovered have led to the interpretation that this area was periodically occupied by Avonlea peoples for approximately 350 years (Smith 1986). Artifacts

recovered from these cultural layers include multiple ash filled hearths, diagnostic projectile points, a barbed fishing spear, and numerous ceramic fragments (Smith 1986).

Avonlea ceramics recovered at the Lebret site included both parallel-grooved and net-impressed wares (Peck 2011). In total, 430 potsherds representing a minimum of seven Avonlea vessels were recovered. These vessels were interpreted as large cooking vessels in exception of one vessel that was identified as a small bowl-shaped vessel (Smith 1986). Similar to net-impressed vessels recovered at the Miniota and the Broadview sites, these vessels also contain angled exterior irregularly shaped punctates with slight internal bosses.

4.5.4. The Avonlea Site

The Avonlea site represents a significant contribution to the understanding of the Avonlea complex. This archaeological site has been selected as the ‘type site’ for Avonlea cultural materials. Identifications of diagnostic artifacts are based upon results from the Avonlea site, including both projectile points and ceramics.

Located east of the town of Avonlea in southeastern Saskatchewan (Fig. 4.9), the Avonlea site was excavated in several stages. The first of such excavations occurred in 1956 by the Saskatchewan Museum of Natural History (SMNH) after surface materials were brought to the attention of local archaeologists. This initial excavation resulted in the recovery of multiple projectile points, a single ceramic rim, and faunal remains. Further excavations were completed in 1983 by Archaeological Resource Management

Section (ARMS) west of the original 1956 excavations and yielded higher frequencies of archaeological materials.

During the 1956 excavation, archaeological materials were recovered indicating a bison kill site. Radiocarbon dates from this excavation yielded a calibrated date of AD 332 to 692 (1500 +/-100 BP) (S-45) (Klimko 1985a) (see Table 9.1). Another radiocarbon age of AD 18 to 893 (1565 +/- 205 BP) (S-2623) was obtained from bone collage during the 1983 investigations. The research objectives of the 1983 investigation involved finding evidence of subsistence from faunal recoveries, Avonlea settlement, and inter- and intra-group relations (Klimko 1985a). These recoveries included numerous ceramic fragments with two parallel grooved vessels identified, projectile points and other lithic materials, fire-cracked rock, large faunal remains, and hearth features (Klimko 1985a). Lithic artifacts were mostly composed of local material, with Knife River Flint representing a small fraction of the material recovered (15%) (Klimko 1985a).



Fig. 4.9 Location of the Avonlea and Garratt sites within Central Saskatchewan.

The ceramics from the Avonlea site are primarily parallel grooved wares. In total, at least four vessels were recovered during the 1956 and 1983 investigations (Klimko 1985a). These parallel grooved vessels are all conoidal with vessels 1 and 2 containing cord-wrapped tool decorations on the rims.

Interpretations of the 1983 recoveries indicate that this area of the Avonlea site was predominately used as a habitation area with cooking and some processing of faunal remains occurring (Klimko 1985a). This is due to the presence of cooking residue on the ceramics as well as the abundance of projectile points as well as bone and stone tools, and fire-cracked rock (Klimko 1983). Bison remains dominated the faunal assemblage indicating greater use of this species of large-mammal. Cultural materials within an elongated oval outline led archaeologists to interpret this as a tent feature. Although these recoveries indicate a possible habitation structure, a lack of post-molds and other signs of structural material are contrary to this interpretation. Based on the amount of ceramics recovered during the 1983 excavations, Klimko (1985) argues that this site represents a warm season occupation.

4.5.5. The Garratt site, Saskatchewan

The Garratt site (see Fig. 4.9) was first discovered when landowner Paul Garratt notified the Saskatchewan Museum of Natural History of cultural material found in his garden (Morgan 1978). This led to excavations in 1966 and 1968 that yielded numerous artifacts from multiple culture types. The Garratt Site is located in Kingsway Park, which

is located in the southern portion of the city of Moose Jaw, Saskatchewan. This multi-component site is further located within an alluvial floodplain on the western edge of the Moose Jaw Creek.

Cultural stratigraphy at this site from most recent to oldest includes a plain and prairie side-notched component, an Avonlea component, and a Besant component (Morgan 1978). The Plains Woodland tradition was located in levels 1 and 2 of the Garratt site. Several side-notched projectile points were also recovered from the Garratt site. Projectile points from the Plains tradition occur earlier on the plains, approximately AD 700 to 1330 followed by the Prairie tradition spanning AD 1330 to the historic period (Kehoe 1973).

The Avonlea ceramics at the Garratt site a wide range of variation including plain and grooved paddle surface impression, rounded lips, and net-impressions (Morgan 1978). Although Avonlea ceramics have been found alongside Laurel wares (MacNeish 1958; MacNeish and Capes 1958), Morgan (1978) argues that the Avonlea ceramics at the Garratt site bear little resemblance to Laurel wares. However, vessel 10 from the Garratt site does contain similarities to Laurel wares (Morgan 1978). This includes plain surface ware, decorative motifs, and positioning of decorations on the rim and upper body (Morgan 1978). Other than ceramics, 19 Avonlea projectile points, 29 pre-forms, a bison metapodial flesher, and a bell-shaped pestle similar to others recovered at the Gull Lake site were recovered (Morgan 1978; Peck 2011). Radiocarbon dates were also obtained from bone collagen and ranged between AD 431 and 679 (1450 +/- 70 ¹⁴C BP) (S-406), and between AD 653 and 881 (1280 +/- 60 ¹⁴C BP) (S-408) (See Table 9.1).

4.5.6 The Sjovold site, Saskatchewan

This multi-component site was first discovered by local landowners who noticed archaeological materials eroding from the Sjovold creek bank (Fig. 4.10). Excavations completed by Dyck and Morlan resulted in the recovery of archaeological materials spanning 4,000 years. The cultural levels were well stratified and provided a comprehensive guide to changes in past life-ways in central Saskatchewan. Major cultural groups that are documented at this site include Hanna, Pelican Lake, Besant, Avonlea, and Moose Jaw Complex, a subset of the Mortlach Complex (Dyck and Morlan 1997). In total, twenty separate occupations are documented indicating a continual landscape use.

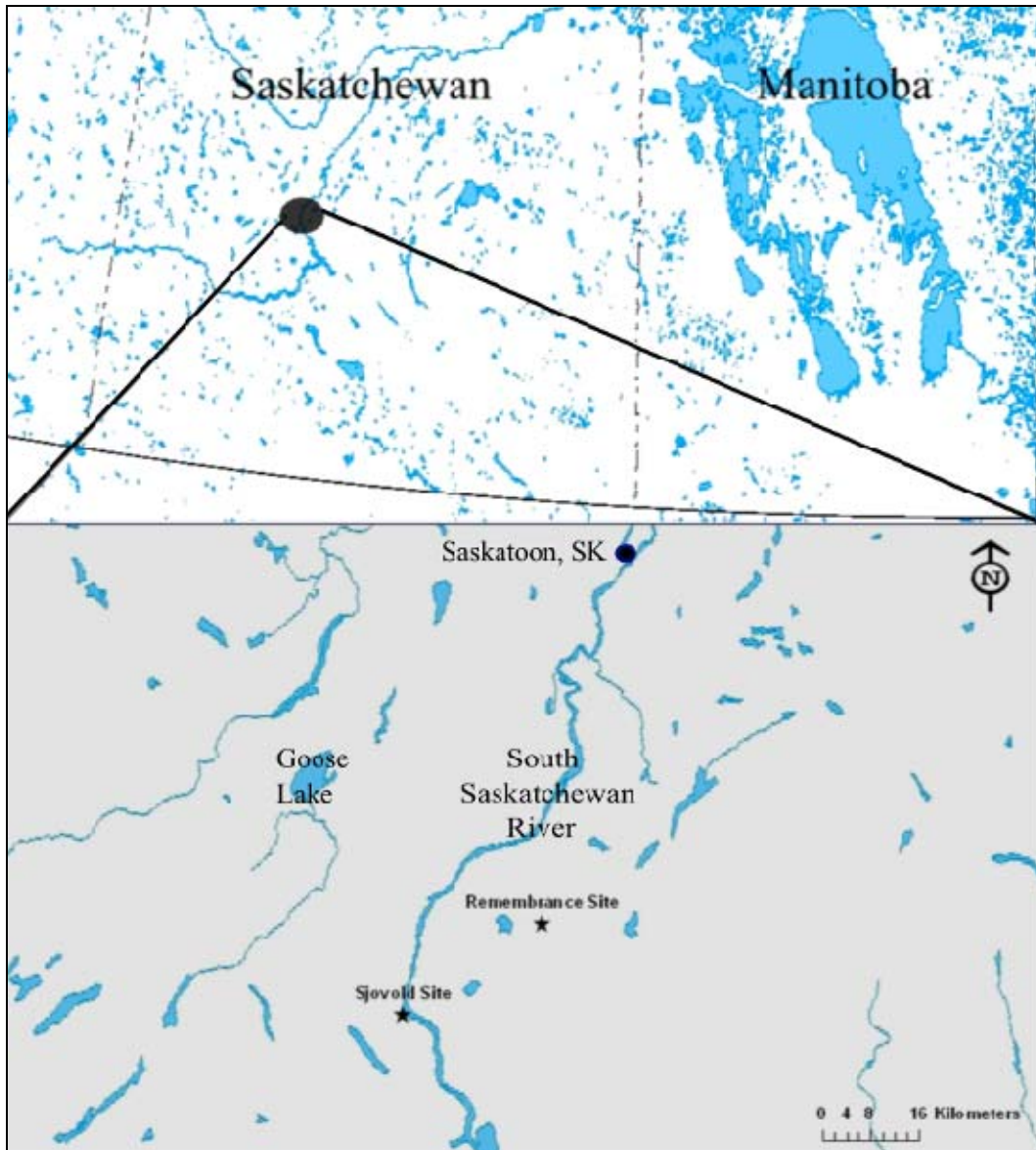


Fig. 4.10 Location of the Sjøvold and Remembrance sites near the South Saskatchewan River, SK.

The Sjøvold site is situated on the western bank of the South Saskatchewan River near Outlook, Saskatchewan. The first Avonlea layer (Level 6) which contained net impressed ceramics yielded two radiocarbon dates of AD 224 to 1042 (1380 +/- 200 BP) (S-1762) and AD 247 to 1024 (1380 +/- 190 BP) (S-1763) (see Table 9.1). The earlier Avonlea layer (Layer 7) at the Sjøvold site where the parallel grooved vessel was

recovered yielded a radiocarbon date AD 60 to 260 (1840 \pm 55 BP) (CAMS^b) (Dyck and Morlan 1997).

Excavations at the Sjovold site yielded numerous faunal remains with bison representing a large majority of the bone recoveries from the Avonlea layers. Non-bison faunal remains were mostly from small mammals such as various species of rabbit (*Lepus* sp.), martin (*Martes* sp.), and dog (*Canis* sp.). Unidentifiable fish vertebrae were also recovered. Only one bone tool was recovered from the Avonlea layers – that was identified as a possible anvil used in the production of pottery (Dyck and Morlan 1997).

Stone artifacts recovered from the Avonlea layers were mostly composed of local materials with only a small amount of non-local materials such as Knife River Flint. Among the lithic recoveries were a single projectile point and bi-face, percussion tools, hammer-stones, and a cylindrical abrader (Dyck and Morlan 1997).

The Avonlea layers at the Sjovold site yielded a large amount of well-preserved pottery. This included one partially complete parallel grooved vessel, discovered *in situ*, and several fragments of net-impressed pottery (Dyck and Morlan 1997). These recoveries represent two of the main types of Avonlea ceramics. The parallel grooved vessel (see Fig. 3.4) contained a thin layer of carbonized food residue on the interior and the exterior of the vessel. An important feature at the Sjovold site was the discovery of two hearth features in layer six in close association with Avonlea ceramics. One of these hearths was identified as an open-kiln based on the discoloration of soil (suggesting intense heating) and proximity of ceramic fragments (Dyck and Morlan 1997).

The location of this site in proximity to the South Saskatchewan River has led archaeologists to infer that this area was used as a temporary campsite by many traveling groups over time (Dyck and Morlan 1997). The continual re-use of this landscape is likely due to the wealth of biodiversity this area would have contained. Within the cultural layers, the Avonlea layers infer a kitchen/kiln work area. This is due to two hearth features and numerous ceramic fragments.

4.5.7 The Remembrance site, Saskatchewan

The Remembrance site is located 60km south of Saskatoon (see Fig. 4.10), SK in a Mixed Grassland/Aspen Parkland transitional zone (Norris 2009). Excavations included eleven shovel test pits yielding 373 ceramic fragments, 44 fragments of faunal remains, and four flakes (Norris 2009). The ceramics were parallel grooved and represent the northernmost parallel grooved ceramics to be recovered (Norris 2009). A radiocarbon age of cal AD 880 to 1020 (1100 +/- 40 ¹⁴C yrs BP) (Beta 270674) was obtained on bone collagen (Norris 2009) (see Table 9.1).

4.5.8 The Gull Lake site, Saskatchewan

The Gull Lake site is situated in southwestern Saskatchewan approximately 70 miles north of Montana and 65 miles east of Alberta (Fig. 4.11). This site is also located

six miles southwest of the town of Gull Lake. Set within the Missouri Couteau escarpment, this bison kill is positioned on the downward slope of this valley (Kehoe 1973).

The Gull Lake site (EaOd-1) represents one of the largest communal bison kill site in Saskatchewan with seven meters of archaeological deposits within a well-defined stratigraphy. It was discovered in 1948 by avocational archaeologist Conrad Dahl (Kehoe 1973). Cultural materials found during a field and test survey were brought to the attention of North Dakota State Historical Society Museum (NDSHS). This led to brief test excavations by Thad C. Hecker from the NDSHS, with further investigations by Boyd Wettlaufer in 1951. These initial test surveys were followed by a large-scale excavation by Thomas Kehoe in 1960 (Kehoe 1973).

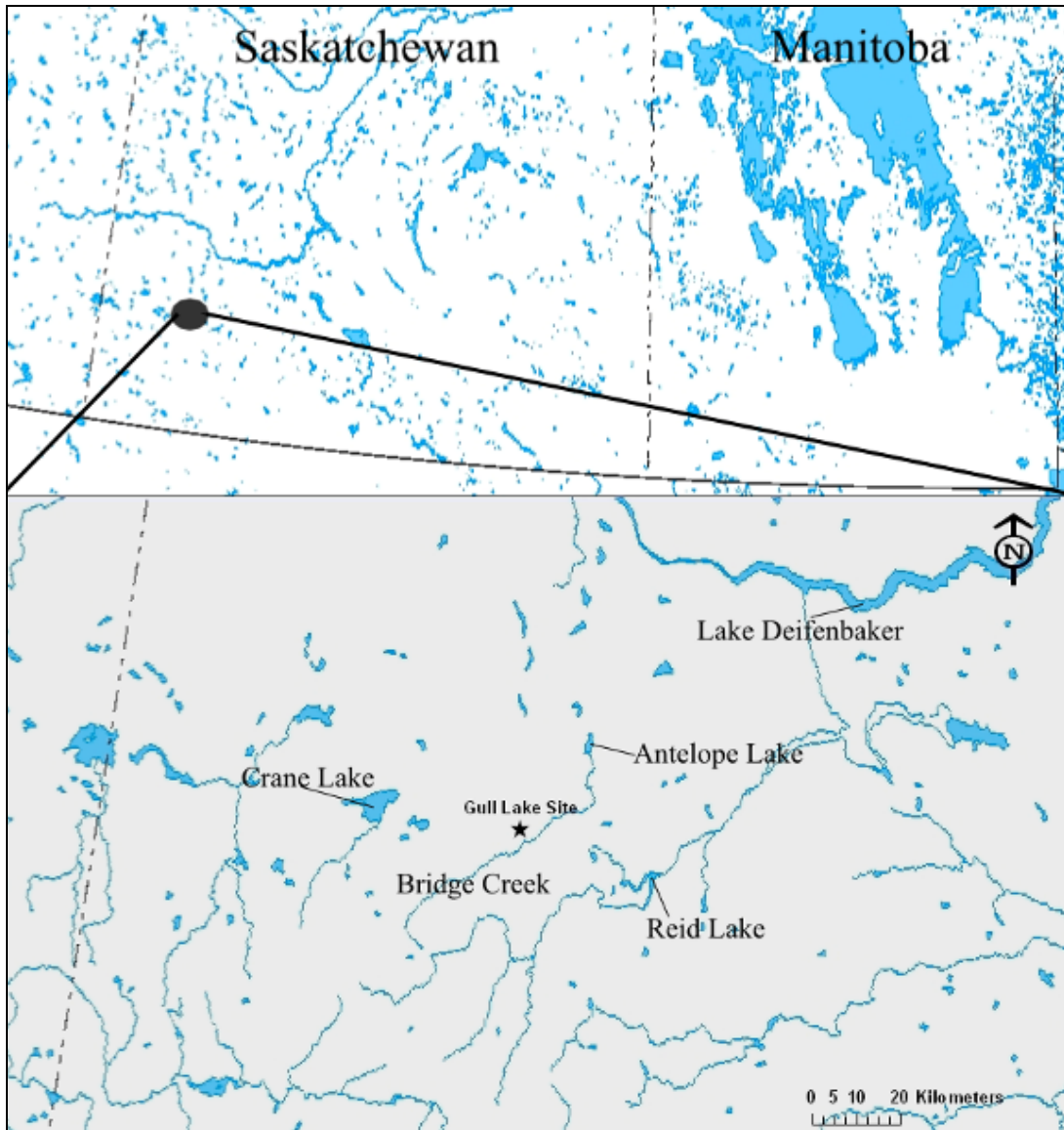


Fig. 4.11 Location of the Gull Lake site (EaOd-1) in Southwestern Saskatchewan.

Within the 52 natural and cultural levels, Kehoe (1973) observed three identifiable cultural traditions: Avonlea, Plains Side-Notched, and Prairie Side-Notched. Separating these levels is a consistent pattern of unburned faunal remains overlaying charcoal deposits followed by butchered faunal remains. Kehoe (1973:38) suggests that this pattern indicates:

... a custom of burning off the remains of a previous drive in preparation for another. The unburned whole bones would, in such case, represent the last in a series of drives, to be followed by a hiatus that permitted natural burial of the debris of the previous drive.

The earliest occupation at the site occurred sometime between 44 BC and AD 252 (1900 +/- 65 BP) (S-256) (Layer 34) and has been identified as a campsite (Kehoe 1973) (see Table 9.1). This layer contained few tools, small amounts of butchered bone, and a large bell-shaped pestle directly associated with the charcoal that provided the radiocarbon date. This occupation was followed by the first bison drive events likely conducted by Avonlea peoples. Other than tremendous amounts of faunal materials, the Avonlea layers yielded 333 projectile point fragments, numerous types of processing tools, and two bell-shaped pestles. Perishable materials that were recovered include a charred wood spatula (Layer 27) and a possible dried hide fragment (Layer 26) (Kehoe 1973). Unfortunately, Avonlea ceramics were not recovered during the 1960 investigations. The Avonlea period of use is somewhere between AD 210 and AD 660 followed by drives conducted by Plains and Prairie traditions beginning around AD 730.

The Plains Woodland side-notch tradition at the Gull Lake site is marked by repeated use of the area for communal hunting of bison. Within the Plains Woodland cultural layers, numerous diagnostic projectile points, stone tools, and ceramics were uncovered (Kehoe 1973). The ceramics that were recovered were described and identified based on exterior finish. These exterior surface expressions included Gull Lake Cord Impressed Pottery, Gull Lake Plain Pottery, Gull Lake Fabric Impressed Pottery, and Gull Lake Incised Pottery (Kehoe 1973).

4.6 The Terminal Phase of Avonlea

The end of the Avonlea phase on the Northern Plains occurs roughly around AD 900 to 1100 (Morlan 1988; Peck 2011). This phase is followed by groups utilizing prairie side-notched projectile points and ceramics exhibiting Middle Missouri influence (Klimko 1985a). These groups have been interpreted as grassland oriented bison hunters and most likely related to the Old Women's complex (Peck 2011).

Continuity between Avonlea pottery and projectile points with those found in the Old Women's complex was initially indicated by Byrne (1973). Further evidence for this connection was provided by Adams (1977) during excavations at the Estuary site (EfOk-16) and Duke (1988) while comparing Avonlea and Old Woman's ceramics. The identification of the Hartley site (FaNq-19) and layer 24 of the Gull Lake site (Kehoe 1973), the Sheep Camp site (EeOc-3), Bakken-Wright site (DiOa-1), Long Creek site (DgMr-1) and the Morkin site (DIPk-2) as Avonlea-Old Woman's transitional sites solidifies this argument (Peck 2011). Contrary to the above, Reeves (1983) indicates that Besant gave rise to the Old Woman's phase due to similarities between Samantha and Cayley series points produced by Old Women's groups. The problem with this theory is more recent evidence suggesting the overlap of Besant and Avonlea with Old Women's dates (Brumley and Rushworth 1983; Morlan 1988; Vickers 1986).

The exact cause of the disappearance of Avonlea cultural materials from the archaeological record has yet to be determined. Whether the appearance of the Old Woman's complex and other Late Woodland groups played a role in the demise of the Avonlea complex requires further archaeological investigations. However, the Avonlea

complex marked a time of innovation and cultural development. The Avonlea peoples were among the first to widely employ bow and arrow technology and ceramics on the Northern Plains. These individuals were well adapted to life on the Northern Plains, with archaeological evidence of this indicating a subsistence strategy, which focused on the procurement of seasonally abundant resources.

CHAPTER 5

PRECONTACT PLANT USE IN THE EASTERN WOODLANDS AND CENTRAL PLAINS

5.1 Introduction

The arrival of domesticated plants in Eastern North America is tied to the development of archaeological complexes spanning the late Woodland to post-contact times. As indicated in Chapter 3, influence from the Eastern Woodlands extended to the Northern Plains and the Eastern Sub-Arctic, which has led some archaeologists to infer connection between these areas (Morgan 1978; Meyer and Walde 2009). Therefore, a discussion regarding the development of these southern areas of influence is necessary to complete an analysis of Northern Plains cultures, more specifically, Avonlea. Two of these key archaeological cultural traditions are the Central Plains Tradition and the Plains Village Tradition, which are located in the Great Plains. The Eastern Woodlands encompasses the eastern part of the United States (Fig. 5.1) and is well-known for the development of large precontact horticultural societies (Adair and Drass 2011; Ahler 2007; Fritz 2011; Tiffany 2007). The Great Plains region spans from the Rocky Mountains in the west to the Eastern Woodland areas to the east. These areas are discussed in terms of important indigenous and ‘tropical’ cultigens, and the role of these plants in their development.



Fig. 5.1 Map depicting the approximate locations of the Eastern Woodlands, Great Plains, and the Central Plains of North America. Boundaries adapted from Adair (2003, 1988) and Smith and Cowen (2003). Base map adapted from [www. photojournal.jpl.nasa.gov/catalog](http://www.photojournal.jpl.nasa.gov/catalog).

5.2 Plant Use on the Great Plains Prior to the Woodland Period

Prior to the Woodland period, plant use on the Great Plains is poorly documented. Much of this is likely due to the greater visibility of faunal-oriented subsistence practices such as big-game hunting at Palaeo-Indian and Archaic sites. Although very little is known with regard to plant use during the Palaeo-Indian period, a few sites in Colorado, Wyoming, and Montana have shed light on this side of subsistence.

At the Barton Gulch site in Montana, a Late Palaeo-Indian ‘Alder complex’ site approximately dated to 7460 cal BP, Davis *et al.* (1989) report the presence of 16 basin-

shaped features. In addition to these archaeological features, remains from 16 edible plant groups were recovered. More evidence of plant use during the Palaeo-Indian period is provided from Plano complex sites in Colorado and Wyoming, which have been interpreted to be similar in function as Archaic sites where broad foraging has been interpreted. Frison (1992) reports the recovery of sunflower (*Helianthus annuus*), prickly pear (*Opuntias* sp.), juniper (*Juniperus* sp.), pigweed (*Amaranthus* sp.), and chokecherry (*Prunus virginiana*) from these sites. It is important to note that although plant remains are difficult to identify from archaeological sites, it is likely that fruit producing plants such as *Prunus* sp., if established in the local environment were likely included in the subsistence strategies of past cultures (Shay 1980).

While limited data addressing plant use during the Palaeo-Indian period is available, more evidence derives from Archaic period sites. This derives from more frequent milling and grinding stones (Adair and Estep 1991), the presence of semi-permanent dwellings (Blakeslee and Rohn 1982), rock-lined pits (Adair 2002), and early evidence for domesticated plants, such as maize. Haberman (1986) infers that during the Archaic period, groups participated in the processing of roots and tubers. Direct evidence of this process is evident at the Stigenwalt site (14LT351) in southeast Kansas that date to approximately 6860 cal BP. At the Stigenwalt site, onion bulbs (*Allium* sp.) were recovered from archaeological features indicating the processing of these edible plants. Plains Archaic sites being chosen because of their proximity to seasonally abundant resources (Adair 2003). In addition to wild plant foods, domesticated plants are also hypothesized to have appeared in the Eastern Woodlands and the Great Plains during the archaic period.

Recovery of maize kernels and cobs from Archaic occupations in eastern and central Colorado at the Recon John Shelter, LoDaiska, Gooseberry Shelter, Medina Rockshelter, and site 5HF1109 indicates the early arrival of maize into this region. However, microfossil analysis of Archaic sites in the Eastern Woodlands at the Lake Shelby site led Fearn and Lui (1995) to conclude that maize was present in both the Eastern Woodlands and the western portions of North America as early as 3,000 years cal BP. This hypothesis is based on pollen analysis of the sediment in Lake Shelby, Alabama, which yielded a single maize pollen grain at a depth dating to approximately 3500 cal BP (Fearn and Lui 1995). This analysis is also supported by microfossil and macrofossil evidence from Archaic sites such as the Tornillo Rockshelter, Dismal Swamp, and Bigbee Lake (Fig. 5.2). Domesticated sunflower seeds were found in the McKean levels at the Lightning Spring site in South Dakota (Keyser 1986). Recoveries of squash fragments increases during the Archaic period in the Midwest and Southeast riverine areas (Kay *et al* 1980; Smith 1992a, 1992b). On the Plains thin rind fragments from the Nebo Hill site (23CL11) have been directly dated to 2298-1985 cal BP indicating the early presence of domesticated squash during the Archaic.



Fig. 5.2 Late Archaic and Early Woodland sites yielding evidence of maize (Adair and Drass 2011; From Fern and Lui 1995). All dates rounded to nearest 100 BP. Base map adapted from [www. photojournal.jpl.nasa.gov./catalog](http://www.photojournal.jpl.nasa.gov/catalog).

In summary, evidence for plant use in the Great Plains prior to the Woodland period has led to the realization of an increased role of plants in the palaeodiet of past cultures (Adair 2003). The plant component of the palaeodiet is often overlooked since the remains typically are not visible at archaeological sites unlike their faunal counterparts. However, new techniques, forms of analysis, and the discovery of earlier sites have led to the indication of a wide ranging use of plants as early as the Palaeo-Indian period in this region.

Archaeobotanical examination of sites in the Eastern Woodlands and the Central Plains has resulted in the identification of cultigens that were originally domesticated in tropical regions, as well as indigenous species domesticated within the Eastern

Woodlands and Central Plains. In the following sections, the main types of these plants will be discussed in terms of timing and dispersal throughout North America as well as their origins of domestication.

5.3 Indigenous Cultigens

5.3.1 Gourds and Squashes

A wide diversity of indigenous cultigens were grown by Eastern Woodland and Central plains cultures prior to the arrival of ‘tropical’ cultigens. These included species of gourds that had been utilized by Eastern Woodland groups by at least the Archaic (Scarry and Yarnell 2011). Fritz (1999) proposes that these plants were originally used as containers, floats, and for their edible seeds. Some species of squash arrived much later, around AD 1000, from Mesoamerica. This included pumpkin (*Cucurbita pepo*) and cushaw squash (*Cucurbita mixta*) while recent indicates an incipient domestication of *Cucurbita pepo* within the Eastern Woodlands (D. Asch and N. Asch 1985; Chomko and Crawford 1978; Conrad *et al.* 1984; Newsom *et al.* 1993; Smith 1984). Ancient remains of wild *Cucurbita pepo* have been recovered from mastodon coprolites at the Page-Ladson site in Florida (12,000 cal BP), and from archaeological sites dating to between 7,000 and 4,000 cal BP in Illinois, Missouri, and Kentucky (D. Asch and N. Asch 1985; Chomko and Crawford 1978; Conrad *et al.* 1984; Newsom *et al.* 1993; Smith 1984). These early dates indicate the presence of these cultigens in North America well within the Archaic period. Decker-Walters further also asserts that pumpkins and marrows were

domesticated in Mexico from an unknown progenitor while acorn, scallop, and crook-neck squashes were likely domesticated from *C. pepo ozarkana* in Eastern North America (Decker-Walters 1993; Decker-Walters *et al.* 2002).

5.3.2 Wild and Domesticated Sunflower (*Helianthus* sp.) and Marshelder (*Iva annua*)

Two members of the Compositae family, *Helianthus* sp. and *Iva annua*, were incorporated into the economic activities of groups inhabiting the Eastern Woodlands and Central Plains as early as the Archaic period (Adair 2003; Scarry and Yarnell 2011). In the Eastern Woodlands for instance, *Helianthus* sp. and *Iva annua* have been estimated to have been domesticated by 4800-4400 cal BP (Scarry and Yarnell 2011). Although these plants were domesticated quite early, wild forms of these plants were most likely collected and consumed much earlier and also in parallel with the domesticated forms. Historic ranges for these plants include North Dakota, East Texas, North Carolina, and southern Quebec (Scarry and Yarnell 2011). These two oily seed-producing plants were key indigenous cultigens grown by horticultural Woodland groups prior to the arrival of tropical cultigens into the Eastern Woodlands and the Central Plains (Adair 2003; Scarry and Yarnell 2011). Although *Iva annua* was not observed by European colonists, *Helianthus* sp. were documented and their descendants are still used presently in modern agriculture throughout the world (Scarry and Yarnell 2011).

5.3.3 Wild Rice (*Zizania* sp.)

Wild rice was an important food crop prior to European contact in North America and is largely confined to Boreal Forest environments requiring adequate water supplies, such as lakes. Mather and Thompson (2000) indicate that wild rice first appears in the palaeoecological record approximately 4,000 BP in the Upper Midwest. Similarly, Birks (1976) and Huber (2000) indicate that the earliest evidence of wild rice appears from Wolf Creek in central Minnesota with macrofossils dating to 9,000 to 10,000 cal BP. Huber (2000) also indicates that wild rice was likely widely available during the Archaic period and although this is prior to the arrival of ceramics. Early encounters of European explorers resulted in observations of the scale and importance of this grain in the life-ways of contact groups.

Identifying the presence of wild rice harvesting and processing at archaeological sites proves difficult since a majority of the tools and equipment necessary were typically made of wood. Jenks (1903) noted that curing techniques often involved sun-curing and fire-curing, both of which involved the use of plant based equipment. Although the equipment used to harvest and process wild rice is difficult to identify in archaeological contexts, storage pits, ricing jigs, and parching features provide indications of wild rice processing at Minnesota archaeological sites such as the Cooper site (21ML9/16), Old Shakopee Bridge site (21ML20), and the Big Rice site (21SL168) (Mather and Thompson 2000). These archaeological features are identifiable based on the in-filled pits in some cases showing signs of intense heat (Mather and Thompson 2000). Furthermore, recent advances in plant microfossil analysis – specifically, the analysis of starch and

phytolith remains in carbonized food residue – has greatly increased the opportunities to identify wild rice consumption at archaeological sites in the Upper Great Lakes region (Thompson 2000; Boyd and Surette 2010).

In Canada, wild rice was used by some of the first ceramic producing cultures in the Boreal Forest. Evidence for wild rice use has been found in Laurel components in the Boreal Forest dating to between 2200 and 1250 cal BP (Valppu and Rapp 2000). Dawson (1983a) and Rajnovich (1980) speculate that while ceramic production and the building of burial mounds increases during the onset of the Laurel complex, this may reflect an increased reliance on wild rice as a form of subsistence that may have resulted in decreased group mobility. Reliance on wild rice in the Northeastern US and in the Boreal Forests of Canada likely continued into contact times as noted by Jenks (1903).

5.3.4 Other Important Indigenous Plants

During the Woodland period chenopodium (*Chenopodium* sp.), knotweed (*Polygonum erectum*), maygrass (*Phalaris caroliniana*), and little barley (*Hordeum pisillum*) represented the core groups of indigenous cultigens grown initially in the Eastern Woodlands and later in the Central Plains (Adair and Drass 2011; Scarry and Yarnell 2011). Similar to *Helianthus* sp. and *Iva annua*, these small grain-producing cultigens were also available well within the Archaic to Early Woodland period in the Eastern Woodlands and the Central Plains (Adair 2003). Around AD 1250 these plants decrease in use in the Eastern Woodlands and Central Plains and were most likely

replaced by the triad of beans, maize, and squash (Adair 1988; Scarry and Yarnell 2011). Other plants that were frequently used by indigenous groups in the Eastern Woodlands include the Jerusalem Artichoke (*Helianthus tuberosus*), Maypops (*Passiflora incarnata*), Giant Ragweed (*Ambrosia triphida*), green varieties such as carpetweed (*Mollugo verticillata*), purslane (*Portulaca oleracea*), and prickly fanpetals (*Sida spinosa*) (Scarry and Yarnell 2011).

5.4. Tropical Cultigens

5.4.1 Maize (*Zea mays* ssp. *mays*)

Maize has been commonly regarded as the most important domesticated food in North and South America (Adair and Drass 2011; Fritz 2011; Pearsall *et al.* 2003; Schneider 2002; Staller and Thompson 2002). The initial use of maize by hunting and gathering groups has been noted to represent a key shift in past life-ways, and in some instances a contributing factor in the development of more sedentary life-styles. Originally domesticated from teosinte approximately 8,000 to 9,000 years ago in Mesoamerica, maize was quickly adapted for use in a wide variety of climates and environments and eventually spread into North America (Matsuoka *et al.* 2002; Piperno *et al.* 2009). The northward diffusion of this crop into the Eastern Woodlands and Plains has received much attention.

One such possibility for the introduction of maize into the Southwest involves the early planting of maize by mobile-hunter gatherers in. This crop may have been viewed by these mobile-hunter gatherers as an attractive addition and supplement to a diet based on foraging (Minnis 1992). This process of mobile-hunting and gathering including maize planting would have continued until the formation of village systems around AD 1000 (Minnis 1992).

Another theory involves the migration of agricultural families originating from western Mexico up into southern Arizona and New Mexico, bringing maize along with them (Hill 2001; Matson 1999). Matson (1999) proposes that maize was present prior to this arrival and that these individuals were acting as middlemen to more northern areas, further aiding in the dispersal of maize. These northern groups may have included or developed into the Basketmaker II villagers inhabiting Colorado (Matson 1999).

While the processes are not well understood, it is thought that maize production from the American Southwest into the Eastern Woodlands and Central Plains. In the Central Plains, Scarry (1993) hypothesizes that maize was dispersed east from the American Southwest around 2,300 BP and grown in scattered places in small amounts by groups already practicing low-level cultivation. In this instance, maize may have been adopted either as an additional source of energy or for ceremonial purposes (Smith and Cowen 2003; Scarry 1993). After maize spread throughout the Central Plains and the Eastern Woodlands, some researchers (Crawford *et al.* 1997; Hart 2001) argue that a cold adapted variety known as ‘northern flint’ was quickly developed. This variety of maize appears at around AD 500 and resulted in maize appearing in northern areas of the Eastern Woodlands and the Central Plains, from North Dakota to the New England area.

Other theories concerning the spread of maize into the Eastern Woodlands and Central Plains involve a northern dispersal via the Mississippi River Valley and the Missouri River Valley. Once maize arrived in the Mississippi River Valley, it quickly became a major crop around 1200-1150 BP accompanying the emergence of large Mississippian chiefdoms such as Cahokia (Lopinot 1994; Simon and Parker 2006). One of these theories involve cultigens, including maize, moving north and west up the Missouri River and associated river valleys on the Northern Plains around AD 1000. This process may have involved adoption of maize by groups who were already cultivating indigenous plants such as chenopodium, maygrass, and wild rice.

The timing of these movements of maize into and within North America has been the subject of much debate. Presently, Adair and Drass (2011) report that the earliest confirmed evidence of maize in the Central Plains comes from the Avoca (1,165 +/- 40 BP) and Patsy's Island (1,010 +/- 40 BP) sites. Adair and Drass (2011) also suggests that maize was not only an important crop introduced to the Central Plains economy but also contributed to creation beliefs in the form of ceremony and in the building of trade relations between groups.

In the Eastern Woodlands, the evidence for the arrival of maize suggests an earlier arrival than anticipated for the Central Plains. Pollen analysis of archaeological sediments at the Lake Shelby site and other Archaic site in the Eastern Woodlands (see Fig. 5.2) has been interpreted by Fern and Lui (1995) to indicate the arrival of maize as early as 3,000 BP. In both the Eastern Woodlands and the Central Plains, therefore, the earliest signs of maize in these regions occur well within the Archaic period. While present in the Eastern Woodlands and the Central Plains during the Archaic, maize was not heavily used until

AD 800-1000 when it became a dominant agricultural crop. The reasons for this sudden increase in use will be discussed later in this chapter.

5.4.2 Beans (*Phaseolus* sp.)

Ethnographic accounts of Indigenous agriculture in the Eastern Woodlands and the Central Plains indicate that the common bean (*Phaseolus vulgaris*) were not only widely dispersed but was a major crop in the food production system of these regions (Adair and Drass 2011; Hart *et al.* 2002). Although beans were widely distributed during contact times, it has been speculated that beans were one of the last introduced crops to arrive in the Eastern Woodlands and the Central Plains (Adair 2003; Adair and Drass 2011; Hart *et al.* 2002) (Fig. 5.3). The earliest evidence of bean in the Eastern Woodlands was recovered from the Tularosa cave (Wills 1988) dating to 2470 \pm 250 ¹⁴C BP. However, in the northeast, Hart *et al.* (2002) estimate the arrival of beans to around AD 750. In the Central Plains, beans may have also arrived relatively late (AD 900 to 1200) Adair (2003).



Fig. 5.3 Approximate locations of sites and locales yielding evidence of domesticated beans (Hart *et al.* 2002; Adair and Drass 2011; Smith and Cowan 2003). Base map adapted from [www. photojournal.jpl.nasa.gov./catalog](http://www.photojournal.jpl.nasa.gov/catalog).

If true, there are many reasons to account for the late arrival of beans into the Eastern Woodlands and the Central Plains. One reason why this tropical cultigen arrived later, or are invisible in the archaeological record, may lie in the cooking methods used for this plant. Fritz (2011) noted that beans were most likely prepared for consumption primarily by extensive boiling. Since these plants were boiled, the chances of these plants becoming carbonized and thus preserved are significantly limited. In addition, since beans needed to be cooked in order to be rendered edible, ceramic vessels able to withstand the heat needed to boil beans would also be necessary. However, ceramics were likely available around 4,000 BP in the American Southeast and by AD 1 to 500 in the majority of the Eastern Woodlands and the Central Plains (Sassaman 2002). When

looking at the food production systems of large Mississippian villages such as Cahokia several other questions are raised. Although cultigens such as maize, squash, *Chenopodium* sp., *Phalaris caroliniana*, *Polygonum erectum*, and other native plants were widely used between 1150 to 650 BP evidence for bean is less available. Even though the food production system needed to accommodate beans was already established at Cahokia, the earliest evidence for bean is located in the ‘Moorehead’ archaeological deposits dating to 700 to 650 cal BP (Simon and Parker 2006).

Although beans are thought to have arrived later among Eastern Woodland and Central Plains, after AD 1200 beans were an important part of the food production system. Indeed, by the time of contact beans were ubiquitous throughout these areas and were included in the agricultural triad along with maize and squash. However, as previously stated, it may be possible that beans are invisible to archaeological techniques and future research is required to understand the timing of its arrival, geographic extent, and economic importance.

5.5 Husbandry Practices Employed for Indigenous and ‘Tropical’ Domesticated Cultigens

In order to interpret the process of by which domesticated plants became included in the food production systems of groups already utilizing indigenous cultigens, it is important to understand how the earlier husbandry practices might have transformed to accommodate maize based horticulture. These practices are also critical factors to consider when modeling how foraging groups might have begun to practice horticulture.

Interpreting these practices proves difficult since written records are scarce and some of these plants decreased in importance prior to the arrival of Europeans. Regardless of information available, speculations have been developed on the husbandry techniques for these plants.

5.5.1 Husbandry Practices: Indigenous Cultigens

Although some ethnographic information is available regarding the major tropical horticultural plants (e.g., Wilson 1917), less is known with regard to indigenous cultigens such as *Chenopodium* sp., *Polygonum erectum*, and *Phalaris caroliniana*. This is largely due to the shift in production from indigenous cultigens to maize and bean around AD 1000, long before the time of European observation and written record.

Although there is little archaeological data available concerning the horticultural practices prior to the arrival of the maize and beans, several speculations have been made. One speculation involves the use of broadcast seeding to sow these indigenous cultigens (Smith and Cowan 2003). Smith and Cowan (2003) have indicated that the small grains of indigenous cultigens were more likely suitable for broadcast planting or planted in rows rather than individually such as maize. Experimental harvesting has shown that in order to produce effective yields, these crops would have likely been densely planted (Asch and Asch 1978; Smith 1992c). *Helianthus* sp., *Cucurbita* sp., and *Iva annua*, on the other hand, were planted in sections of the garden where they had room to spread (Scarry and Yarnell 2011). Wilson (1917) notes that these space-requiring plants were originally

planted in the same manner as the small seed varieties, but as they became larger due to domestication, they were cultivated in small, strategically-placed, hills. This new planting strategy has been hypothesized by Gremillion (1993) as an antecedent to techniques later used for maize.

Asch and Asch (1985) indicate that some of these cultigens such as maygrass (*Phalaris caroliniana*) and little barley (*Hodeum pisillum*) ripen in late spring to May. Furthermore, Cowan (1978) suggests that these plants would have been treated as summer crops during cultivation but may have also been strategically planted in the Eastern Woodlands during the fall to provide crops when other resources such as fruits and nuts were scarce (Scarry and Yarnell 2011). While this may indeed be the case in the Eastern Woodlands, this strategy may have differed in the northern temperate areas.

Questions have also been raised as to whether or not these indigenous cultigens were grown in separate gardens or interspersed (Scarry and Yarnell 2011). Because maize, beans, and squash were known to have been cultivated together (Wilson 1917), it has been proposed that indigenous cultigens were also grown together (Scarry and Yarnell 2011). Broadcast seeding has been suggested by Scarry and Yarnell (2011) to indicate a separation of crops but archaeological evidence of both mixed and separated seeds suggests that this may not be the case.

Another area of speculation has been the size of these ancient fields (Asch and Asch 1985; Fritz 2000; Johannessen 1993; Scarry and Yarnell 2011). It has been assumed that small-scale gardening or horticulture was the norm, but Johannessen (1993) and Asch and Asch (1985) have argued that the large quantities of seeds recovered at

archaeological sites may actually point to farming in fields. On the other hand, Fritz (2000) has contended that there is no generic value when discussing scale of these crops and it is more likely that at times these plants were more intensively cultivated while during other times the scale of cultivation was more modest.

As for harvesting, Scarry and Yarnell (2011) speculate that this was likely completed through a process of beating the small seed producing plants and catching the seeds with a hide blanket. Other tools such as stone bifaces, and hoes made from bone, shell, and stone were also used (Scarry and Yarnell 2011). Once these plants were harvested, they were likely consumed raw in the form of a ‘trail mix’ or ground together for bread, added to stews, and also used to create porridges (Fritz 2000; Smith and Cowan 2003; Wilson 1917).

5.5.2 Techniques and Traditions of Domesticated Plant Horticulture

Interviews by Wilson (1917) with Buffalobird-woman, a Hidatsa elder, provided insight on the introduction of maize into the Hidatsa life-way, and the techniques used to cultivate maize and other domesticate. Prior to the arrival of maize into the Hidatsa economy, Buffalobird-woman notes that her people had always cultivated plants such as ground beans and wild potatoes. When a Hidatsa war party encountered a Mandan village, the Hidatsa eventually acquired maize through group transactions. This initial acquisition of maize led to the adoption of a gardening economy based on corn, bean, squash, sunflower, and tobacco. Buffalobird-woman reported that plants were sown

within deeply incised river valleys such as the Missouri, since prairie land was too difficult to cultivate. Women, with occasional assistance from the men, conducted the majority of the gardening.

Buffalobird-Woman (Wilson 1917) reported that maintenance of these garden plots was completed with digging sticks, antlers, and scapula hoes. Sunflower, maize, beans, squash and tobacco were all planted together although at different times, in the same garden plots. Sunflower was the first to be planted and the last to be harvested, maize was planted in May or when gooseberry plants were in full leaf, squash was planted in early June, and finally beans were planted immediately after squash. The placement of these crops typically involved sunflower forming the perimeter of the plot with maize, bean and squash being grown in the center (Fig. 5.4). Typically, six to eight seeds were sown typically in raised mounds that were placed four feet apart. Trees that were located in these plots were often left to provide support for lookout structures and as a source of shade for women who were watching the crops. These horticulturalists practiced a rotating planting system whereby crops were rotated into new areas when the yields decreased in productivity. Within these plots, empty spaces were left for the later planting of green corn, which was eaten immediately after harvest. During the growth season, these crops were supervised by groups of Hidatsa women under the protection of men from the village in order to deter pests such as birds and deer.

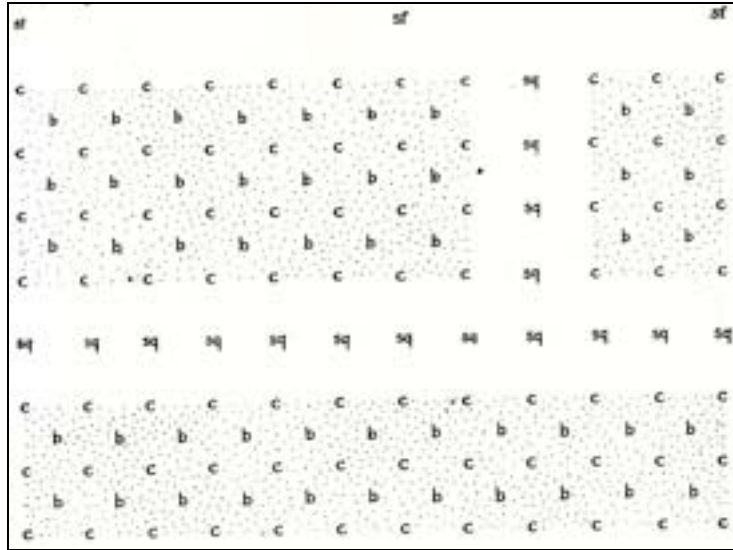


Fig. 5.4 Organization of a traditional Hidatsa garden, reported by Buffalobird-woman (sf= sunflower, c= maize, b=beans, and sq= squash) (from Wilson 1917).

After these crops were harvested, several techniques were used to prepare these foods for storage. The parching of sunflower seeds involved the cooking of the seeds in clay pots and rocking the pot over the hot coals (Wilson 1917). Squash were cut into slices and skewered on wooden rods to dry, which were subsequently placed on a wooden structure (Wilson 1917). The maize seeds were removed from the cobs in an enclosed structure to prevent the escape of any seeds and typically crops yielded enough for the entire village throughout the winter. Maize kernels were then prepared for storage through a process of half-boiling followed by drying and shelling.

Winter storage of this surplus was completed in cache pits that were constructed outside of the villages. These subterranean structures were lined with grasses and contained a wooden floor. Buffalobird-woman outlined a specific orientation of the foods within storage pits (Wilson 1917). Typically, cobs were placed on the outside, kernels in

the inside with squash and beans in the center (Fig. 5.6). These structures were hidden from enemy groups, such as the Sioux (Wilson 1917).

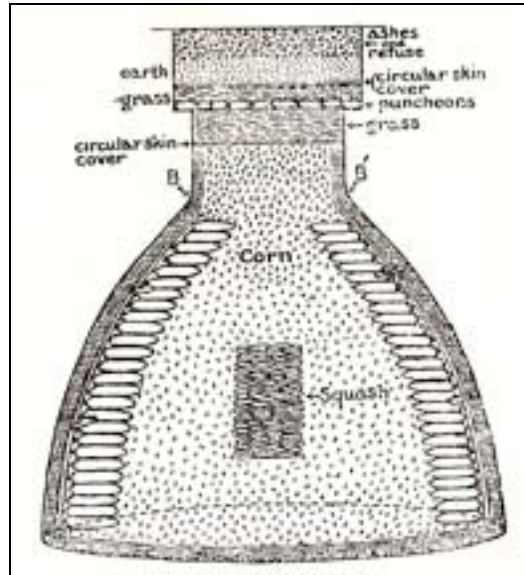


Fig. 5.6 Depiction of a Hidatsa storage pit recounted by Buffalobird-woman (Wilson 1917).

5.6 The Role of Plants in the Formation of the Plains Village Tradition

The arrival and adoption of horticulture into the life-ways of foraging groups was likely a period of immense change. An excellent example of this transition can be found in the development of the Plains Village Tradition in the Great Plains of North America (see Fig. 3.1 and Fig. 3.2). The following paragraphs provide descriptions of the archaeological complexes prior to the development of horticulture and after this transition.

The Plains Village Tradition is marked by the increase use of domesticated plants in correlation with decreased group mobility (Ahler 2007; Tiffany 2007). This tradition likely developed out of local Woodland groups and involved a semi-sedentary life-way

based on both farming and the gathering of wild resources (Adair 2003). Some of these groups, such as the PVT occupying the Middle Missouri Valley were likely the ancestors to historically documented cultures such as the Mandan, Hidatsa, and the Arikara. The influence of the PVT was widespread during this time period, manifesting in Plains Woodland materials recovered from Manitoba, Saskatchewan, and Eastern Montana to the north. This extended northern influence is present in the One-Gun phase of Saskatchewan and has been noted to contain evidence of PVT influence in artifact assemblage (Byrne 1973). Although there is little evidence of PVT settlements in the northernmost plains, influence is still visible in ceramic wares found in Manitoba (Boyd *et al.* 2006) and Saskatchewan.

By AD 900 to 1300, the PVT tradition was incredibly diverse with multiple archaeological complexes occurring in localized regions throughout the Great Plains. Within the PVT, several phases that have been documented include the Initial Middle Missouri Variant (IMMV), Extended Middle Missouri Variant (EMMV), Terminal Middle Missouri Variant (TMMV), Great Oasis complex, Oneota, Mill Creek, St. Helena, and Cambridge complexes. The Central Plains Village Tradition (CPVT) also includes numerous sub-phases such as the Upper Republican, Nebraska, Smokey Hill, Pamona, Bluff Creek, Pratt, Steed-Kisker, Mississippian, Maybrook, St. Helena, Itskari, Great Bend, and White Rock complexes.

The development of the Middle Missouri Tradition (IMMV and EMMV) on the Great Plains reflects a transformation from dispersed late Woodland groups who settled in unfortified, short-term farming hamlets, and into nucleated, highly organized and fortified farming villages (Anderson 1987; Lensink 1997, 1998). The appearance of

fortifications around farming villages suggests an escalation in conflict between groups. Bowers (1948) and Wood (2001) postulate that the origin of the IMMV is likely a result of migrations from the eastern Missouri trench. Tiffany (2007) follows this interpretation by indicating that the IMMV is an indigenous development in the Missouri trench, which then spread eastwards into the prairies. One of these MMT predecessors has been identified as the Great Oasis complex (Tiffany 1983) and sites containing both late Woodland variants likely the antecedent to MMT groups include the Scalp Creek (39GR1), Elk Creek (39GR2), and the Arp site (39BR101) (Grant 1961; Haberman 1993; Hurt 1952).

The Mill Creek culture of the MMT appears to be a result of gathering Great Oasis groups who coalesced into fortified dwellings around AD 1100 (Tiffany and Alex 2001). Prior to coalescence, Great Oasis groups practiced a life-way involving the occupation of short-term, unfortified and widely dispersed hamlets. Following coalescence, characteristics of Plains Village groups include nucleated villages with semi-subterranean, long rectangular houses containing interior hearths, storage pits, fortifications, and ceramics containing a flaring s-shaped profile (Tiffany 2007). Tiffany and Alex (2001) interpret this rapid change in organization and settlement to increased contact with Mississippian groups resulting in the re-organization of their social structure from a kin based structure to a weakly ranked tribal structure within multiple generations.

Another significant contribution to this transition also involves the increased use of domesticated crops such as maize, beans, squash, and sunflowers as well as indigenous cultigens such as *Chenopodium* sp. and *Amaranthus* sp. (Tiffany 2007). Lehmer (1971) indicates that this transition may have resulted in the adoption of a diversified economy

that included both bison hunting and foraging supplemented by domesticated crops. Although maize was included in the diet of the Great Oasis groups included among the late Woodland, it is regarded as not becoming a staple in the Plains Village economy until after AD 1000, such as the case in the Mississippian areas (Tiffany 2007).

The increased role of maize in the palaeodiet of Plains Village groups has been seen to be a primary motivator for Late Woodland groups to adopt a more permanent settlement pattern (Tiffany 2007). Tiffany (2007:7) argues that maize horticulture “...involves co-operation, highly labor intensive activity that requires field preparation, planting, harvesting, and storage.” An extensive amount of energy is required to create and maintain horticultural fields essentially tying individuals to plots of land (Tiffany 2007). Not only does the adoption of agriculture involve increased sedentism, it also includes a shift of group focus from an individual family to extended clans. The extended clans became a primary focus likely due to co-operation needed to create and maintain agricultural plots and to obtain and trade goods between and within these early Plains Village groups.

The means by which these groups incorporated Mississippian cultural traits is thought to reflect either increasingly intrusive Mississippian sites into the Upper Missouri Valley, or the gradual adoption of Mississippian life-ways by Late Woodland groups already resident in the eastern Central and Northern Great Plains. Tiffany (2007:14) adds that the development of the MMT is a result of “...an indigenous response by resident peoples to the process of agricultural intensification, production, and resultant tribalization throughout the Prairie Plains...” and is further described by Tiffany

(1983:107) as a multi-linear process that resulted in a melting pot of various groups on the Northern Plains.

This transition in North Dakota appears in a similar fashion although significantly later. In North Dakota, this transition from foraging/semi-farming to farming occurs later as the re-organization of settlements involves highly dispersed groups gathering in smaller areas throughout the seasonal round (Ahler 2007). This is not a rapid transition as more sedentary sites such as the Menoken Village site appears around AD 1200 (Ahler 2007). Similar to southern Plains Village areas, this transition likely involved an increased focus on gardening within a bison focused economic strategy.

5.7 Development of Maize Agriculture in the Eastern Woodlands

Early evidence for the use of Maize in the Eastern Woodlands is present at three middle woodland sites: the Harness site in south-central Ohio, the Holding site in the American Bottom, and the Icehouse Bottom site in the Little Tennessee River Valley in eastern Tennessee (Smith and Cowan 2003). Directly dated maize remains from portions of these sites have yielded AMS ages ranging from AD 1 to 200 and it is estimated that maize is added to the list of crops available in the Middle Woodland period in the Eastern Woodlands around AD 100 to 200. The location of these Middle Woodland sites containing maize indicate that maize was widespread in the southern portion of the Eastern Woodlands and had been incorporated into the food production economies.

Pollen records obtained from the Black Pond in Tennessee indicate a consistent presence of maize beginning around AD 400 but as Smith and Cowan (2003) note, this is the only pollen record yielding such information and the extent to which this plant was used is still unknown. This domesticated crop likely traveled northwards from Mexico through Arizona and eventually reached the Eastern Woodlands.

Although maize has been estimated to be present in the Eastern Woodlands by at least AD 100 to 200, it is regarded as playing a minor role in the food production economy of Eastern Woodland groups until AD 800. Reasons for why maize was not of primary importance prior to AD 800 in the Eastern Woodlands have received much attention. Smith and Cowen (2003) indicate that a few reasons may include selective use for ceremonial activities similar to Middle Hopewellian societies, differential preservation due to processing techniques that may limit the visibility of maize in archaeological contexts, a lack of political structure available during Middle Woodland times that was necessary for the development of maize-based agriculture, lack of time allocated to the development of maize agriculture, or other unknown reasons. Similar to the development of Plains Village horticultural economies, the foraging to farming transition in the Eastern Woodlands is also poorly understood. A rapid shift occurs around AD 800 to 900 involving an increase in sedentary lifestyle and agriculture focused on domesticated plants.

The development of maize-based food production strategies is typically identified as a contributing factor to the development of large villages in the Eastern Woodlands and the Central Plains. However, agriculture was already present in the Eastern Woodlands prior to the arrival of maize in the form of indigenous cultigens such as

Chenopodium sp., *Helianthus* sp., *Iva annua*, *Cucurbita* sp., and *Phalaris caroliniana*.

Even though agricultural techniques were already established prior to the arrival of maize, Smith and Cowan (2003) indicate maize agriculture is a whole different system. Maize-based agriculture requires significantly more time invested in the sowing, maintenance, and processing for consumption. While the planting of indigenous seeds involves a broadcast seeding pattern, maize horticulture required systematic placement of seeds in individually planted mounds. Maize agriculture also involved invested time in weeding, field upkeep, and protection from pests. After these plants were harvested, they also required increased time investment in preparation for consumption. Although indigenous cultigens required little preparation prior to consumption, maize (with the exception of green ears that could be eaten raw or simply boiled) required grinding, soaking, parching, or boiling to make the mature kernels palatable.

Although significantly more time and energy needs to be invested in maize cultivation and maintenance compared to indigenous cultigens, the benefits far outweigh this invested time and energy (Hyde 1917; Will and Wilson 1917; Smith 1992c). One of the benefits of maize agriculture is the limited time needed to complete harvesting of crops (Will and Hyde 1917). Maize kernels are ‘pre-packaged’ in ears and simply need to be snapped off the plant. In contrast, indigenous cultigens, with the exception of squash and sunflower, are not pre-packaged and may lose the seed prior to harvesting. Will and Hyde (1917) report that an entire crop yielding suitable amounts for an entire Hidatsa village could be harvested in 10 days. This differs significantly when comparing this strategy to harvesting a one-hectare plot of *Iva annua* and *Chenopodium* sp. Smith (1992) indicates that this harvesting which would yield enough to sustain a single family unit

would require a team of 5 individuals over 30 nine-hour days to complete the harvest. Another advantage to maize agriculture is that maize could be cooked in multiple ways or eaten raw unlike indigenous plants, which must be boiled, parched, or ground into flour. Smith and Cowan (2003) also note what they call a ‘taster’s choice’ effect. When maize ripens the water content of the kernels decreases and there is an increase in sugar content, which results in a sweet taste. In contrast to bland tasting indigenous cultigens the appealing flavor of maize may have been a significant reason for the adoption and dispersal of maize agriculture. In summary, while maize based agriculture requires additional upkeep and maintenance, limited harvesting times and the produced yields of maize agriculture represent significant advantages over indigenous cultigens.

CHAPTER 6

LITERATURE REVIEW OF STARCH AND PHYTOLITH RESEARCH

6.1 Introduction

Plant microfossil analysis provides the opportunity to recover information from archaeological materials where conventional archaeological methods cannot (Dickau *et al.* 2007; Pearsall *et al.* 2004; Piperno 2006; Piperno *et al.* 2000; Sandweiss 2007; Torrence *et al.* 2006; Zarrillo and Kooyman 2006). The following chapter is designed to outline the history of plant microfossil analysis, the formation of starch and phytoliths, taphonomy, archaeological uses, and recent applications.

6.2 History of Analysis

Starch and phytoliths were initially discovered over 100 years ago (Struve 1835), but unlike pollen, have only recently been incorporated into archaeological investigations. Only until recently have protocols for the careful examination for these residues been developed (Haslam 2004).

Since starch is a key energy source and widely targeted by people for consumption, starch has received a lot of attention in residue analyses (Loy 1994). The

early goal of this research in the Americas was to identify the source areas of major domesticated plants (Haslam 2004). Studies by Piperno *et al.* (2000; 2009) and Perry (2004), for example, have significantly increased knowledge of human-plant interactions in the Americas. Recently, such investigations have increased in North America. The first major research completed in the New World was completed by Bruier (1976) and Shafer and Holloway (1979). Further studies by Boyd *et al.* (2008), Hart *et al.* (2003), Thompson (2000), Yost and Blinnikov (2011), Zarrillo and Kooyman (2006) and Boyd and Surette (2010) allowed for the tracking of some domesticated and non-domesticated plants through time in the Northeastern Woodlands and Northern Plains.

Archaeobotanical research in the Pacific has been completed by Barton (2007), Fullagar (1986), Haslam (2004), Loy (1991), Lentfer (2009a), and Torrence (2006). This research is targeted towards the identification of starch granules from tuberous plants collected by ancient peoples (Haslam 2004). Early starch analysis began in the 1980's when Tom Loy and Richard Fullagar discovered starch grains in numerous archaeological contexts in the South Pacific (Fullagar 2006). After these initial studies, the importance of completing starch grain research in conjunction with use-wear analysis has greatly increased (Fullagar 2006; Kononenko *et al.* 2010).

Phytolith research has been completed in both the New and Old Worlds. Old World phytolith research began much earlier with studies by Netolitzky (1900) and Schellenberg (1908). Use of phytoliths in archaeological investigations flourished in the 1970's and the 1980's with main research topics on the origin and dispersal of major economic plants and the reconstruction of past environments (Pearsall 2000). Presently, phytolith research in the New World is regularly employed in the search for more

information on the timing and dispersal of domesticated plants (Boyd *et al.* 2006, 2008; Boyd and Surette 2010; Bozarth 1987, 1990; Hart *et al.* 2003, 2007; Pearsall *et al.* 2004; Pearsall 2002; Piperno *et al.* 2004, 2009; Staller and Thompson 2002; Thompson 2000; Zarrillo and Kooyman 2006;).

6.3 Formation, Chemistry, and Composition

6.3.1 Formation of Starch Granules

Starch granules are created by plants as a means to store energy for short term or reserve use (Gott *et al.* 2006). In the chloroplasts of plants, energy derived through photosynthesis starts as a series of reactions where the outcome is glucose (Gott *et al.* 2006). Glucose is a simple sugar that provides the sources of protein, fat, and complex carbohydrates (Gott *et al.* 2006). A portion of the glucose created during this reaction is then transported to amyloplasts where glucose building blocks are transformed into reserve starch (Gott *et al.* 2006). This type of starch grain is created for long-term energy storage that a plant may require for future use. Another type of starch is known as transient starch, which is formed in the chloroplasts and is designed for daily use (Gott *et al.* 2006; Haslam 2004; Zarrillo 2008). During starch grain formation, successive layers are built around a central point known as the hilum (Gott *et al.* 2006; Haslam 2004; Henry *et al.* 2009). It is estimated that under normal growing conditions, about one layer is added to a starch granule per day (Tester 1997). If the situation arises that a plant

requires some of this stored energy, reserve starch is converted back into glucose (Gott *et al.* 2006; Piperno and Holst 1998).

Starch grains are comprised of crystalline and non-crystalline regions made up of different compounds (Gott *et al.* 2006). Two types of hydrogen-bonded polysaccharide molecules (amylose and amylopectin) are the basic building blocks of starch granules (Calvert 1997; Lamb and Loy 2005). Amylose is an un-branched glucose molecule while amylopectin is a branched glucose molecule. These molecules are in the form of a 6 carbon atom ring. In amylose, the first and the fourth are linked creating a 1-4 bond. Amylopectin differs in that while it does contain a 1-4 bond, it also contains a 1-6 bond (Gott *et al.* 2006). Starch grains typically contain less amylose than amylopectin. Genetic and environmental factors control the amylose-amylopectin ratio in plants. In economic plants, amylose ranges from 20-30% (Gott *et al.* 2006). The amylose and amylopectin are present in starch granules in the form of an arrangement of alternating amorphous and crystalline rings (Calvert 1997; Gott *et al.* 2006). These rings are essentially the growth rings displayed by starch grains. It is hypothesized that the soft amorphous layers are where most of the amylose is located while the harder crystalline layers are where the amylopectin is located (Gott *et al.* 2006). The amylopectin crystals are comprised of radically arranged double helices (Calvert 1997). These layers are not definite, Gallant *et al.* (1997) proposes that serpentine channels run through the starch granules.

6.3.2 Location

Starch grains are located within many areas of plants. As mentioned above, transient starch grains are created in the chloroplasts during times when photosynthesis activity is high. Thus, transient starch grains are located in the leaves of plants (Haslam 2004). Storage starch on the other hand is created for energy reserve. The main locations of storage starch is in storage organs, which include roots, tubers, fruits, and seeds (Zarrillo 2008). Underground Storage Organs (USO's) such as roots and tubers, are important sources of reserve starch and have been targeted by humans as an energy source for centuries (Gott *et al.* 2006). USO's contain an incredible amount of starch. For example, starch forms 65-90% of the dry weight of potato (*Solanum tuberosum*) and manioc (*Manihot esculenta*) tubers (Gott *et al.* 2006). Although some of these plants contain an abundance of starch, some plants also contain toxins that need to be removed to allow consumption. Varieties of manioc contain cyanide and in order to make this plant suitable for consumption, South American groups grated this tuber and squeezed the remains through a basket to leach any toxins (Gott *et al.* 2006). Similar to manioc, arrow arum (*Peltandra virginica*) also requires substantial preparation to allow consumption (Messner and Schindler 2010). In the Eastern Woodlands of the United States, arrow arum rhizomes were processed by many groups despite the fact that this particular rhizome contains allelochemicals that may severely injure or kill an individual (Messner and Schindler 2010). Groups avoided these toxins by cooking these plants at different intervals, thus reducing the toxins. It is likely that the amount of time required to make some of these USO's palatable was deemed acceptable considering the amount of energy that may be obtained. Ethnographic reports of arrow arum indicate that the

rhizomes of this particular plant grew as large as a man's thigh (Messner and Schindler 2010). USO's of this size would be a valuable source of energy for groups participating in hunter-gathering subsistence. Examples of USO's that are located on the northern plains include white-pond lily (*Nymphaea odorata*), Indian Breadroot (*Psoralea esculenta*), and arrow arum (*Peltandra virginica*).

As previously stated, another common starch location is in fruits and seeds of particular plants. As fruits mature, starch is slowly converted to sugars (Gott *et al.* 2006). However, depending on the plant, a large amount of starch may be available in mature fruits. Bananas and plantains for example, retain as much as 90% of their dry weight in the form of starch (Gott *et al.* 2006). Numerous berry-producing plants (e.g., *Prunus virginica*) have been gathered by many groups and incorporated into their diet (Zarrillo and Kooyman 2006). However, these berries contain little starch and most of the starch is located in the seed of the berry. Seeds require a source of energy to aid in the development of a seedling (Gott *et al.* 2006).

6.3.3 Starch Granule Morphology

The morphology of starch grains is largely genetically determined (Nikuni 1978; Oliveira *et al.* 1994). Variations in starch morphology within plant taxa exist due to internal and external factors. The amount of starch grains produced and the variety of morphological types are dependent on the plant taxa. Although morphology is largely dependent on plant taxa, not all starch grains are diagnostic, meaning they can be used to identify a plant species. Some plants produce up to 109 different types, making taxonomic identification based on starch grains difficult (Lentfer 2006). Starch granules

contain numerous features that allow for easy differentiation from other types of microfossils. The hilum may be located in the direct center of the grain (centric) or may be located towards one end of a starch granule (eccentric) (Gott *et al.* 2006). Starch grains produced by maize, for example contain a central hilum while potato (Fig. 6.1) and some types of squashes contain hilums that are eccentric. When starch is deposited around the hilum, it is deposited in concentric layers (Haslam 2004). These concentric layers can be visible on some starch grains and are termed lamella or growth lines. Occasionally, features known as fissures emanate from the hilum and transect these growth lines. Examples of these features can be viewed in Fig 6.1.

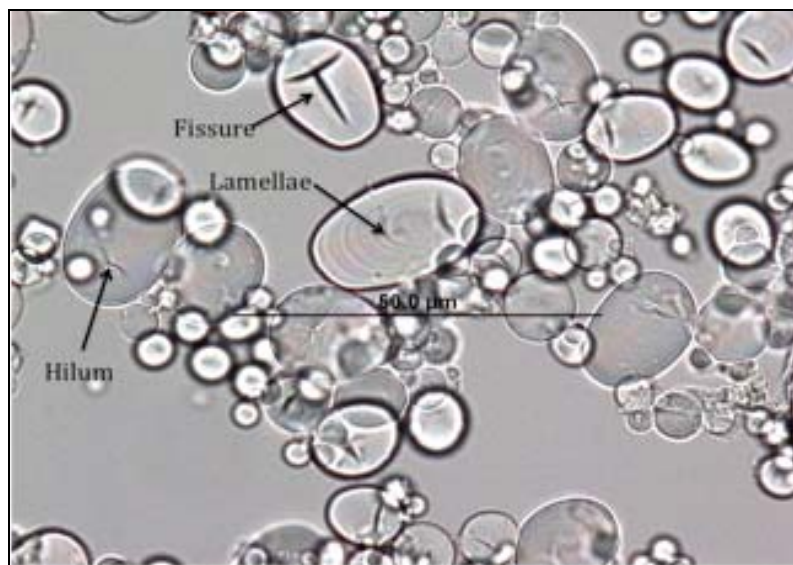


Fig. 6.1 Photomicrograph of *Solanum tuberosum* (White Potato) starch under plane-polarized light (PPL), showing major morphological features (lamellae, fissure, and hilum).

6.3.4 Starch Granule Types

Depending on how starch granules form, they may appear as one of three granule types: simple, compound, or semi-compound (Hall *et al.* 1989). Simple starch granules appear as individual starch grains free from other structures. Examples of simple starch grains include varieties of maize. Compound starch grains are comprised of multiple sub-granules that are docked together, typically near facets (Hall *et al.* 1989; Gott *et al.* 2006). Although multiple sub-granules are linked together, they still exhibit individual extinction crosses. During food preparation, compound sub-granules break up and appear as individual sub-granules (Gott *et al.* 2006). An example of a plant that produces compound starch granules is white-pond lily (*Nymphaea odorata* ssp. *tuberosa*) (Fig. 6.2). Semi-compound starch grains consist of multiple sub-granules that are fused together by a layer of amyloplasts surrounding the starch grain. When viewed under cross-polarized light, semi-compound starch granules exhibit a single extinction cross (Hall *et al.* 1989). It is important to note that plants may produce more than one starch granule type. For example, white-pond lily produces several types of compound starch granules as well as several types of simple starch granules.

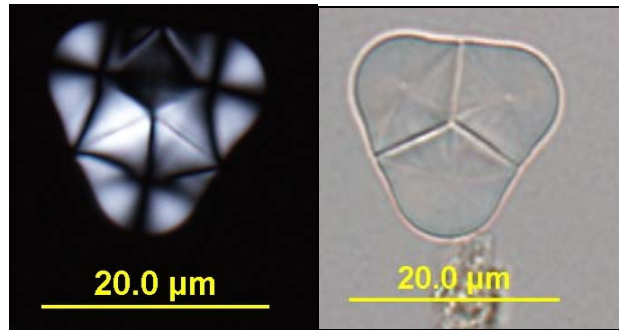


Fig. 6.2 Examples of compound starch granules from *N. odorata* ssp. *tuberosa* under cross-polarized (XPL) and plane-polarized (PPL) light. Note that each sub-compound grain exhibits an individual extinction cross (left).

6.3.5 Size and Shape

Plants produce a vast array of starch shapes and sizes. As previously stated, there are two main types of starch grains (storage and transient). Typically storage starch grains are considerably larger than the smaller every-day use transient starch grains. Starch grain sizes range from 1-200 μm in size, with the transient type ranging from 1-5 μm (Haslam 2004). Atkin *et al.* (1999) indicated that size is positively correlated with the amount of water in the starch grain. Other variables that may influence the size of starch grains include plant taxa, maturity, storage site, and nutritional status (Gott *et al.* 2006). Various plants produce starch grains of a set size range. For example, diagnostic starch grains from *Zea mays* are typically 20 μm in diameter while species of potato produce starch grains in excess of 40 μm . Size ranges vary from plant to plant and are governed by the genetic characteristics of the plant taxa. Within a particular plant species younger starch grains are smaller than mature starch grains (Gott *et al.* 2006). Some researchers argue that starch granules continue to grow until a threshold size is reached (Moorthy and

Ramanujam 1986; Noda *et al.* 1992b). The location of a starch grain in a storage organ may also influence size. Node *et al.* (1992) indicate that starch granules of sweet potato increase in size towards the center of the tuber. The environmental conditions and the nutrition available also play a role in determining the size of starch grains. Plants collected and analyzed from drought areas have been found to contain starch grains that are significantly smaller and in fewer numbers than plants from nutritional rich areas (Gott *et al.* 2006).

As with size, plants also produce a plethora of starch grain shapes. Identification of starch grain shape is an important step when trying to determine plant species based on starch grains. The major starch grain shapes include round, elongated, faceted, kidney-shaped, polyhedral, and irregular (Gott *et al.* 2006). Starch grains that are tightly packed in storage organs may exhibit a faceted shape. These facets on the surface of the starch grain are the result of being packed tightly together with other starch grains within a storage organ. An example of such grain compaction occurs in varieties of *Zea mays* (Fig. 6.3). *Zea mays* produces an incredible amount of starch – for example 1kg of starch comprises 1×10^{12} individual starch grains (Swinkles 1985). This large amount explains why maize starch grains are almost always faceted.

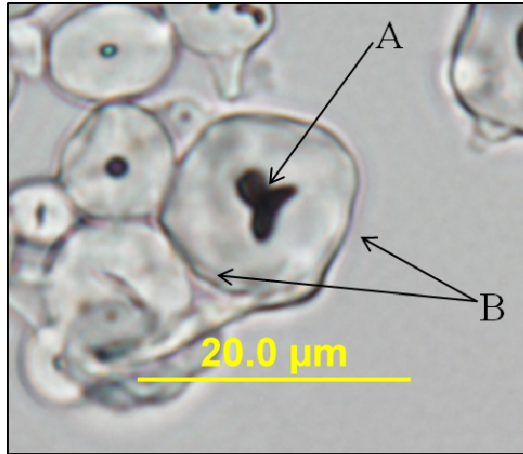


Fig. 6.3 Photomicrograph examples of faceted starch granules from Yellow Mandan Maize (*Zea Mays*) (PPL). A indicates a Y-Fissure and B indicates faceted sides.

6.3.6 Birefringence

When viewed under cross-polarized light (XPL), starch grains appear white against a black background. This characteristic is known as birefringence (Barton and Fullagar 2006). This attribute is in large part due to the highly ordered arrangement of soft amorphous and hard crystalline shells causing light to travel at different velocities through the starch grain (Barton and Fullagar 2006). Birefringence may be influenced by chemical stains that could mask this effect or by damage to the starch grain causing a disruption in the molecular arrangement (Lamb and Loy 2005; Barton 2007). Extinction crosses become visible when a starch granule is viewed under cross-polarized light (Fig. 6.4). This extinction cross appears as dark lines transecting the starch granule with a central point located at the hilum.

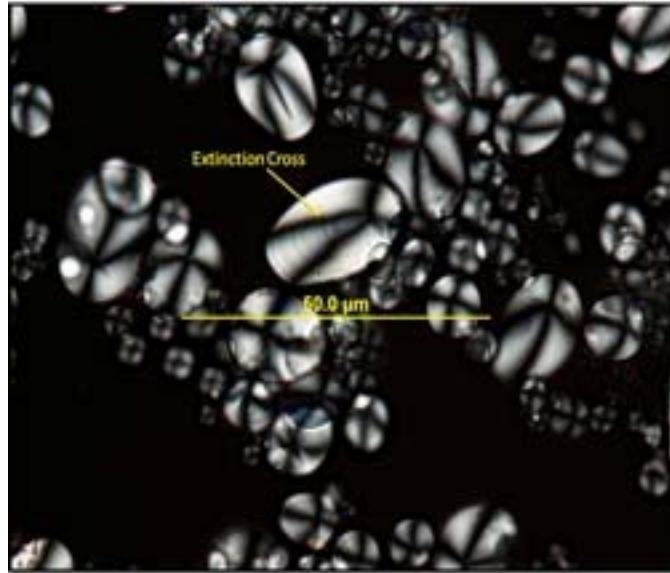


Fig. 6.4 Photomicrograph of *Solanum tuberosum* (White Potato) (XPL).

6.3.7 Staining

Since starch grains are comprised of concentric rings of amylose and amylopectin, they react to particular stains. The outcome of this reaction is a change in color, which depends upon the amylose-amylopectin ratio (Lamb and Loy 2005). Iodine staining is a common technique that is employed to identify starch (Barton and Fullagar 2006). When stained with iodine, starch grains turn purple-red in color. Other stains such as trypan blue (Barton 2007) or Congo red (Lamb and Loy 2005) are also used to identify damaged starch grains. Loy and Lamb (2005: 1434) indicate, "...the loss of the regular and compact arrangement of starch layers and absorption of water caused by cooking allows Congo red to react with the amylose content of starch granules."

6.4 Formation of Phytoliths

Although many plants produce phytoliths as well as starch grains, phytoliths are vastly different, notably being produced as a waste product rather than a means to store energy. Other functions include plant support (Piperno 2006) and also to reduce damaging effects of toxic heavy metals (Sangster and Hodson 2001). Phytoliths can be found in many areas of plants including the stems, leaves, roots, and inflorescences (Pearsall 2000). Phytoliths are composed of non-crystalline silica dioxide ($\text{SiO}_2 \cdot n\text{H}_2\text{O}$) that has been formed as the result of monosilica acid, commonly found in ground water, being drawn up by the vascular system of plants and deposited in cells (Piperno 2006). These non-crystalline structures also contain a small amount of water (4-9%) (Piperno 2006). The waste-product (monosilica acid) is deposited into epidermal and other cells of plants and eventually formed into bodies of silica that mimic the area in which the silica is deposited (Pearsall 2000; Piperno 2006). Being composed of inorganic silica, phytoliths are quite durable. Phytoliths have been recorded in numerous environments dating back to 80 million years (Prasad *et al.* 2005). When the surrounding plant material dies, the phytoliths are deposited in the surrounding environment (Li *et al.* 2010; Piperno 2006). Phytoliths retain the shape of the cells in which the silica was formed, making the identification of source area possible. Phytoliths vary slightly within plant families regardless of environmental conditions (Blinnikov *et al.* 2001). However, not all plant species produce phytoliths (Piperno 2006) and this furthers the need for comparative analysis in archaeobotanical research.

6.5 Taphonomy

When archaeological materials bearing plant microfossils are originally deposited, numerous variables may influence the amount or condition of these microfossils. Haslam (2004) identifies two areas of archaeological importance for plant microfossils, artifact surfaces and surrounding matrix. The following section deals with what occurs when plant microfossils are deposited. Phytoliths and starch grains are both useful proxies in identifying human-plant interactions, but how they are manipulated by humans and the surrounding environment is crucial in the completion of this research.

6.5.1 Movement in Soils

One archaeobotanical approach deals with the reconstruction of past environments based on the analysis of plant microfossils found in soil samples at archaeological sites. This analysis requires knowledge on how or if plant microfossils move when deposited in soils. Studies by Haslam (2006) and Therin (1998) have been developed to test how starch grains move in the soil. These experimental studies involved the creation of structures to hold soil columns where starch grains would be placed and then measured after an extended period of time. These types of analysis were completed in an effort to identify any bias in conducting environmental reconstructions based on plant microfossils. Experiments by Haslam (2006) indicate that a limited amount of the starch granules larger than 10 μ m moved approximately 4mm per day in the soil. The majority of the starch grains undergo little movement in situ. Haslam (2006) did however

find that in the presence of groundwater, starch grains did migrate upwards.

Understanding the dynamics of starch grain movement in soils is crucial in verifying the antiquity of archaeological samples.

6.5.2 Gelatinization

Cooking residue studies by archaeobotanists seek to recover archaeological plant microfossils by creating a link between consumption and plant availability. The cooking of plant material also affects the condition of the plant microfossils, starch in particular. In the presence of water, starch grains have been estimated to take 30% of their weight in water (Gott *et al.* 2006). When this water is heated, starch grains continue to swell. If the water is heated above the gelatinization threshold point, starch grains will remain swollen or form into a jelly-like mass if the temperature continues to increase. Threshold temperatures vary depending on the type and size of starch grains. Typically larger starch grains are more susceptible and gelatinize at lower temperatures than smaller starch grains (Haslam 2004). An average threshold temperature ranges between 50-70 degrees Celsius. However, recent experimental analysis by Messner and Schindler (2010) has indicated that starch granules are capable of withstanding high temperatures in the absence of water. Through the testing of charcoal cooking methods, they discovered that starch grains remain unaltered even after 30 minutes of cooking time (Messner and Schindler 2010). Alternatively, when starch grains are heated in a moist environment starch gelatinization increases substantially. Messner and Schindler (2010) also noted that gelatinization is a complex process that is influenced by the type of starch grain, method

of cooking, and the addition of chemicals in the cooking process. In addition, Barton (2007) notes when examining cooked starch residue, it is common to find starch grains that are completely gelatinized while others appear unaltered.

6.5.3 Mechanical Wear

When plants are used for subsistence, they often must be processed for consumption. A common form of processing involves the use of stone tools to break down the plant material for further use, and this can affect plant microfossils, particularly starch. Unlike phytoliths, starch grains are rather fragile and susceptible to mechanical damage (Henry *et al.* 2009). Evidence of milling, grinding, and pounding can be seen on starch grains in the form of tears, loss of birefringement, and shearing (Fig. 6.3). The addition of trypan blue was used by Barton (2007) to identify damaged starch grains. He noted (Barton 2007) that small cracks on the exterior surface of the starch grain permit the penetration of the trypan blue stain, thereby indicating damage to the starch grain. Since trypan blue and Congo red are only noted to stain damaged starch tissue (Barton 2007; Lamb and Loy 2005), the amount of stain accepted by the starch grain enables inference about the degree of damage (Fig. 6.3). Similar to Barton (2007), Babot and Apella (2003) and Zarrillo and Kooyman (2006) reported that damage to starch grains may appear as cracks, breaks, altered extinction crosses, and unnatural fissures.

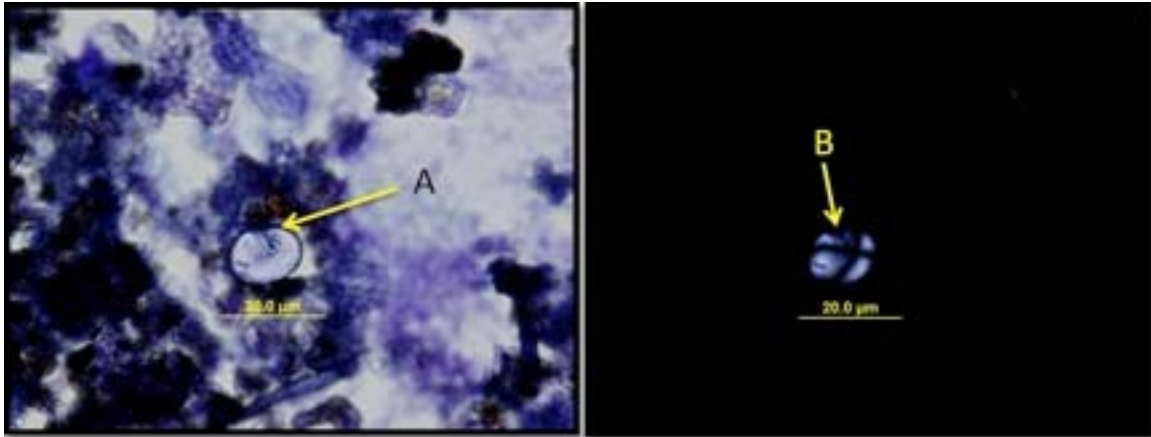


Fig. 6.3 Photomicrographs of damaged starch granule stained with trypan blue recovered from a surface collected grinding stone. A (Left PPL) and B (Right XPL) indicate a damaged area of a starch granule suggesting mechanical wear. Note the darkening of the stain near the damaged area of the starch granule.

6.5.4 Enzymes, Bacteria, and Fungi

Barton (2007) reports that under normal soil conditions, the majority of the starch granules are digested by enzymes within the first 3 days of deposition. This process resembles an asymptotic curve in that after this initial flurry of decomposition, the amount of activity significantly decreases (Barton 2007). Enzymes are described as biological catalysts that are employed by fungi and bacteria to lower the activation energy required to breakdown starchy materials (Haslam 2004). The enzymes responsible for the degradation of starch granules are known as amylases. In general, starch granules are degraded in two steps. The first step involves the gelatinization or hydrolysis of a starch granule after which the granule is transformed by enzymes back into sugars (Haslam 2004). After this step, other sugar reducing enzymes are activated. The duration of this process largely depends on the type of soil (pH), temperature, and anatomical

features of starch grains. While conducting experiments of enzyme activity on comparative starchy plants, Haslam (2004) identifies that the larger starch grains are less susceptible to enzyme degradation. This pattern is inversely related to the gelatinization threshold temperature mentioned earlier (Messner and Schindler 2010). Starch degrading enzymes have been located in numerous types of soil conditions, temperature zones, and depths. Cheshire *et al.* (1974:495) explains that polysaccharide-decomposing bacteria may represent 20 to 30% of the total bacterial population. The breakdown of starch in soils is small phase of the carbon cycle and without protection; archaeological starch may be incorporated into this process (Haslam 2004). Starch granules are limited to a single cell wall. This is largely due to the fact that starch grains are formed so that they can be easily broke down and converted into energy when a plant needs it (Langejans 2010).

The odds of starch preservation would seem low, but starch granules have been found from archaeological contexts all over the world, some as old as 105,000 years (Mercador 2009). This indicates that survival and interpretation may be possible. There are three main explanations for why archaeological starch may still persist. One reason is that starch granules are protected from degradation by artifacts or carbonized food residue, thus limiting the exposure to amylases (Haslam 2004). Similarly, charred organic remains (i.e. tubers) may also provide a protective barrier from fungi and bacteria (Langejans 2010). Another possibility may be explained by the presence of starch clusters or tightly packed groups of starch grains that provide a barrier to further starch degradation (Fig. 6.5) (Fullagar *et al.* 2006). The likely reason for the persistence of starch granules that are recovered from archaeological contexts is the sheer weight of numbers that starch grains are produced (Haslam 2004). It may be possible that there are

simply so many starch grains deposited and outnumbering starch degrading fungi and bacteria. Other theories involve the presence of clays and heavy metals in the soil that slows or inactivates certain enzymes (Haslam 2004).

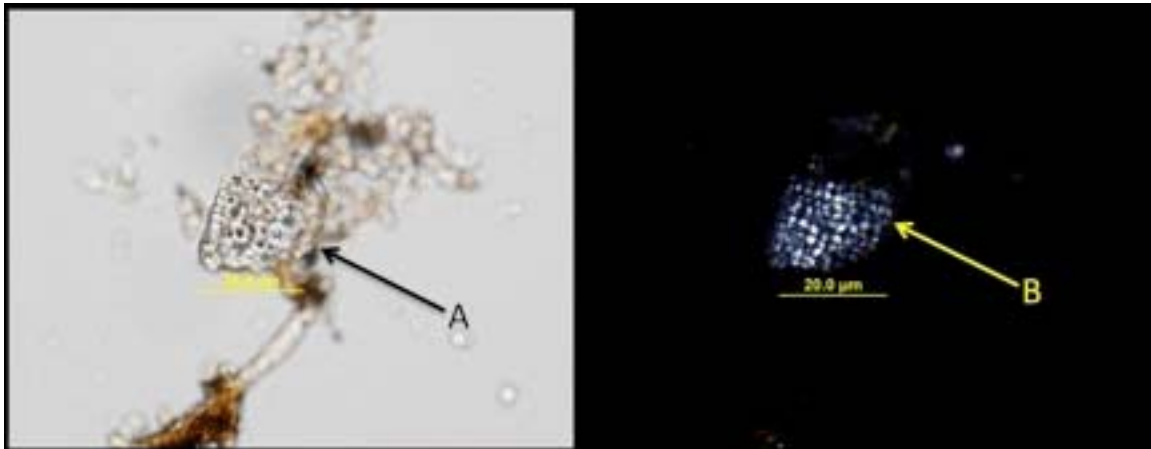


Fig. 6.5 Photomicrographs of a starch grain cluster recovered from a surface collected grinding stone. A (Left) indicates the starch cluster under polarized light while B (Right) indicates starch cluster under cross-polarized light.

6.5.5 Differential Preservation of Phytoliths

Although phytoliths are quite durable, they remain susceptible to variations in soil conditions. Differential preservation of phytoliths in soils is largely dependent on the type of phytolith and the soil context in which the phytolith is deposited (Piperno 2006).

Weaker phytoliths such as epidermal phytoliths, from tree and shrub species have been shown to have poorer survivability in soil contexts than stronger solid silica phytoliths (Piperno 2006). Other factors affecting phytolith preservation include the presence of aluminum (Sangster and Hodson 2001), phytolith surface area (Piperno 2006), and the

ability of the surrounding plant tissues to decompose (Piperno 2006). Aluminum and other metals have been shown by Sangster and Hodson (2001) to slow down phytolith dissolution. Piperno (2006) notes that greater amount of surface area of a phytolith, the greater it's solubility. Another factor affecting phytolith preservation includes the pH conditions of the soil in which phytoliths are deposited. In highly alkaline (exceeding 9) soils yield few phytoliths, suggesting that they are rapidly dissolved (Cabanés *et al.* 2010; Piperno 1985a, 1985b).

Plant material that is burnt through human or natural forces subsequently causes changes to phytoliths. Burning plant material carbonized organic material within silica phytoliths (Boyd 2002; Kealhofer 1996; Li *et al.* 2010). Li *et al.* (2010) also notes that woody phytoliths exhibiting a contorted shape may be the result of burning.

6.6 Archaeological Sources of Plant Microfossils

Starch and phytoliths can be recovered from a wide range of archaeological contexts. The main archaeological sources where starch and phytoliths may be recovered include carbonized food residue, stone tools and other artifacts, soils, dental calculus, and coprolites.

6.6.1 Carbonized Food Residue Analysis

Ceramic residue analysis provides subtle clues into dietary practices of past cultural groups (e.g. Boyd and Surette 2010; Boyd *et al.* 2006, 2008; Hart *et al.* 2003;

Staller and Thompson 2002; Surette 2008; Zarrillo 2008). Plant microfossils that are collected from carbonized food residue were deposited by past cultural groups and through their identification, provide direct information regarding diet, trade networks, horticultural practices, and ritual consumption (Barton 2005; Lentfer *et al.* 2002).

Carbonized food residue appears on the surfaces of ceramics when organic materials are heated to the point of carbonization. Carbonized food residue appears as encrustations adhering to the surface of pottery (Fig 6.6). These encrustations may appear on the interior as well as the exterior of the pottery.



Fig. 6.6 Photomicrograph of carbonized food residue from the interior portion of a ceramic sherd (#439) from the Miniota Site (EaMg-12). Note the cracking on the encrustations typical of carbonized food residue.

Carbonized food residue has been employed to identify the timing and dispersal of many key economic plants (Boyd and Surette 2010; Boyd *et al.* 2006, 2008; Hart and Matson 2009; Hart *et al.* 2003; Staller and Thompson 2002; Thompson 2000; Thompson and Mulholland 1994). Diagnostic phytoliths and starch grains have been identified within carbonized food residue indicating consumption or processing of these plants.

There are several limitations to carbonized food residue analysis. The main disadvantage is that this method can only provide evidence if plant materials were cooked. This is the main reason why multiple proxies, such as stone tool analysis and sediment analysis, are used in conjunction with ceramic residue analysis. Since starch grains were exposed to heat via cooking, may be damaged beyond recognition (Henry *et al.* 2009). This reinforces the need for multiple forms of plant microfossil analysis since phytoliths, due to their inorganic composition, are less susceptible to heat damage.

The presence of ceramics is also a significant limitation of carbonized food residue analysis. For example, recent evidence suggests that maize was originally domesticated 8,700 years ago, well before the arrival of ceramics (Piperno *et al.* 2009). Ceramic analysis in this area would inform researchers little in regards to the origin of early domesticates. Researchers in this situation turn their attention towards the analysis of stone tools and soils.

Another complication arises from the fact that if there is very little or no cooking residue adhering to ceramics, the chances of finding plant microfossils is low. Low amounts of residue may result from cooking strategy or rather, the amount of time past groups allocated to cleaning cooking vessels. However, while conducting research for

this thesis, numerous possible maize phytoliths were recovered from carbonized food residue with an overall sample size of 2.3 mg. While this sample size is well below average sample sizes for this research (30 mg), it is notable that positive results were achieved.

Limitations are also present when attempting to identify how often or how important a particular plant were to past groups. Ceremonial or ritual use of particular plants rather than extensive seasonal use may be difficult to differentiate when looking at the presence of diagnostic phytoliths or starch grains. Since carbonized food residue represents multiple cooking events over life-cycle of a ceramic vessel it is difficult to distinguish between certain plants being consumed once or numerous times. One way to avoid this problem is by increasing the amount of samples examined at archaeological sites of interest and comparing this data to research completed on different groups through time and space. Subsequent comparisons may increase the likelihood of identifying the extent of plant use by a particular culture group.

6.6.2 Stones, Bones, and other Artifacts

Stone tool analysis provides insight into processing and site activities, diet, and the function of cultural materials (Barton and White 1993; Field and Fullagar 1998; Mercador 2009; Pearsall *et al.* 2004; Piperno *et al.* 2000, 2004). This form of analysis can be applied to a wide range of artifacts from some of the earliest archaeological sites. Valuable plant microfossil evidence may be recovered from archaeological sites where subsistence was based on hunting and gathering (Kononenko *et al.* 2010; Li *et al.* 2010;

Zarrillo and Kooyman 2006), areas of plant domestication and early agriculture (Perry *et al.* 2007; Piperno *et al.* 2009), or ritual feasting and ceremonial activities (Duncan *et al.* 2009). Mercador (2009) was able to identify Mozambican grass seed starch granules from the surface stone tools from the middle stone age (105,000 BP). Artifacts that have yielded plant microfossils include stone tools (Barton 2007; Lamb and Loy 2005; Lui *et al.* 2010; Mercador 2009; Zarrillo and Kooyman 2006), wooden implements (Barton 2007), bone artifacts (Babot and Apella 2003; Kononenko *et al.* 2010), gourd containers (Duncan *et al.* 2009), and copper axes (Loy 2006).

Where carbonized food residue analysis can only provide evidence of plant materials that were cooked, recent studies have shown the value of stone tool analysis yielding independent verifications of important plants without the use of carbonized food residue (e.g., Pearsall *et al.* 2004). If past groups were eating plant materials raw, data regarding these consumed plants will not be captured by this method. By incorporating stone tool analysis into this research project, this missed data may be captured.

Analysis of residue on stone tools has two significant disadvantages: provenience and contamination. Most stone tools that are used to process plant and animal materials are not diagnostic to a particular culture (Zarrillo and Kooyman 2006). Therefore, a researcher must have confidence that stone tools used for analysis are supported by radiocarbon dates from associated archaeological contexts and excellent site stratigraphy to validate the age of these stone tools.

Another problem with residue analysis of stone tool or other objects is the antiquity and context of the residue. Is the residue being examined originally from the

artifact or contamination from the surrounding soil matrix? This may create a problem when looking at artifacts where soil samples from the surrounding soil were not collected. Research by Piperno *et al.* (2009) incorporated the collection of soil columns near where stone tools were deposited to enable systematic soil sampling and analysis.

Much research has been conducted to obtain information regarding the survival of organic residues on the surface of certain artifacts. Barton (2007) was able to identify starch granules on the surface of stone and wooden implements from Australia that had been curated for 77 years. He concluded that these intact starch granules may have been protected due to their location in micro-fissures on the surface of the stone tool, protection from enzymes by starch granules closer to the area of exposure, or a combination of both (Barton 2007). Lamb and Loy (2005) conducted similar research and also concluded that residues that are hidden on the working surface of stone tools are sealed off by bacterial residue.

6.6.3 Soils

Another avenue of plant microfossil research involves the collection and analysis of archaeological soils and sediments. Through the identification of plant microfossils, researchers have been able to recreate past environments or provide insight on human activity areas (Haslam 2004). This form of analysis may or may not be coupled with other forms of residue analysis (ceramics and artifact analysis). Studies have been completed in a vast array of archaeological settings including rock-shelters (Balme and

Beck 2002), gardening sites (Horrocks *et al.* 2008; Horrocks and Rechtman 2009; Horrocks and Nunn 2007), and early village sites (Li *et al.* 2010). Samples have been collected from soil and sediments in stratigraphic layers as well as archaeological features such as storage pits and hearths. The collection of phytoliths and starch microfossils as well as pollen, micro-charcoal, and diatoms from archaeological soils may be used to provide evidence of early plant use, reconstruct environments through time (Li *et al.* 2010), and provide information regarding human activities such as early horticulture (Pearsall 2000) and anthropogenic burning (Boyd 2002; Li *et al.* 2010).

The recovery of phytoliths from archaeological and modern soils has been completed in numerous studies to obtain information about past environmental conditions as well as human activities. When plants decompose, their phytoliths are left behind and can persist in soils for thousands of years. Researchers look for these remaining phytoliths in an effort to interpret their meaning. Pearsall (2000) notes that in order to confidently interpret phytoliths from soils, modern soil samples should be taken to provide a control sample to identify any downward movement of phytoliths.

However, there are several problems in the analysis of starch granules from archaeological soils. Unlike phytoliths, starch granules are more susceptible to degradation from organic and inorganic processes. Haslam (2004) identifies differential preservation of starch granules in soils as a major problem in starch analysis. Variations in starch survival due to genetic factors or size may result in some starch granules surviving more than others resulting in a bias (Haslam 2004). Differences in soil properties within archaeological sites may also result in differential preservation. Haslam (2004) concludes that until further research is completed on the dynamics of starch

preservation in soils, the burial environment must be included in the interpretation of starch granules.

6.6.4 Dental Calculus

Starch and phytoliths have been recovered from the dental calculus of early humans (Fox *et al.* 1996; Hardy *et al.* 2009; Wesolowski *et al.* 2010) to extinct species of Pleistocene mega-fauna (Gobetz and Bozarth 2001). Dental calculus provides a direct link to the consumption of plant materials (Hardy *et al.* 2009). However, it is important to note that not all starch found in dental calculus is the result of consumption. Hardy (2008) notes that some human groups soften plant fibres by chewing to enable use of these fibres. This is further supported by research completed by Nelson (1997) where dental calculus was employed to identify evidence of Peruvian women using their teeth to prepare fibres for use in textiles.

Plaque biofilms are located on the surfaces on or around teeth and are the location of microbial communities (Hardy *et al.* 2009). Dental calculus is formed when the plaque biofilms accumulate and mineralize. Dental calculus, unless removed, build up over time (Gobetz and Bozarth 2001). The mineralized plaque undergoes excellent preservation as samples have been obtained from the late Pleistocene (Gobetz and Bozarth 2001). Starch and phytoliths may become trapped in these microbial communities and thus incorporated into the dental calculus. Saliva is a rich source of amylase (Hardy *et al.*

2009) and usually breaks down starchy plant material. However, starch grains may avoid this degradation if they are incorporated into dental calculus.

Dental calculus may also be used to identify consumption patterns of grazing animals. Phytoliths have been recovered from the dental calculus of late Pleistocene mastodon to provide implications on diet. Research has been completed on stomach contents of these extinct mega-fauna (Hartnagel and Bishop 1921), but little had been completed in terms of dental calculus. Gobetz and Bozarth (2001) were successful in capturing numerous grass phytoliths possibly an indication of grazing.

Count sizes are a significant limiting factor in this form of analysis. Generally starch and phytoliths may be found in extremely low amounts that may hinder interpretation of plant consumption or use. Another problem of dental calculus is that dental calculus represents a lifetime of consumption; it is possible that some foods were heavily exploited for a short period of time, which would create an over-interpretation of consumption. Since these samples are obtained from past living individuals, permission and ethical clearance is needed to conduct this form of research. Depending on the political or cultural situation this form of analysis may not be permitted.

Conducting multiple archaeobotanical approaches to a single research question may circumvent many problems that affect food residue analysis. Alone, carbonized food residue analysis, artifact analysis, soil analysis, and dental calculus analysis can achieve valuable information on past environments and human activities. However, by employing more than one of these proxies to a research question, errors may be reduced while providing a more complete understanding of past plant use and consumption.

6.7 Building a Comparative Plant Collection

In order to confidently identify plant varieties based on starch grains, building a starch database from modern plants is a necessity. Since plants produce an abundance of starch grains in various shapes and sizes, research must be completed in the creation of starch databases and plant keys for geographic regions. This involves collecting starch samples from plants in the field (herbariums, garden plots, or wild plant surveys), processing these plants for starch, and then mounting samples on slides for microscopic analysis.

Research by Lentfer (2009b) has indicated the need for comparative collections for the interpretation of plant microfossils. Through analysis of several banana species, Lentfer (2009a) noted that analysis of starch morphotypes rather than size evaluations allows for classification of diagnostic starch granules. This research can be rather cumbersome due to the amount of variation within plant species in terms of starch grains. While analyzing several species of banana Lentfer (2009a) found 109 different morphotypes with 18 appearing in different species.

In order to confidently identify plant microfossils in archaeological residues it is crucial to develop a reference collection pertaining to the geographic location of the research question. Lentfer (2009b:82) states:

Given the general lack of readily accessible, broad-scale collections, therefore, it is often the case that the establishment of new or additional comparative reference collections tailored to suit particular research questions is a mandatory component of research design.

This enables researchers to produce confident results while eliminating possible microfossil ‘confusers’ that may result in a misidentification or over-interpretation of archaeological residue analysis.

6.8 Recent Applications of Starch and Phytolith Analysis in Archaeology

6.8.1 Laser Differential Interface Contrast (DIC) Microscopy

A new technique involves the identification of starch grains through the analysis of lamella density. This process involves the use of a laser DIC microscope to allow the analysis of the internal structure of starch granules (Hong *et al.* 2006) and has not been completed in any similar archaeological research. Laser DIC microscopes were previously used to examine live cells for biological research (Hong *et al.* 2006). Hong *et al.* (2006) show that by using various velocities of light and focusing them through a particular starch granule certain internal features, such as lamella can be identified and counted. In this study, Hong *et al.* (2006) analyzed a comparative collection of maize starch granules and were able to create a mean density average of 12.1 +/- 1.6 lamella rings per maize starch granule. This is valuable in archaeobotanical research because it allows identification of maize starch based on internal morphology. This technique is also rapid, with minimal preparation (Hong *et al.* 2006) and allows an alternative approach to the starch granule the identification.

6.8.2 Stains and Peels

The application of stains to archaeological starch residues is a procedure that has been developed to aid in the identification of damaged starch grains (Barton 2007; Lamb and Loy 2005). Trypan blue and Congo red are two stains that are applied to starch residue. Starch grains are only stained if the structure of the starch grain is compromised. In other words, trypan blue and Congo red only stain damaged starch tissue. This aids in the verification of tool function as well as the antiquity of the starch granules recovered from stone tools. If the starch granules can be identified via staining, it is likely that the damage was a result of tool function. This is a relatively new procedure and more work is needed to fully understand the potential this procedure for archaeobotany.

Through the use of silica peels, further information can be collected regarding tool function of artifacts yielding archaeological residue. Some researchers (Fullagar 1991; Lui *et al.* 2010) have applied silica peels to the surface of stone tools containing plant residue. The silica peels may capture striations indicative of use-wear from the surfaces of stone tools (Lui *et al.* 2010). This procedure provides supplementary evidence towards plant microfossil interpretations of stone tool function.

6.8.3 Experimental Analysis

Recent experimental analysis has been completed on modern plants to collect more information on how these plants were prepared in the past. This information

includes the effects of cooking on starch granules, differential preservation of organic food residues, starch and phytolith movements in soils, and cooking techniques of wild plants. Examples of experimental analysis will be outlined in the following paragraphs.

Studies have been completed involving the preparation and cooking of modern starchy plants to identify changes to starch morphology (Henry *et al.* 2009; Messner and Schindler 2010). Messner and Schindler (2010) examined tubers and rhizomes from arrow arum (*Peltandra virginica*). Their research involved several testing several ethnographic cooking methods including charcoal broiling, two types of earth ovens, and sun drying (Messner and Schindler 2010). Through their research, they indicate that starch grains can survive intense heat in the absence of water, but when moisture is present the chances of gelatinization greatly increases (Messner and Schindler 2010). Messner and Schindler (2010) were also able to identify the point of detoxification of this plant during preparation.

Similar research was conducted by Henry *et al.* (2009). During this study, a wider selection of economic plants was subjected to various processing and cooking strategies to identify changes to starch grain morphology. These plants included wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), oats (*Avena sativa*), millet (*Panicum miliaceum*), sorghum (*Sorghum bicolor*), rice (*Oryza sativa*), lentils (*Lens culinaris*), green peas (*Pisum sativum*), chick peas (*Cicer arietinum*), and mung bean (*Vigna radiata*) (Henry *et al.* 2009). Results from the various cooking and food preparation techniques indicated a positive correlation between cooking time and increased damage to starch grain morphology (Henry *et al.* 2009).

A key subject of organic residue taphonomy is the understanding of what happens to residues adhering to cultural materials in the archaeological record. Recent experimental analysis by Langejans (2010) attempted to provide further information on this topic. Langejans (2010) applied various organic residues, including starch, to the surfaces of experimental stone tools. These tools were then left in various environments for a year in both Sibudu (South Africa) and Zelhem (the Netherlands) (Langejans 2010). Some of these samples were buried, located under shelter, or exposed on the surface (Langejans 2010). Results of this analysis varied with each organic residue, of these residues starch grains were the least likely to survive (Langejans 2010). This study does however contain several problems. The duration of this particular experiment is one year, suggesting that caution should be used when extrapolating to consideration of archaeological samples. Another problem is that although materials were deposited at these two sites at the same time of year, they were not during the same seasonal cycle. The variances in seasonal changes may influence the result of this research by increasing the amount of variables.

6.9 Conclusion

Plants have and continue to be a valuable source of energy in the human diet. Past cultures have been shown to incorporate plants into their subsistence strategies in varying degrees. Starch and phytolith analysis provides archaeobotanists with valuable

information regarding human-plant interactions including diet (Boyd *et al.* 2008; Fox *et al.* 1996; Hart *et al.* 2003; Holst *et al.* 2007; Pearsall 2002; Perry *et al.* 2007; Piperno 2009; Piperno *et al.* 2000, 2009; Staller and Thompson 2002; Zarrillo and Kooyman 2006), processing techniques (Babot and Apella 2003; Barton 2007; Barton *et al.* 1998; Bruier 1976; Lamb and Loy 2005; Lui *et al.* 2010; Messner and Schindler 2010; Perry 2004), agricultural practices (Horrocks *et al.* 2008; Horrocks and Rechtman 2009; Piperno 2006), and trade (Boyd and Surette 2010; Kononenko *et al.* 2010). Variations in the size and morphology of these plant microfossils enable archaeobotanists to differentiate between plant groups (Bozarth 1987, 1993, 1999; Iriarte 2003; Lentfer 2009a, 2009b; Mulholland 1993; Pearsall *et al.* 2003). Starch and phytoliths have been shown to be quite durable surviving cooking and processing techniques, biological decay, and numerous soil conditions (Barton 2007; Haslam 2004; Henry *et al.* 2009; Lamb and Loy 2005; Langejans 2010; Messner and Schindler 2010). Plant microfossils can be recovered from numerous archaeological contexts including carbonized food residue (Boyd *et al.* 2006, 2008; Hart and Matson 2009; Hart *et al.* 2003; Staller and Thompson 2002; Thompson 2000; Thompson and Dogan 1987; Thompson *et al.* 1994; Zarrillo 2008), artifacts (Barton 2007; Lamb and Loy 2005; Langejans 2010; Lui *et al.* 2010; Zarrillo and Kooyman 2006), archaeological soils (Boyd 2002; Cabanes *et al.* 2010; Horrocks and Rechtman 2009; Horrocks and Nunn 2007; Li *et al.* 2010; Pearsall *et al.* 2003; Sullivan and Kealhofer 2004; Therin 1998), and dental calculus (Fox *et al.* 1996; Gobetz and Bozarth 2001; Hardy 2008; Nelson 1997; Wesolowski *et al.* 2010). In order to complete starch and phytolith analysis it is necessary to have an understanding of the types of starch granules and phytoliths produced by economic and wild plant species and

also how these particular plant microfossils react to human and non-human interactions. Although starch and phytolith analysis is a relatively new form of archaeobotanical research, this form of analysis can provide confident results pertaining to past human-plant interactions.

CHAPTER 7

METHODS

7.1 Sample Selection Criteria

The archaeological sites chosen for this thesis were based on several factors, including: the presence of ceramics containing food residue, well-defined stratigraphy, dated cultural remains, and amount of published background literature for the sites.

Since carbonized food residue analysis is integral to this research project, ceramics containing residue were a priority when selecting archaeological sites and samples. If ceramics were not present or did not contain residue, efforts were focused on stone tools that may have been used by Avonlea people to process plant materials. This is the case when considering the Gull Lake site (EaOd-1). In this instance, a well-defined Avonlea cultural level was identified based on diagnostic projectile points, but no ceramics were recovered. However, multiple stone tools were recovered from this layer, and these materials were analyzed. Other archaeological materials such as fire cracked rock (FCR) and soil samples were also collected from Avonlea components when available.

Although the presence of Avonlea ceramics can provide an estimated time-frame of the cultural materials, archaeological sites with well-defined stratigraphy and

radiocarbon dates were sought to ensure that samples would be obtained that would fall between AD 300-900, which is the time-frame addressed in this thesis. All of the sites included in this project, with the exception of the Broadview site (EbMp-6), contained well-defined cultural layers as well as a radiocarbon chronology. In addition to a radiocarbon chronology, the amount of background material published on the archaeological sites was also a major consideration. Published interpretations of site activities and archaeological materials recovered aided in the interpretation of data gathered from the archaeological residue obtained from these archaeological sites. Although not a major component of this thesis, non-Avonlea ceramics were obtained from multi-component Avonlea sites. These were collected along with the Avonlea ceramics in order to identify possible changes in diet over time at the same site.

7.2 Plant Microfossil Analysis of Archaeological Materials and Features

Plant microfossils, more specifically starch grains and phytoliths, were chosen to identify plant use during the Avonlea complex for a number of reasons. First of all, many researchers have demonstrated that starch and phytoliths provide insight on plant use and consumption of past peoples (e.g., Boyd and Surette 2010; Boyd *et al.* 2006, 2008). Secondly, these plant microfossils are more favorable than plant macroremains due to their ability to survive in a wide variety of depositional contexts; the sheer abundance of microfossils produced by plants, and established identification criteria that can be used to build interpretations regarding palaeodiet. Plant macrofossils have been shown to provide useful information regarding the presence of domesticated plants in past cultures (Adair

1988). However, this form of analysis is severely limited by the inability of plant macrofossils to preserve through time other than when carbonized or in areas of unique preservation. In contrast, starch and phytoliths are quite durable, and may be recovered from a wide variety of archaeological contexts. (Barton 2007; Boyd and Surette 2010; Boyd *et al.* 2006, 2008; Hardy *et al.* 2009; Hart *et al.* 2003; Haslam 2004; Pearsall *et al.* 2003; Staller and Thompson 2002; Wesolowski *et al.* 2010; Zarrillo and Kooyman 2006). These microfossils have been documented in the coprolites of extinct dinosaur species (Prasad *et al.* 2005), to the earliest hominid stone tools (Mercador 2009). The ability of starch and phytoliths to survive a wide variety of depositional conditions is valuable because it increases the chances of finding these plant microfossils, subsequently allowing a wider assemblage of the Avonlea complex to be studied. The variety of sources for archaeological plant microfossils allows interpretations to be drawn from many components of past life-ways including processing stages (Zarrillo and Kooyman 2006), cooking and consumption (Messner and Schindler 2010), as well as storage and cultivation (Duncan *et al.* 2009; Horrocks *et al.* 2008). Starch and phytoliths are also produced in large quantities by many plants that were targeted by humans for consumption. Not only are they produced in plants in vast quantities, but variations between and within plant species allow for the identification of important plant types based on starch and phytolith recoveries (Bozarth 1987, 1993; Holst *et al.* 2007; Piperno *et al.* 2009).

Microfossils from multiple behavioral contexts were employed during this research to identify the plant component of the Avonlea palaeodiet including carbonized food residues, stone tool analysis, and soil analysis. Not limiting the research to one form

of analysis increases the chances of finding archaeological plant microfossils but also provides a more holistic view of the role of plants in subsistence strategies. For instance, if the site's occupants were not cooking specific plants, the microfossils produced by these plants would be absent from carbonized food residue analysis. However, if carbonized food residue is coupled with the analysis of particular processing tools that this same group was using, this data would be captured. Using multiple techniques may allow researchers to identify not only what plants people were cooking, but also how they were processing and preparing these plants, and what plants were naturally present at the archaeological site or present at the archaeological site due to anthropogenic means. Employing this strategy was useful for this thesis and is recommended by the researcher for future endeavors in this field.

7.3 Basic Laboratory Protocols

For this research it is important to note that non-powdered gloves were used in the handling of ceramic and stones samples as well as lab materials. Only new pipettes, centrifuge tubes, and other lab materials were used and between all steps in the processing sequence these materials were replaced in order to eliminate any sources of contamination within and between samples. Although the processing of plant materials was also completed in a separate location in the lab, efforts were made to reduce the chances of contamination. This was completed by thoroughly washing lab materials that were used in the processing of plant materials, the lab area used for processing these materials, and the storing of comparative plant materials in a separate location from

archaeological samples. At no point were comparative phytoliths present or modern maize specimens present in the lab. After washing of lab materials was completed, these materials were placed in the sonicator to further remove any remaining plant materials.

7.4 Carbonized Food Residue Analysis

As with other types of residue, carbonized residue analysis involves the removal, processing, and analysis of this material for plant microfossils. Carbonized residue is removed from ceramics with the aid of a clean dental pick and performed under a microscope (Boyd and Surette 2010; Boyd *et al.* 2006, 2008; Hart *et al.* 2003; Staller and Thompson 2002; Surette 2008). The removed sample is then weighed, labeled and stored in microcentrifuge containers for further analysis. The next phase in this analysis is the removal of starch grains prior to acid digestion. This is completed by treating the carbonized food residue with 5ml of hydrogen peroxide (H₂O₂). Hydrogen peroxide is used because it disaggregates starch from other carbonized materials (Zarrillo 2008); this is necessary to separate starch granules held within carbonized food residue. The application of hydrogen peroxide in the separation of starch grains from carbonized food residue has previously been completed by Zarrillo (2008) for the analysis of ceramic residue from the Lockport Site (EaLf-1, 2). In order to reduce the possibility of starch destruction during processing, 6% hydrogen peroxide solution was used instead of acid treatment. Samples were left in hydrogen peroxide for 24 hrs. Subsequently, the hydrogen peroxide was removed from the sample through the addition of water. The sample was then centrifuged and the supernatant was removed through the use of a

pipette. This step was repeated twice to ensure the complete removal of the hydrogen peroxide. The next step involved the sieving of the sample through 118 μ m nitrex cloth to filter starch grains from the remaining carbonized materials. It is possible that phytoliths, pollen, and other microfossils may also pass through the 118 μ m nitrex cloth. These other types of plant microfossils are also useful and were noted when analyzing starch samples. The starch sample are then placed in a microcentrifuge tube and filled with reagent alcohol to preserve the starch grains until mounted on slides. All materials that do not pass through the 118 μ m nitrex cloth, represent the phytolith sample from the carbonized food residue that are further trapped within this carbonized material. After the starch grains were removed, the residue was then digested in a heated nitric acid (30%) bath for a period of 12-24 hours (Boyd and Surette 2010; Boyd *et al.* 2006, 2008; Hart *et al.* 2003; Staller and Thompson 2002; Surette 2008). Periodically, nitric acid was added during this stage to maintain a reaction within the sample. Following this period, the nitric acid was removed with new disposable pipettes and the plant microfossils were then mounted onto slides. Comparative samples were mounted in both 'Entellen New' and thiodiethanol. This enabled comparison of refractive indexes of starch grains. Archaeological samples were mounted in solely in 'Entellen New.' 'Entellen New' was selected in order to limit the movement of plant microfossils during the analysis.

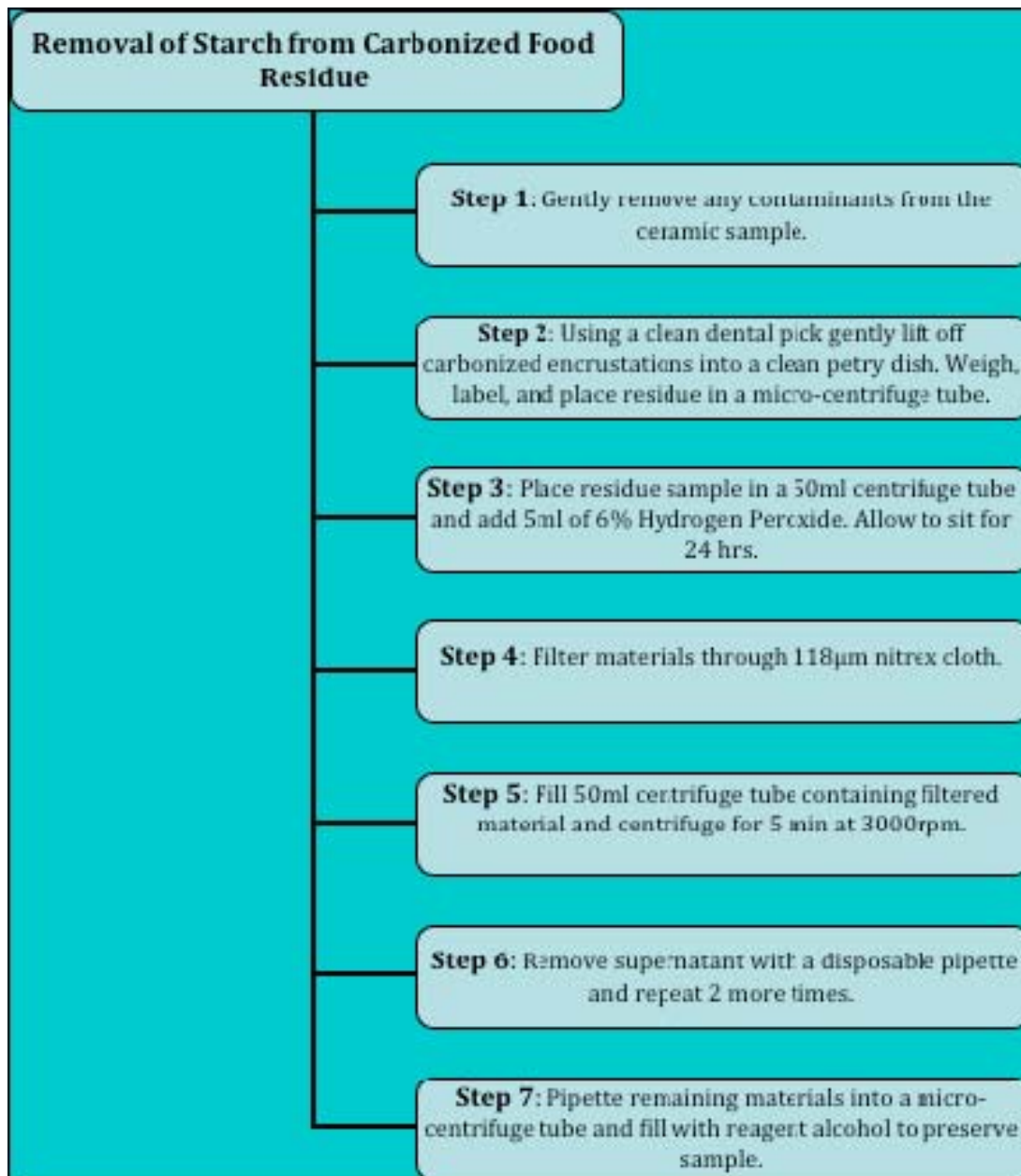


Fig. 7.1 Removal of Starch from Carbonized Food Residue.

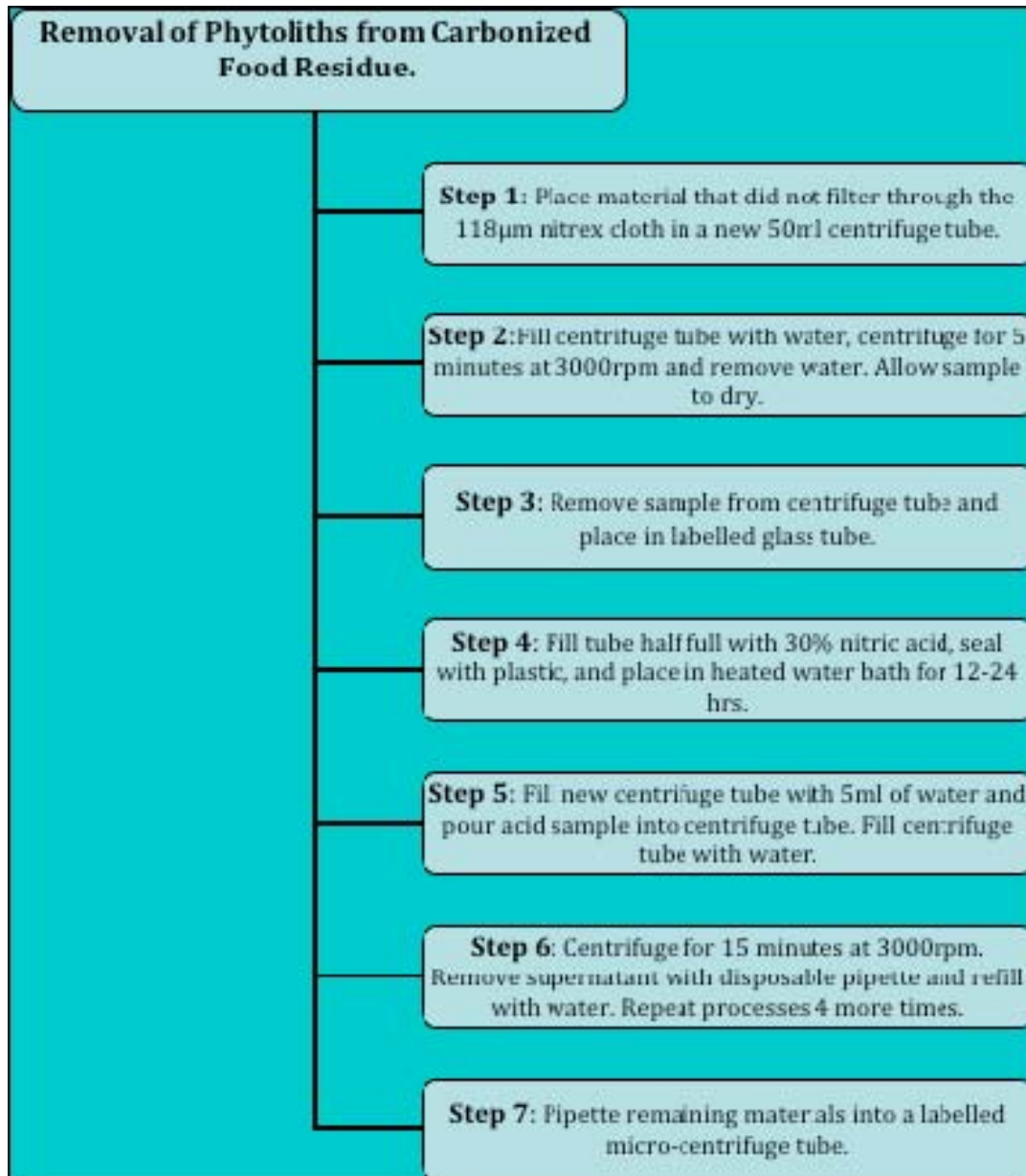


Fig. 7.2 Removal of Phytoliths from Carbonized Food Residue.

There are alternative techniques that are employed in the processing of carbonized food residue. Methods by Zarrillo (2008) and Zarrillo *et al.* (2008) involve the use of heavy liquid separation of starch and phytoliths from carbonized food residue. Although this technique yields results, it is time consuming and expensive to complete. Difficulties

in capturing starch granules due to inadequate specific gravity of heavy liquids used for this analysis have also been noted (Zarrillo 2008). Rather than using heavy liquid separation, the methods used in this thesis are less expensive and time consuming, and also increases the amount of plant microfossils that may be analyzed by filtering and digesting carbonized samples in acid. This method also ensures that the majority of the starch grains in the carbonized food residue sample are removed prior to digestion in acid. This is important considering plant identifications based on starch grains may be limited if the starch grains have been altered beyond recognition by the nitric acid.

7.5 AMS Radiocarbon Dating of Organic Food Residues

Other than analyzing plant microfossils, it is possible to gain further information from ceramic food residue. Carbonized food residue is may be AMS radiocarbon dated (Boyd *et al.* 2008; Staller and Thompson 2002). This is useful when residue amounts are high (>30mg), but when the residue amounts are low, priority should be to use the sample for microfossil analysis rather than dating. This is because other organic materials within the occupation layer may potentially be used to establish chronological control. Residue samples from the Miniota site (EaMg-12) were large enough to facilitate AMS dating and were sent to Beta Analytic for analysis. This form of analysis has been noted to be affected by the Freshwater effect. Fischer and Heinemeier (2003) note that derived dates from food residue may be older as a result of the Freshwater reservoir effect. This is the result of cooking fish and mollusks in ceramics, which in turn affects ^{14}C dates.

Furthermore, Fischer and Heinemeier (2003) suggest that dates derived from ceramic food residue may need to be treated with caution.

7.6 Extracting Food Residue from Stone Tools and Fire-Cracked Rock (FCR)

For this thesis, three different sub-samples of residue were removed from stone tools and fire-cracked rock (FCR). The method that I employed was modified from several sources (Pearsall *et al.* 2004; Perry 2004; Zarrillo and Kooyman 2006). The goal of residue analysis has been described by Loy (1994) as the practice of extracting the maximum amount of data from small samples. Increasing the level of extraction in stone tool residue analysis essentially improves the likelihood of extracting more data from stone artifacts.

The first two stages of this method consisted of using a dry brush to gently remove any adhering residue followed by using a wet brush to further remove any materials from the stone tool. For this analysis, the entire artifact is brushed to increase the total amount of materials that may be analyzed. Areas that exhibit wear patterns or are likely candidates to contain trapped plant microfossils obviously receive more attention. Materials removed during these first two stages are collected in 50 ml centrifuge tubes, the tubes are then filled with water, centrifuged for a period of 5 minutes at 3000 rpm, and allowed to dry after the excess water is removed with a pipette. After this was completed, the stone tools were placed in a Ziploc bag with water to be placed in a sonicator for 30 to 60 minutes to remove any remaining material. The artifact

is placed in a Ziploc bag filled with enough water to submerge the artifact in an effort to capture residue as it is removed through sonication. Once sonication is completed, the residue was poured into a 50 ml centrifuge tube, centrifuged, and allowed to dry after the supernatant was removed. Removing the residue in three stages allows for the identification of any contamination that may be present on stone tool. Presumably, contaminating plant microfossils would be located on the surface and not likely penetrate the micro-fissures contained in stone tools. Hence, removing the surface materials separately may increase confidence regarding the antiquity of the archaeological samples.

After the dry brush, wet brush, and sonicated samples were allowed to dry, they were then weighed to provide a total value for materials recovered from the stone artifacts. After the residue is removed from the stone artifacts, heavy liquid separation involving sodium metatungstate was used to separate starch and phytoliths from unwanted materials. A total of 5ml of sodium metatungstate solution with a specific gravity of 1.7g/L is added to the residue samples. These samples are then mixed to increase the amount of residue that is in contact with the heavy liquid. The samples are centrifuged for a period of 10 minutes at 3000 rpm. After centrifuging, the supernatant (which contains the starch) is collected with a pipette and placed in a new centrifuge tube. This process is completed again to further increase starch yields. The materials that were residing at the bottom of the tube contain the phytoliths that need to be further separated. This separation is completed by adding 5ml of sodium metatungstate with a specific gravity of 2.3g/L. The procedure used to remove starch is then followed to allow the separation of phytoliths from the artifact residue. The starch and phytolith centrifuge tubes are filled with water and centrifuged for 5 minutes at 3000 rpm. The supernatant is

then removed from the tubes with a pipette and is filled and centrifuged again two more times to fully remove the sodium metatungstate. Once the sodium metatungstate was removed, starch and phytolith samples were then mounted on slides for examination.

Several researchers only analyze a small portion of the stone or wood artifact that is most likely to contain residue (Barton 2007). Although this does yield results, it also limits the amount of materials that may be analyzed. This technique is useful in areas where it is likely that a lot of plants have been intensively processed with stone or wooden implements. In these cases only analyzing a small portion of the stone tool is acceptable due to the high amounts of starch or other plant microfossils that are likely present. However, in situations where the amount of plant processing is questionable or even unlikely, increasing the sample area that will be analyzed greatly benefits the amount of material that may be analyzed. Another variation arises in the removal of residues from archaeological materials. During an analysis of *Cucurbita* containers in South America, Duncan *et al.* (2009) first completed a sonicated stage to remove adhering residue followed by a wet brush stage. However, as outlined above, I opted to extract three separate sub-samples in order to address possible contamination.

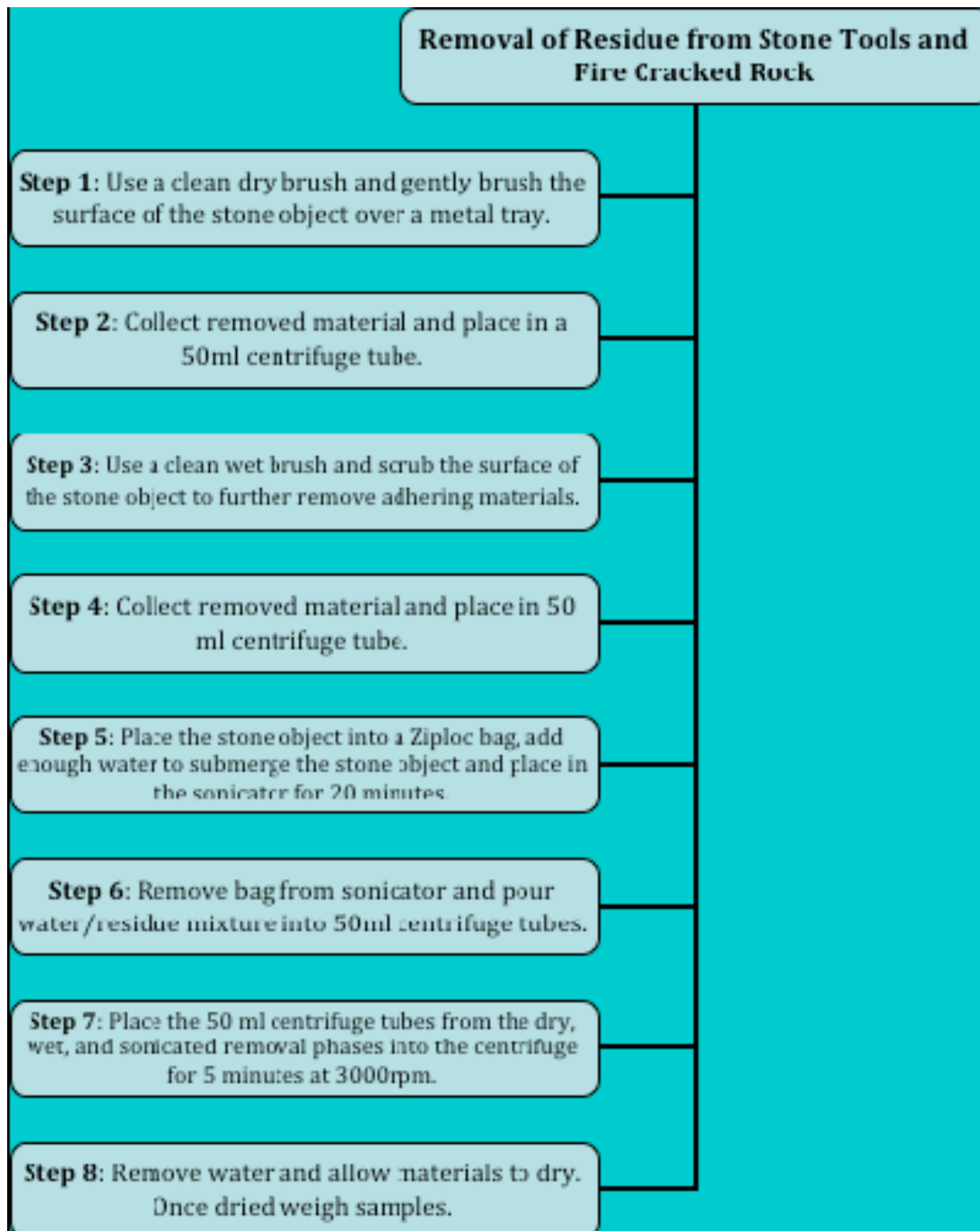


Fig. 7.3 Removal of Residue from Stone tools and Fire Cracked Rock.

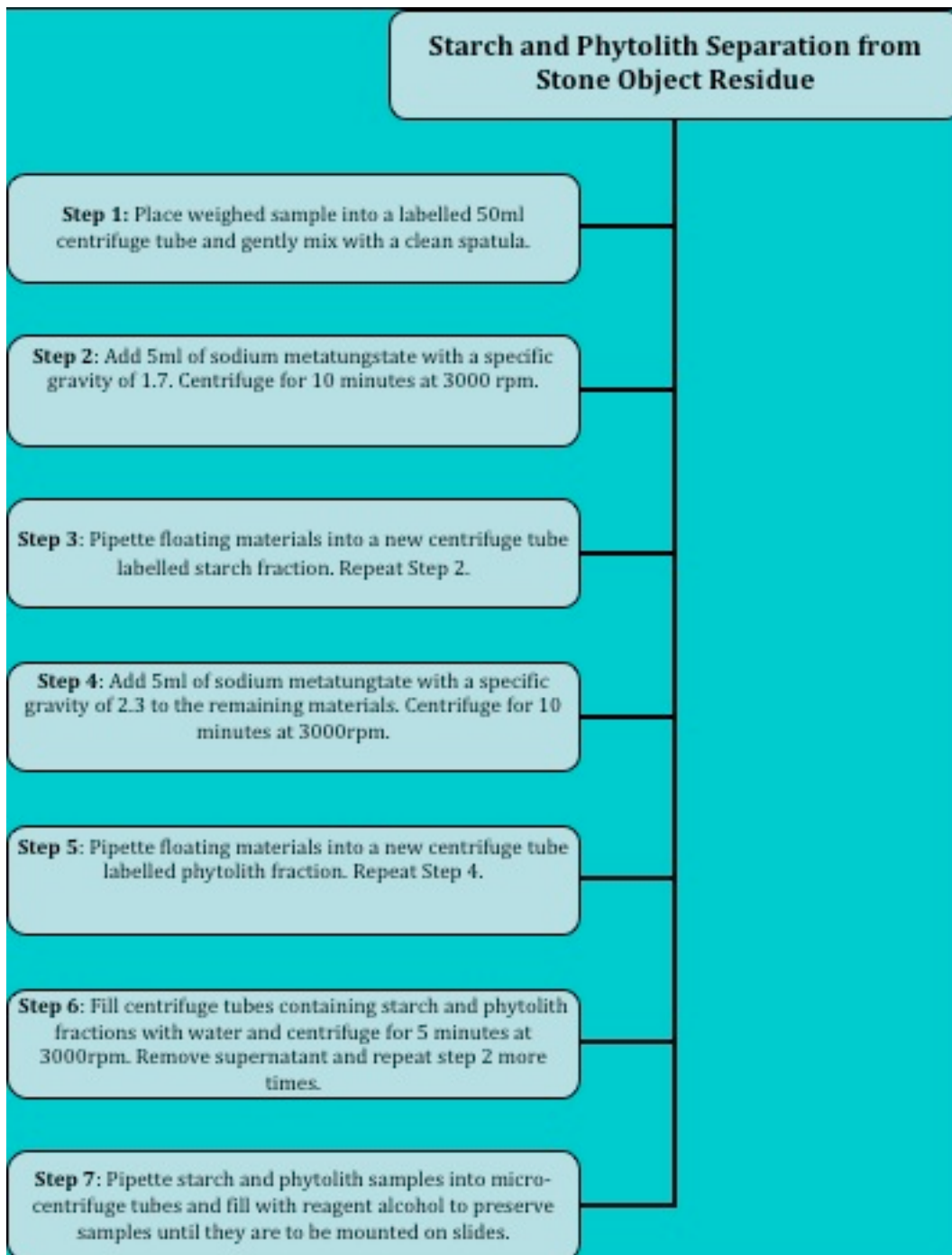


Fig. 7.4 Starch and Phytolith Separation from Stone Object Residue.

7.7 Archaeological Soil Analysis

The analysis of archaeological sediment for microfossils has been completed by numerous researchers with similar methodological approaches (Boyd 2000; Coil *et al.* 2004; Horrocks 2005; Horrocks *et al.* 2004; Lentfer *et al.* 2003). This process involves deflocculation to remove heavy particles, followed by density separation, use of acids to digest carbonates, and the removal of phytoliths and starch grains (Horrocks 2005). This method is a generally accepted and provides both reliable and time efficient removal of plant microfossils (Horrocks 2005).

7.8 Mounting of Starch and Phytolith Samples

Plant microfossils removed from archaeological materials and features were mounted on slides in 'Entellen New' mounting medium. This process differs slightly for starch samples. The differences are due to the need to document damaged or gelatinized starch grains through the aid of archaeological stains such as 'trypan blue' or 'Congo red.' When mounting starch samples, a few drops of the starch sample are placed on a slide with a few drops of an archaeological stain. The stain and the starch sample are mixed and spread on the slide with the tip of the pipette and then allowed to dry. After the stained starch sample has dried, several drops of 'Entellen New' mounting medium are placed on the slide followed by a slide cover to seal the sample. In some instances it was also necessary to remove calcium carbonates that were found in high abundance in the starch and phytolith samples from stone tools. These were removed by placing several

drops of 1% hydrochloric acid (HCl) on the samples after they were spread out and allowed to dry on the slide. The drops of hydrochloric acid (HCl) were spread over the sample. This concentration of acid was strong enough to digest calcium carbonate without damaging starch grains. After the acid was allowed to dry, the mounting medium was added to phytolith samples while the starch samples were rehydrated with ethyl alcohol to allow the archaeological stains to be added.

This form of mounting medium is a dry mount and has one major limitation. 'Entellen New' is limited by the inability to allow researchers to move or rotate plant microfossils. However, since the number of archaeological plant microfossils on a slide may be low, it was deemed necessary to ensure that these microfossils would be held and preserved for future use and identification. Using wet mount mediums do allow researchers to rotate microfossils for further identification, but these mounts do not preserve as well and it is possible that some plant microfossils may become 'lost' since they are free to move. Using a dry mount also is less time consuming and allows for multiple storing techniques that do not hinder the archaeological specimens on the slide.

7.9 Identification of Plant Microfossils (Phytoliths and Starch Grains)

While analyzing archaeological samples for plant microfossils, counts of both phytoliths and starch grains were completed. All microfossil slides were analyzed with an Olympus Differential Interference Contrast (DIC) microscope (BX51) and photographed with an Olympus digital camera (DP71). For phytoliths, 250 phytoliths were counted and

identified for each sample to provide a representation of the residue. Phytoliths were identified and compared to reference material by Brown (1984) and Twiss *et al.* (1969). If the diagnostic types were not identified during the 250 count, the remaining sample was scanned for this diagnostic type until the sample was exhausted. Starch grains were viewed under both plane and crossed polarized light. Furthermore, all undamaged starch was counted and identified while gelatinized clusters and damaged grains were estimated. In addition to phytoliths, pollen, and diatoms were also identified if present.

7.9.1 Maize (*Zea mays* ssp. *mays*) Phytoliths

Over the past several decades, a considerable amount of effort has been made by scholars to identify phytoliths characteristic of maize (Pearsall 2000, Pearsall *et al.* 2003). Previous techniques were based on the analysis of cross-shaped phytoliths (Iriarte 2003; Piperno 2006). Cross-shaped phytoliths are produced in the leaves of maize and are characterized by a width of 16 μm or more (Piperno 2006). Research by Pearsall *et al.* (2003) has determined that maize can also be identified by several rondel phytolith types from the cob area of the plant (Fig. 7.5). Three important rondel phytolith morphotypes are: 'wavy-top', 'ruffle-top', and 'half-decorated' (Pearsall *et al.* 2003). The wavy-top variety is the most useful phytolith because it is only found in maize (Pearsall *et al.* 2003). The use of wavy-top rondels has been employed by several researchers since its discovery (Bozarth 1993; Boyd and Surette 2010; Boyd *et al.* 2006, 2008; McKey *et al.* 2010; Pearsall *et al.* 2003, 2004). This form of rondel phytolith has been identified in archaeological sites from South America to the Great Plains (Bozarth 1993; Hart *et al.*

2003; Iriarte *et al.* 2004; Staller and Thompson 2002). The wavy-top rondel was first identified as a diagnostic form through research completed by Bozarth (1993). This research involved the analysis of 40 native grasses (see Appendix) of the Great Plains and 18 domesticated plants. After comparative analysis was completed, Bozarth (1993) reported that wavy-top rondels were non-existent in the native grasses examined. Furthermore, recent comparative analysis by Surette (2008) suggests that the application of the wavy-top rondel as an indicator of maize can be applied in Boreal Forest and prairie contexts. This included phytolith analysis of 38 grass species (see Appendix) native to both the Prairies and Boreal Forest. Of these grass species Surette (2008) reported no rondel phytoliths that mimicked forms commonly found in maize. Both cross and rondel identification criteria were used in this thesis due to their success in other studies. It is important to note that many of the grasses that are dominant in this study area (see Chapter 2) were analyzed in both of these studies (Bozarth 1993; Surette 2008), thus limiting the potential for false-positive identifications of maize rondel phytoliths.

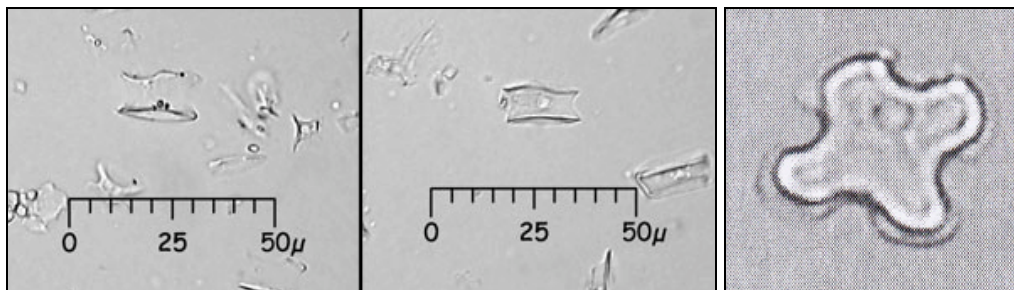


Fig 7.5 Photomicrographs of diagnostic maize phytoliths. Wavy-top rondels (Left and Middle) (Pearsall *et al.* 2003) produced in the glumes of maize cobs and an example of a variant 1 maize cross (Right) (Iriarte *et al.* 2004).

7.9.2 Maize (*Zea mays* ssp. *mays*) Starch Grains

Maize produces an enormous amount of starch that is stored in the kernels. Diagnostic maize starch grains are around 20µm in size, contain up to 6 compacted sides (facets), and exhibit a Y or X fissure and a 90° extinction cross (Fig. 7.6). These starch grains can be confidently used to identify *Zea mays* due to the lack of similar starch grains produced by wild or domesticated plant species observed in the 154 plant samples in the Lakehead University starch database.

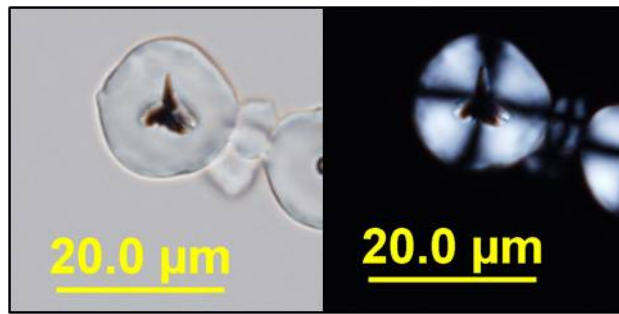


Fig. 7.6 Photomicrographs of diagnostic maize starch grains under cross-polarized light (Right) and polarized light (Left).

7.9.3 Maize (*Zea mays* ssp. *mays*) Pollen

Although pollen was not a major criteria searched for during this research, pollen that was present in the residues that could also be identified were incorporated into this study. Samples identified as maize pollen were compared with pollen guidelines by McAndrews (1973). McAndrews (1973) describes pollen as a large circular monoporate pollen grain averaging 75-95µm (see Fig. 7.7).



Fig. 7.7 Scanning Electron Micrographic image of *Zea mays* ssp. *mays* pollen (from www.biologie.uni-regensburg.de).

7.9.4 Squash (*Cucurbita*) and Bean (*Phaseolus*) Phytoliths

The identification of squash and bean starch is primarily based on the research of Bozarth (1987, 1990). By analyzing present-day squash and bean phytoliths, Bozarth (1987, 1990) was able to identify phytolith indicators for these species. Comparative samples for squash included multiple types from *C. pepo* and *C. maxima* squash varieties. Bozarth (1987) also analyzed 36 plants commonly occurring Central Plains for comparison. After analysis of the rind and stem portion of squash varieties, Bozarth (1987) discovered large scalloped shaped phytoliths that were only produced by squash varieties. As for bean varieties, through analysis of Kentucky Wonder Beans (*Phaseolus vulgaris*), Shield-figured beans (*Phaseolus vulgaris*), and *P. polystachios* Bozarth (1990) discovered these varieties produced numerous long hook-shaped phytoliths (Fig. 7.8). Analysis of 113 reference plant samples, revealed that while a few plants produce hook-

shaped phytoliths, these varieties are smaller than *Phaseolus* types (Bozarth 1990). Bozarth (1987, 1990) compared these phytolith indicators of bean and squash with archaeological materials and found that both archaeological and present day bean and squash can be identified by hooked shaped (beans) and scalloped (squash) phytoliths.



Fig. 7.8 Photomicrographs examples of silicified hook phytoliths (Left) and scalloped-shaped squash phytoliths (Right) (Missouri Phytolith Database 2011).

7.9.5 Bean (*Phaseolus*) Starch Grains

Common bean *Phaseolus vulgaris* and *Phaseolus lunatis* frequently produce elongated starch grains that range from 25 to 40 μm in size. A common feature of bean starch grains is that the extinction cross slightly touches. These starch grains often exhibit grain cracking along the medial line of the starch grain and may appear in semi-compound varieties (Fig. 7.9). Until recently the use of bean starch and other starch types in archaeological residue analysis has been somewhat limited in North America due to an absence of extensive comparative starch analysis. This is a primary motivator for the completion of a detailed comparative starch analysis for this research to increase the amount of plant types that can be identified in the archaeological samples from the

Northern Plains. After the analysis and comparison of comparative plant samples, *Phaseolus* starch types has been shown to provide confident identifications. Possible confusers of this type of starch are significantly smaller and do not produce semi-compound that are produced in *Phaseolus* varieties.

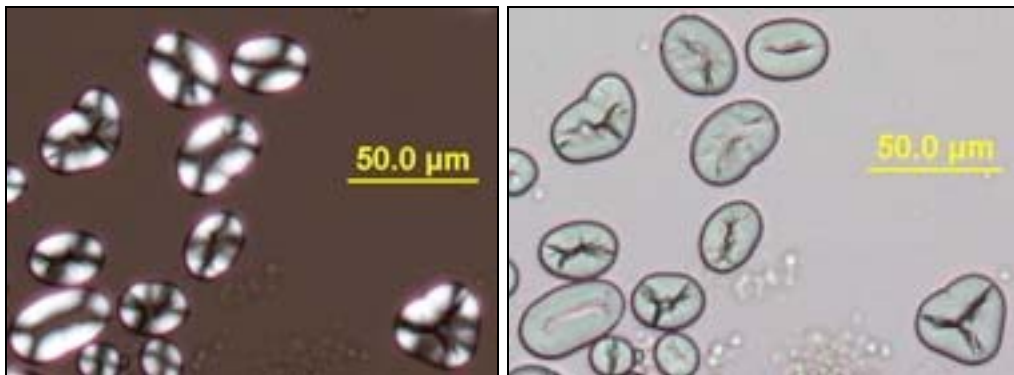


Fig. 7.9 Photomicrographs of elongated bean (*Phaseolus vulgaris*) Starch Types under cross-polarized light (Left) and polarized light (Right).

7.9.6 Wild Rice (*Zizania* sp.)

Identifications of *Zizania* were based upon criteria developed by Surette (2008) and Boyd and Surette (2010) for rondel phytoliths. These rondel phytoliths contain multiple spikes on the top of the rondel with indentations on the base (Fig. 7.10).

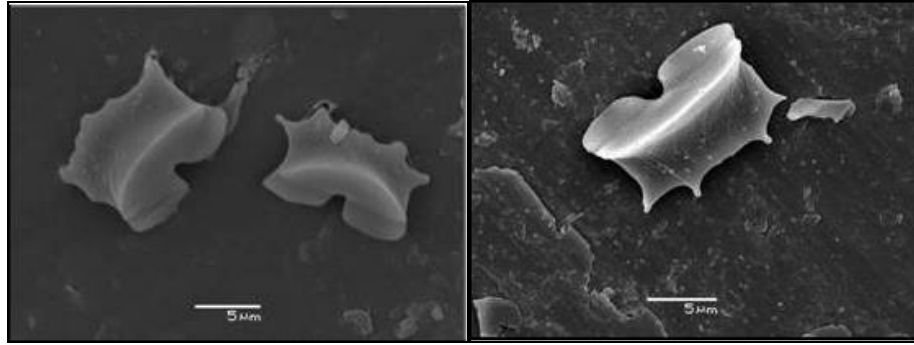


Fig. 7.10 Comparative Scanning Electron Microscope (SEM) examples of *Zizania* sp. rondel phytoliths (D, H) (Photographed by Surette 2008).

7.9.7 Damaged Starch

Since starch grains were to be analyzed from carbonized residue and stone tools it was likely that grains may be damaged from processing (e.g., grinding or cooking) in antiquity. Archaeological stains such as ‘trypan blue’ and ‘Congo red’ have been documented to aid in the identification of damaged starch. In this thesis both stains were applied to an archaeological sample that had already been analyzed and yielded positive results for domesticated starch. It was determined that there is very little difference between ‘Congo red’ and ‘trypan blue’ other than color.

7.10 Comparative Starch Reference Key

In order to properly identify ancient plant microfossils recovered from archaeological materials from particular areas, a comparative collection from the specific geographic region is crucial. Building a comparative collection validates identification criteria, provides the possibility to identify undocumented plant microfossils, and also adds to the background literature for further research projects. For the completion of this research a comparative starch key was developed consisting of 45 plant types (Table 7.1) including both domesticated and wild plants.

Table 7.1

List of Comparative Plants Analyzed for Starch Reference Key

Family	Scientific Name	Common Name	Portion	Location
Aceraceae	<i>Acer negundo</i>	Manitoba maple	Seed	Living Prairie Museum
Apiaceae	<i>Heracleum lanatum</i>	Cow parsnip	Rhizome	Lakehead Herbarium
Apiaceae	<i>Lomatium foeniculaceum</i>	Desert biscuitroot	Root	Lakehead Herbarium
Apiaceae	<i>Osmorhiza longistylis</i>	Smooth sweet-cicely	Rhizome	Whitefish Lake, ON
Apiaceae	<i>Perideridia gairdneri</i>	Yampa	Tuber	Lakehead Herbarium
Araceae	<i>Peltandra virginica</i>	Green arrow arum	Tuber	Lakehead Herbarium
Araceae	<i>Symplocarpus foetidus</i>	Skunk cabbage	Rhizome	Thunder Bay Area
Betulaceae	<i>Corylus americana</i>	American hazlenut	Fruit/Seed	Living Prairie Museum
Betulaceae	<i>Corylus cornuta</i>	Beaked hazlenut	Fruit/Seed	Thunder Bay Area
Caprifoliaceae	<i>Viburnum opulus</i>	High brush cranberry	Fruit/Seed	Thunder Bay Area
Cucurbitaceae	<i>Cucurbita pepo</i>	Acorn squash	Fruit	Locally Purchased
Cucurbitaceae	<i>Cucurbita maxima</i>	Buttercup squash	Fruit	Locally Purchased
Cucurbitaceae	<i>Cucurbita moschata</i>	Butternut squash	Fruit	Locally Purchased
Cucurbitaceae	<i>Cucurbita maxima</i>	Hubbard squash	Fruit	Locally Purchased
Cucurbitaceae	<i>Cucurbita maxima</i>	Kabosha squash	Fruit	Locally Purchased
Cucurbitaceae	<i>Cucurbita pepo</i>	Pumpkin	Fruit	Locally Purchased
Cucurbitaceae	<i>Cucurbita pepo</i>	Zucchini squash	Fruit	Locally Purchased
Cucurbitaceae	<i>Lagenaria</i> sp.	Common gourd	Fruit	Locally Purchased
Fabaceae	<i>Phaseolus vulgaris</i>	Black turtle bean	Seed	Locally Purchased
Fabaceae	<i>Phaseolus vulgaris</i>	Green bean	Seed	Locally Purchased
Fabaceae	<i>Phaseolus lunatum</i>	Lima bean	Seed	Locally Purchased
Fabaceae	<i>Phaseolus vulgaris</i>	Pinto bean	Seed	Locally Purchased

Fabaceae	<i>Phaseolus vulgaris</i>	Red kidney bean	Seed	Locally Purchased
Fabaceae	<i>Phaseolus vulgaris</i>	Romano bean	Seed	Locally Purchased
Fabaceae	<i>Phaseolus vulgaris</i>	White navy bean	Seed	Locally Purchased
Fabaceae	<i>Phaseolus vulgaris</i>	Yellow eyed bean	Seed	Locally Purchased
Fabaceae	<i>Psoralea esculenta</i>	Indian breadroot	Tuber	Living Prairie Museum
Fagaceae	<i>Quercus macrocarpa</i>	Bur oak	Fruit/Seed	Living Prairie Museum
Liliaceae	<i>Lilium philidelphicum</i>	Western lily	Tuber	Lakehead Herbarium
Marantaceae	<i>Maranta arundinacea</i>	Arrowroot	Rhizome	Lakehead Herbarium
Nymphaeaceae	<i>Nymphaea odorata odorata</i>	White Pond lily	Tuber	Thunder Bay Area
Nymphaeaceae	<i>Nymphaea odorata</i> ssp. <i>tuberosa</i>	White Pond lily	Tuber	Thunder Bay Area
Orchidaceae	<i>Platanthera dilata</i>	Tall white bog-orchid	Rhizome	Lakehead Herbarium
Poaceae	<i>Hordeum jubatum</i>	Foxtail barley	Seed	Lakehead Herbarium
		Broad-leaved spring beauty	Tuber	Thunder Bay Area
Portulacaceae	<i>Claytonia caroliniana</i>			
Ranunculaceae	<i>Caltha palustris</i>	Marsh marigold	Rhizome	Thunder Bay Area
Rosaceae	<i>Amelanchier alnifolia</i>	Saskatoon	Fruit/Seed	Living Prairie Museum
Rosaceae	<i>Prunus nigra</i>	Canada plum	Fruit/Seed	Whitefish Lake
Rosaceae	<i>Prunus pensylvanica</i>	Pincherry	Fruit/Seed	Living Prairie Museum
Rosaceae	<i>Prunus virginiana</i>	Chokecherry	Fruit/Seed	Living Prairie Museum
Sparganiaceae	<i>Sparangium eurycarpum</i>	Giant bur reed	Rhizome	Thunder Bay Area
Typhaceae	<i>Typha latifolia</i>	Cattail	Rhizome	Thunder Bay Area
Poaceae	<i>Zizania aquatica</i>	Southern wild rice	Seed	Locally Purchased
Poaceae	<i>Zizania palustris</i>	Northern wild rice	Seed	Locally Purchased

7.10.1 Selection and Collection of Comparative Starch Samples

Domesticated plant species that were incorporated into this starch reference key were chosen based on how little research had been completed on each type. For example, common bean can be identified through the use of silicified hook phytoliths and also produce distinct starch grains but not enough research has been completed to allow positive identifications of bean to be made based on starch alone. Native plants chosen for this study were based on several factors including: availability, documented use, and presence of starch. Obviously, if a plant is unavailable due to environmental conditions or simply unavailable, starch analysis is difficult to complete. Therefore plants that could be collected or obtained through herbariums were preferred.

Presence of documented accounts of plant use by aboriginal peoples on the Great Plains was another major consideration for selection. Publications summarizing traditional plant use in the study area (Shay 1980) were vital in selecting plants that may have been consumed during Avonlea times. Shay (1980) not only includes the plants that were traditionally used in Manitoba, but also includes the part of the plant that was consumed and the amount of documented uses of these plants (Table 7.2).

Native legume and grass species of the Northern Plains, may possibly produce 'confuser' starches to maize and beans. However, of the commonly consumed wild plants of Manitoba, Shay (1980) noted only one species of legume (common pea) that is exotic to the Northern Plains, therefore limiting its availability during Avonlea times. As for grasses, these were not incorporated into this study due to their inability to generate

starch grains large enough to create misidentifications of maize. In addition, very few ethnographic accounts of grass use have been recorded on the Northern Plains, further limiting the potential of Northern Plains grasses to cause any confusion with Maize.

Finally, since starch was the main target for analysis, plants that produced adequate amounts of starch grains were preferred. This would allow sufficient numbers to facilitate a complete analysis of starch grains produced by certain plant taxa.

Table 7.2
Common Wild Edible Plants of Manitoba

Family Name		Plant Part Used									Number of Uses
Scientific	Common	Number of Species	Roots and Tubers	Sap	Greens	Flowers	Fruit	Seeds	Nuts		
Aceraceae	Maple	1	0	1	0	0	0	0	0	1	
Alismataceae	Water-plantain	3	3	0	0	0	0	0	0	3	
Araceae	Arum, Wild Calla	1	1	0	0	0	0	1	0	2	
Araliaceae	Sarsaparilla	2	2	0	2	0	0	0	0	4	
Ascepiadacea	Milkweed	5	1	0	5	5	0	5	0	16	
Balsaminaceae	Touch-me-not	1	0	0	1	0	0	0	0	1	
Betulaceae	Birch	3	0	1	0	0	0	0	2	3	
Cannabinaceae	Hemp	1	0	0	1	0	0	0	0	1	
Caprifoliaceae	Honeysuckle	5	0	0	0	1	5	0	0	6	
Caryophyllaceae	Pink	4	0	0	4	0	0	0	0	4	
Chenopodiaceae	Goosefoot	7	0	0	7	0	0	5	0	12	

Compositae	Aster	14	4	0	11	3	0	2	0	20
Cornaceae	Dogwood	2	0	0	0	0	2	0	0	2
Cyperaceae	Sedge	8	8	0	8	8	0	8	0	32
Eleagnaceae	Silverberry	3	0	0	0	0	3	0	0	3
Empetraceae	Crowberry	1	0	0	0	0	1	0	0	1
Ericaceae	Blueberry	8	0	0	1	0	8	0	0	9
Fagaceae	Beech	1	0	0	0	0	0	0	1	1
Gramineae	Grass	2	1	0	1	0	0	1	0	3
Hippuridaceae	Mare's Tail	1	0	0	1	0	0	0	0	1
Juncaginaceae	Arrow-grass	1	0	0	0	0	0	1	0	1
Labiatae	Mint	3	3	0	0	0	0	0	0	3
Leguminosae	Pulse, Pea	7	3	0	0	0	1	3	0	7
Liliaceae	Lily	5	5	0	4	0	0	0	0	9
Linaceae	Flax	2	0	0	0	0	0	2	0	2
Myricaceae	Sweet Gale	1	0	0	0	0	0	1	0	1
Nymphaeaceae	Water-lily	1	1	0	0	0	0	1	0	2
Oleaceae	Olive, Ash	1	0	0	0	0	0	0	0	1
Onagraceae	Evening Primrose	1	1	0	1	0	0	0	0	2
Oxalidaceae	Wood-Sorrel	2	0	0	2	0	0	0	0	2
Polygonaceae	Buckwheat	5	2	0	5	0	0	5	0	12
Polypodiaceae	Fern	2	1	0	2	0	0	0	0	3
Ranunculaceae	Crowfoot, Buttercup	1	0	0	1	1	0	0	0	2
Rosaceae	Rose	18	3	0	0	4	15	0	0	22
Rubiaceae	Madder, Bedstraw	3	0	0	3	0	0	0	0	3
Saxifragaceae	Saxifrage	6	0	0	0	0	6	0	0	6
Solanaceae	Nightshade,	1	0	0	0	0	1	0	0	1

	Tomato									
Sparganiaceae	Bur-reed	2	2	0	0	0	0	0	0	2
Tiliaceae	Linden, Basswood	1	0	1	0	1	0	0	0	2
Typhaceae	Cat-tail	1	1	0	1	1	0	1	0	4
Umbelliferae	Parsley	4	2	0	3	0	0	0	0	5
Urticaceae	Nettle	0	0	0	2	0	0	0	0	2
Violaceae	Violet	6	0	0	0	0	0	0	0	6
Vitaceae	Vine, Grape	1	0	0	0	0	1	0	0	1
Zosteraceae	Pondweed	8	8	0	6	0	0	0	0	8
Totals		158	52	3	72	24	42	36	3	234

Table Source: Adapted from Shay (1980).

7.10.2 Processing and Analysis of Comparative Plant Materials

Once the plants were collected, they were processed through a combination of grinding, and sieving through 118 μ m nitrex cloth to concentrate starch grains for analysis. After processing, these samples were placed on microscope slides and mounted with Thiodiethanol (30%). Thiodiethanol is comparable to glycerol, and was chosen for this analysis due to its refractive qualities enabling detailed images to be taken of the analyzed starch grains. Starch grains were also viewed under ‘Entellen New’ mounting medium, which is the primary medium used for archaeological samples for comparison. Any differences noted between mounting media will aid in the identification of the refractive index of particular starch grains. This may be important when attempting to differentiate between plants based on starch.

Table 7.3

Processing of Comparative Starch for Comparative Collection

Step	Description
1	Collect recent plant materials (field/herbarium).
2	Grind or cut up plant materials in mortar and pestle.
3	Separate starch grains (118 μ m nitrex cloth).
4	Centrifuge phytolith samples for 5 min at 3000 rpms, remove supernatant.
5	Mount starch grains with Thiodiethanol.
6	Seal slide cover with nail polish and allow to dry.

The next step included completing microscopic analysis of the starch samples. This involved counting 300 starch grains from each sample and taking photomicrographs and detailed illustrations of each starch grain type. The number of starch grains counted per sample was based on Lentfer (2009b) and was designed to capture a representative range of starch types for each plant. After the first set of plants was analyzed, they were compared with local varieties in an effort to identify any starch confusers. Out of the 154 samples on record in the Lakehead University starch database, the few that did contain similar starch types were incorporated into this study.

Following the analysis, the starch grain types for all of the samples analyzed were organized based on morphology. This strategy involves using morphology as the main criteria for starch categorization (Lentfer 2009b). Since size is highly variable between and within plant species, starch dimension is not a desirable attribute when building a starch key. Whereas size is highly variable, morphology can be useful in starch reference

keys due to the possibility of identifying morphological trends that may eliminate confusing starch grains. Therefore after morphology, starch grain types were then separated by size.

CHAPTER 8

RESULTS

The results for this thesis are divided into two sections. The first section describes the results of my analysis of modern starch assemblages from native Plains species. The objective of this work is to identify starch morphotypes that are diagnostic of edible wild plant species in this region. The second section describes the starch and phytolith content of carbonized and non-carbonized food residue, and soil samples, from the Avonlea sites examined.

8.1 Comparative Results

During the starch comparative analysis, starch grains from 45 plant species were analyzed. These plants were chosen based on recorded plant use among indigenous Plains groups (Shay 1980) and presence of adequate amounts of starch in a given species to enable analysis. Plants that produce starch morphotypes that are similar to those found in important economic plants (i.e., ‘confusers’) were also included.

8.1.1 *Phaseolus vulgaris* sp.

The starch grains produced by cultivated bean species received more attention in this analysis compared other domesticated and wild plants. Several varieties of *Phaseolus vulgaris* were analyzed ('black turtle,' 'green,' 'pinto,' 'yellow-eyed,' 'red kidney,' 'white navy,' and 'romano'), in addition to *Phaseolus lunatus* ('white lima').

Generally, starch grains produced by bean varieties are quite large in size and typically have an elongated shape (Fig. 8.1). Average lengths range from 20 μ m to more than 50 μ m. These starch grains are among the largest observed in this study.

Another characteristic observed within bean varieties was the presence of numerous circular starch grains with 90° extinction cross and no distinguishing characteristics. Upon rotation to examine three-dimensional morphology, it was observed that some of these circular starch grains were simply elongated starch grains that were situated perpendicular to the slide. Compound starch grains were also observed within bean varieties. These compound varieties typically appeared as elongated starch grains that were angled or heart-shaped and contained merging extinction crosses (Fig. 8.1). A distinguishing feature observed in the starch grains produced by bean varieties consisted of longitudinal cracking visible in both polarized and non-polarized light (see Figure 8.1).

As previously mentioned, the most frequent types of starch grains produced by bean varieties were either elongated, circular, or compound. In fact, in all of the bean varieties examined, no bell-shaped starch grains were observed. The elongated starch grains (Table 8. 1) were observed in high numbers and in multiple bean varieties.

Although a high amount of circular starch grains were observed, these starch types contained no diagnostic features and were present in all beans studied.

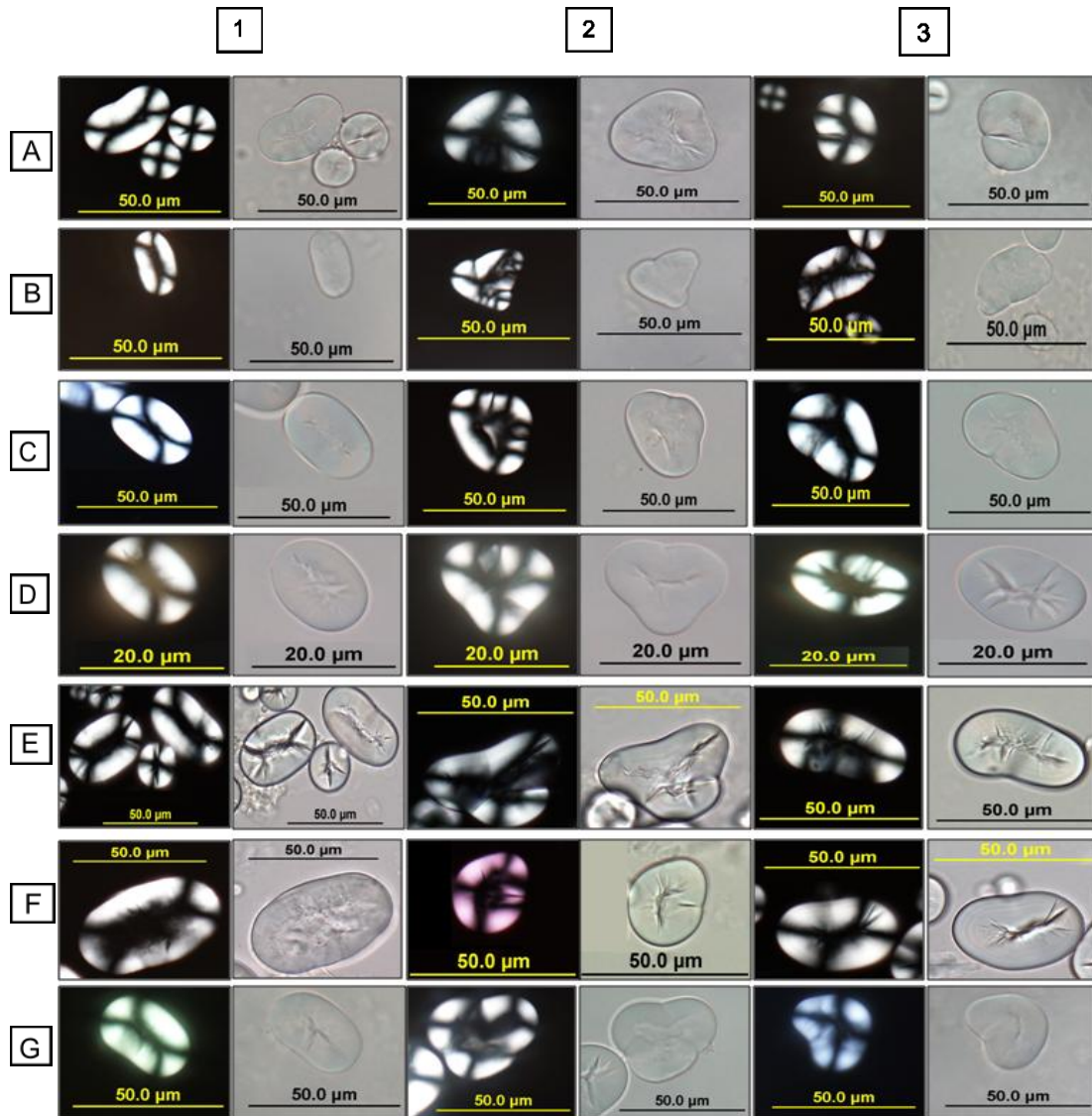


Fig. 8.1 Bean starch grain types noted in all samples. Dark images were taken under cross-polarized light (XPL). A column 1 indicates elongated bean starch grains, column 2 indicates semi-compound starch grains, and column 3 represents angled bean starch grains. Each row represents examples from one type of bean. These types are ‘black turtle’ (A), ‘green’ (B), ‘lima’ (C), ‘pinto’ (D), ‘red kidney’ (E), ‘white-navy’ (F), and ‘yellow-eyed’ (G).

Table 8.1

Common elongated starch grain counts observed for each species of bean studied.

	Black Turtle	Green	Lima	Pinto	Red Kidney	Romano	White Navy	Yellow Eyed
2.a.i.b.4.	0	0	0	0	0	0	0	0
2.a.i.b.5.	0	21	0	0	0	0	0	0
2.a.i.b.6.	0	0	0	0	0	0	0	0
2.a.i.b.7.	0	0	0	0	0	0	0	0
2.a.i.b.8.	0	0	0	0	0	0	0	0
2.a.i.b.9.	0	0	0	0	0	0	0	0
2.a.ii.a.1.	0	0	0	0	0	0	17	0
2.a.ii.a.10.	0	0	0	0	49	0	0	14
2.a.ii.a.11.	0	0	0	0	0	0	0	0
2.a.ii.a.12.	50	0	0	0	0	0	0	0
2.a.ii.a.13.	0	0	0	0	0	0	0	0
2.a.ii.a.14.	0	0	0	0	5	0	0	0
2.a.ii.a.2.	0	0	0	21	0	0	10	0
2.a.ii.a.3.	60	35	0	85	0	0	0	62
2.a.ii.a.4.	0	0	0	45	0	0	0	0
2.a.ii.a.5.	0	0	0	0	0	13	0	0
2.a.ii.a.6.	24	0	0	19	0	0	30	0
2.a.ii.a.7.	0	0	52	9	0	0	0	0
2.a.ii.a.8.	0	0	0	0	0	87	0	0
2.a.ii.a.9.	0	0	0	0	102	0	36	60
2.a.ii.b.1.	0	45	0	0	0	0	0	0
2.a.ii.b.10.	0	0	0	0	0	0	0	0
2.a.ii.b.11.	0	0	0	0	0	0	0	0

2.a.ii.b.12.	0	0	0	0	0	0	0	0
2.a.ii.b.13.	0	0	0	0	0	0	0	0
2.a.ii.b.9.	0	0	0	0	0	0	0	0
2.b.i.a.1.	0	0	6	0	0	0	0	0
2.b.i.b.1.	0	0	0	0	0	0	0	0
2.b.i.b.2.	0	0	0	0	0	0	0	0
2.b.i.b.3.	0	0	0	0	0	0	0	0
2.b.i.b.4.	0	0	0	0	0	0	0	0
2.b.i.b.5.	0	0	0	0	0	0	0	0
2.b.i.b.6.	0	0	0	0	0	0	0	0
2.b.i.b.7.	0	0	0	0	0	0	0	0
2.b.ii.a.1.	0	0	0	0	0	35	0	0
2.b.ii.a.10.	7	0	7	0	0	0	0	0
2.b.ii.a.11.	0	0	0	0	0	22	0	0
2.b.ii.a.12.	0	0	0	0	22	0	0	0
2.b.ii.a.13.	0	0	0	0	0	0	0	0
2.b.ii.a.14.	0	0	0	0	0	0	0	0
2.b.ii.a.15.	0	0	0	5	0	0	0	0
2.b.ii.a.16.	0	0	0	0	0	4	0	0
2.b.ii.a.2.	27	0	0	10	0	0	0	0
2.b.ii.a.3.	0	0	0	0	0	0	0	15
2.b.ii.a.4.	0	0	0	3	0	0	0	0
2.b.ii.a.5.	0	0	17	9	0	0	0	20
2.b.ii.a.6.	0	0	17	0	0	0	0	0
2.b.ii.a.7.	15	0	0	0	0	0	0	0
2.b.ii.a.8.	0	0	0	0	0	0	17	16
2.b.ii.a.9.	0	0	0	0	0	0	0	0

2.b.ii.b.1.	0	10	0	0	0	0	32	0
2.b.ii.b.2.	0	12	0	0	0	0	0	0
2.b.ii.b.3.	0	73	0	0	0	0	0	0
2.b.ii.b.4.	0	10	0	0	0	0	0	0
2.b.ii.b.5.	0	0	0	0	0	0	0	0
2.c.i.a.1.	0	0	9	7	0	0	0	0
2.c.i.a.2.	0	0	4	0	0	0	0	0
2.c.i.b.1.	0	0	0	0	0	0	0	0
2.c.i.b.10.	0	0	0	0	0	0	0	31
2.c.i.b.11.	0	0	0	0	0	0	0	0
2.c.i.b.12.	0	0	0	0	0	0	0	0

Legend: Grey indicates counts 0-10 per sample, Pink indicates counts 10-50, Blue indicates counts 50-100, Green indicates counts 100-150, and Yellow indicates counts 150 and above. A total of 300 starch grains were counted for each bean species.

8.1.2 *Cucurbita* sp.

As with the bean species, the analysis of squash species received greater attention due to its economic importance among New World farming populations. The squash species that were analyzed included *Cucurbita maxima* ('buttercup,' 'hubbard,' and 'kabosha') *Cucurbita moschata* ('butternut'), *Cucurbita pepo* ('pumpkin,' 'zucchini,' and 'acorn'), and *Lagenaria sp.* ('common gourd').

Squash starch grains were more difficult to interpret than those produced by bean species. For example, squash starch grains not only produced a large amount of starch grains, but also did so with a high degree of variation. Squash starch grains produced a large amount of highly variable bell-shaped starch grains that in some instances were still

in their semi-compounded form. Most of these bell-shaped starch grains were not produced by multiple squash species. This high degree of variation makes identification of squash based on starch grains difficult. Other than the general morphology (bell-shaped) no other characteristics enabled a species identifier. Similar bell-shaped starch grains were also found in numerous wild plants, limiting the effectiveness of starch grains as species indicators (see 8.1.5).

The size range of starch grains were dependent on both the variety of squash analyzed and the type of starch grain that was produced. Typically, some *Cucurbita pepo* types ('pumpkin' and 'zucchini') produced smaller starch grains (range: 5-15 μ m) while the other species produced starch grains that were generally larger (range: 15-30 μ m).

As stated above, bell-shaped starch grains were dominant in the starch assemblages for squash species. Other than bell-shaped starch grains, circular starch grains were frequent within squash species. Bell-shaped starch grains that were observed in high quantities can be viewed below (Fig. 8.2).

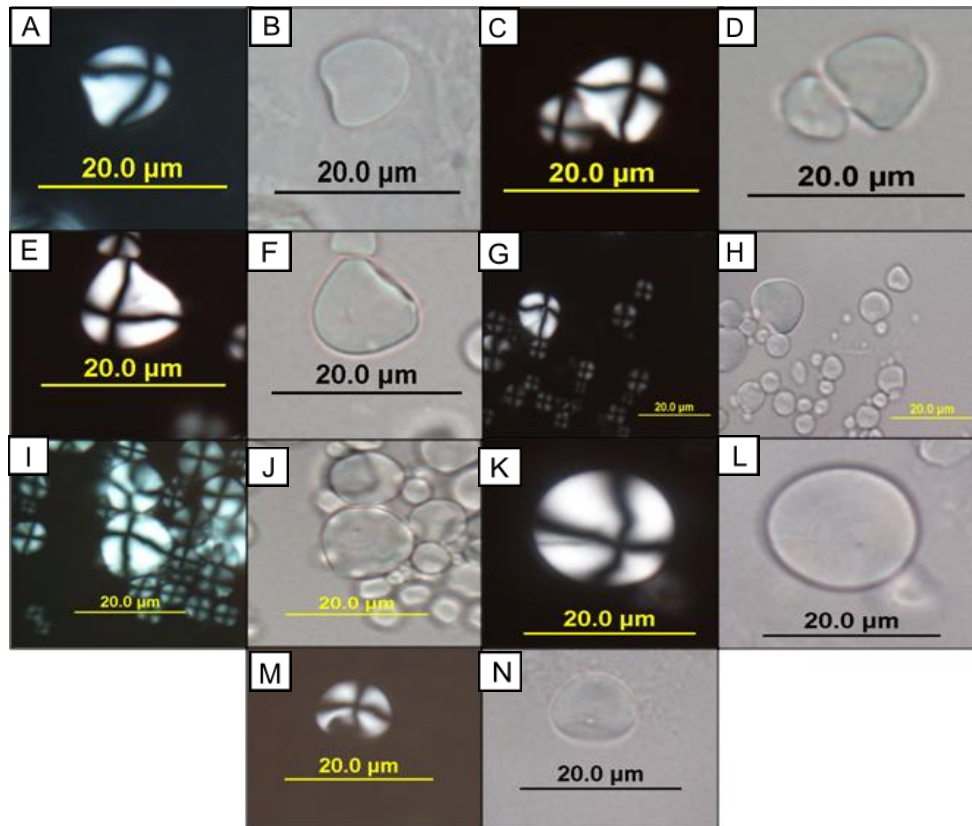


Fig. 8.2 Photomicrographs of starch grains produced by *Cucurbita* sp. Bell-shaped starch grains from *Cucurbita pepo* ('acorn') (A-B), *Cucurbita maxima* ('buttercup')(C-D), *Cucurbita maxima* ('hubbard') (E-F), *Cucurbita moschata* ('butternut') (G-J), *Lagenaria* sp. ('common gourd') (K-N) viewed under XPL and PPL.

8.1.3 *Zizania* sp. (Wild Rice)

Similar characteristics were observed in both *Zizania* species. The starch grains observed in both species were quite small (3-8 μ m). These starch grains were also angular in shape and found in large clusters (Fig. 8.3). The extinction crosses for these starches were typically a 90° cross. Because wild rice starch grains are small and share characteristics of starch found in other plants, it may be difficult or impossible to identify this plant in archaeological contexts using starch alone. However, although the angular

morphology of the *Zizania* sp. starch was not seen in other samples in this study, there are no other distinguishing characteristics that can be used for identification purposes.

Although wild rice starch may not be distinctive, previous research (Surette 2008, Yost and Blinnikov 2011) has shown that wild rice produces unique rondel phytoliths. These rondel phytoliths exhibit multiple indentations on the base and multiple spikes on the top of the rondel (Surette 2008).

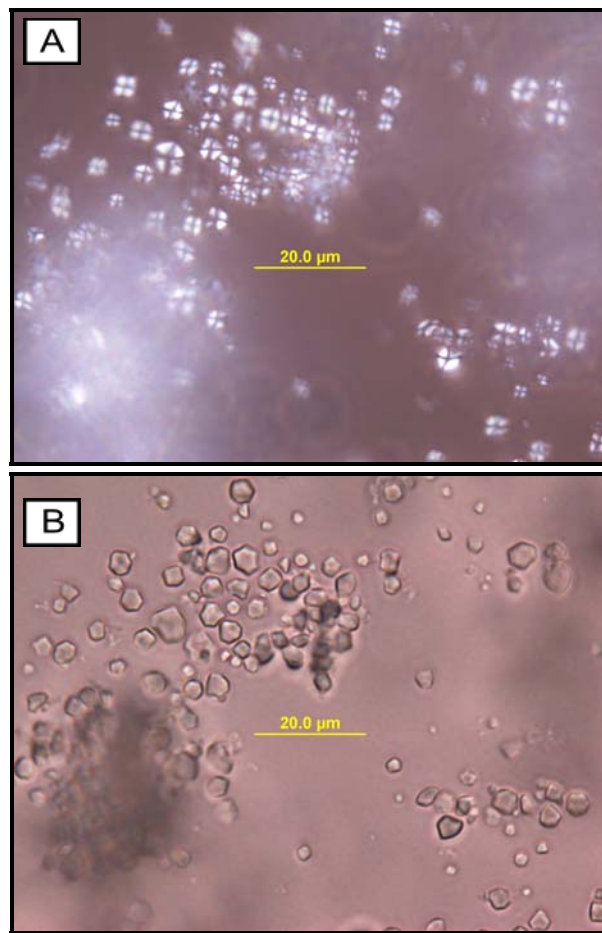


Fig. 8.3 Photomicrographs of *Zizania palustris* starch grains viewed under XPL (A) and PPL (B).

8.1.4 Berries, Nuts, and Acorns

Many native plants on the Plains produce berries, and many of these berries were food sources for indigenous groups (Shay 1980). Berries from *Prunus virginiana* (chokecherry), *Prunus pensylvanica* (pincherry), *Prunus nigra* (Canada plum), *Amelanchier alnifolia* (Saskatoon), and *Viburnum opulus* (high-brush cranberry) were included in my comparative analysis. Of the seeds and nuts that were examined, only *Acer negundo* (Manitoba maple), *Quercus macrocarpa* (bur oak), *Corylus cornuta* (beaked hazelnut), and *Corylus americana* (American hazelnut) were analyzed. It is important to note that upon initial analysis, the starch observed from the berry producing plants was primarily found in the seeds of the berry rather than the pericarp. Therefore, in order to concentrate the amount of starch for analysis, only the seeds of the berries were processed.

Generally, the starch grains that were observed within the berry-producing species were small in size (1-8 μ m). These starch grains were also primarily circular in shape. A common feature found in the *Prunus* species consisted of extinction crosses similar to the stitching on a baseball (Fig. 8.4). This characteristic was commonly found in *Prunus* species and can be used to identify berry starches. Other features of the berry starch grains included a roughened surface texture and a dark hilum in the centre of the circular starch grains. Compound species of these starch grains were also observed. Frequently produced starch types in berries are shown in Fig. 8.4 *Amelanchier alnifolia* starch grains were similar in size and shape to those found in the *Prunus* species examined. The extinction crosses, however, were more irregular. The surface texture of *Amelanchier*

alnifolia starch grains were also rougher (Fig. 8.4). *Viburnum opulus* starch grains were analyzed as a possible ‘confuser’ with the berry species. These starch grains did produce small circular starch grains with similar extinction crosses. However, these starch grains were slightly smaller, averaging around 3-4 μm and the surface texture of the starch grains exhibited a less roughened texture.

Similar to starch grains produced by the berry species, *Corylus americana* starch grains were circular, roughened, and contained a similar extinction cross that did not touch. However, starch grains produced by hazelnut were larger ($<5\mu\text{m}$) and were more angular rather than circular. Interestingly, the starch grains produced by the *Corylus cornuta* contained starch grains that exhibited 90° extinction cross and a smooth surface. These starch grains were also found in clusters within large sacs. These features of *Corylus cornuta* starch grains are significantly different from features exhibited by related *Corylus americana* starch grains.

The starch grains produced by *Quercus macrocarpa* and *Acer negundo* were quite large and exhibited multiple irregular shapes. *Quercus macrocarpa* starch grains produced an array of irregular elongated shapes. The extinction crosses exhibited by these starch grains were irregular and did not always touch (Fig. 8.4).

Starch grains produced by *Acer negundo* included circular, bell-shaped, and elongated forms. The starch grains were of smaller sizes, typically less than $20\mu\text{m}$ in diameter. The small bell-shaped starch grains were frequently in semi-compounded forms and contained single or multiple facets. These semi-compounded starch grains consisted

of two starch grains exhibiting separate extinction crosses, but were linked together. The types of starch grains produced most commonly in these plants can be seen in Fig. 8.4.

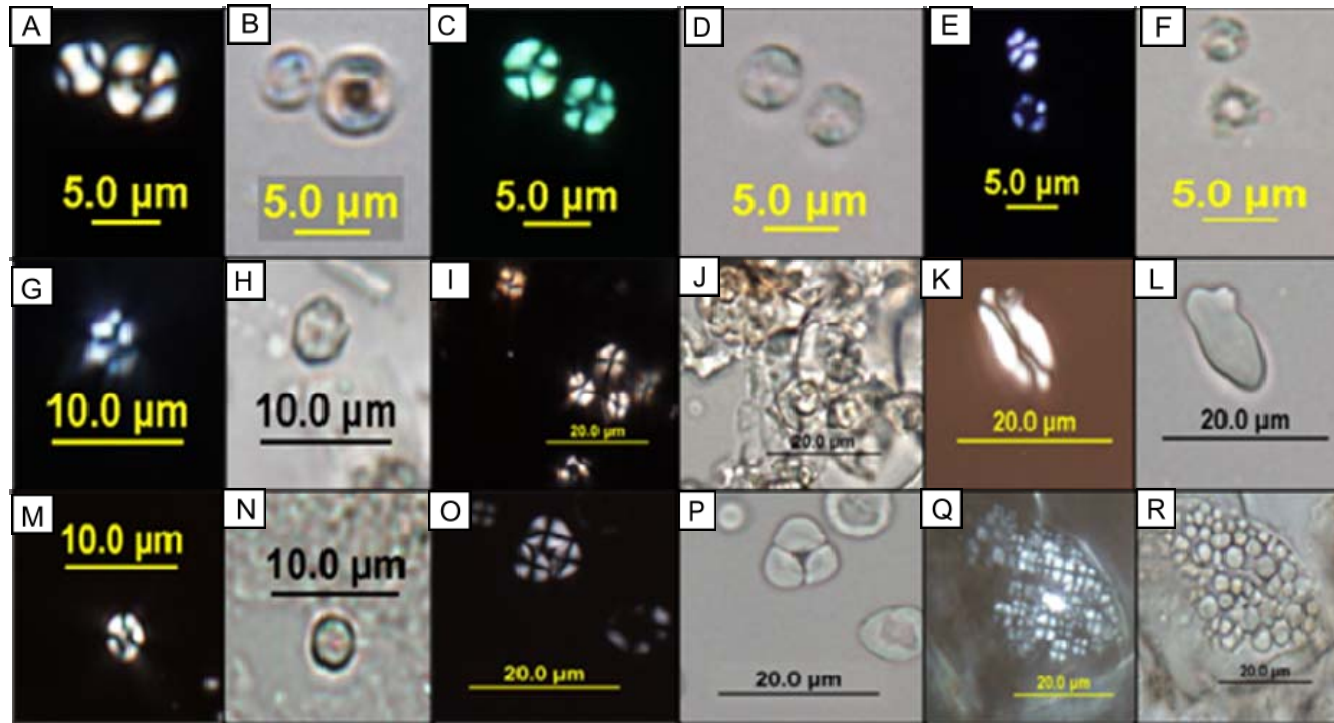


Fig. 8.4 Examples of starch grains produced by berry, seed, and nut species. Circular starch grains from *Prunus nigra* under XPL (A) and PPL (B). Circular starch grains from *Prunus virginiana* under XPL (C) and PPL (D). Circular starch grains recovered from *Prunus pensylvanica* under XPL (E) and PPL (F). Circular starch grain from *Amelanchier alnifolia* under XPL (G) and PPL (H). Circular starch grains from *Corylus americana* under XPL (I) and PPL (J). Elongated starch grain from *Quercus macrocarpa* under XPL (K) and PPL (L). Circular starch grain from *Viburnum opulus* under XPL (M) and PPL (N). Compound starch grains recovered from *Acer negundo* under XPL (O) and PPL (P). *Corylus cornuta* starch grains located in a sac viewed under XPL (Q) and PPL (R).

8.1.5 Tubers

In addition to fruit-bearing specimens, tuber-producing plants were analyzed in this study. A list of these plants can be viewed in Table 7.5 of Chapter 7. These tuber-producing species included *Psoralea esculenta* (Indian breadroot), *Peltandra virginica* (green arrow arum), *Nymphaea odorata tuberosa* (white pond-lily), and *Lilium philadelphicum* (western lily). Tubers are created as storage systems for plant species, thus, a large amount of tightly packed starch grains were observed in all of the tubers examined.

Overall, starch grains produced by tubers were larger than those found in berries. The size ranges for berry and seed starch grains rarely exceeded 10 μ m whereas tuber starch grains were commonly found in excess of 20 μ m in width. An exception to this trend was *Typha latifolia* (cat-tail), where the starch grains observed were quite small and found in large, tightly packed, sacs (Fig. 8.5). Similar sacs were noted in archaeological samples from the Avonlea site (see Fig 8.18). Therefore, in some instances these sac-like structures will preserve in the archaeological record. Starch grains contained in these sacs from *Typha latifolia* were small, circular, and bell-shaped.

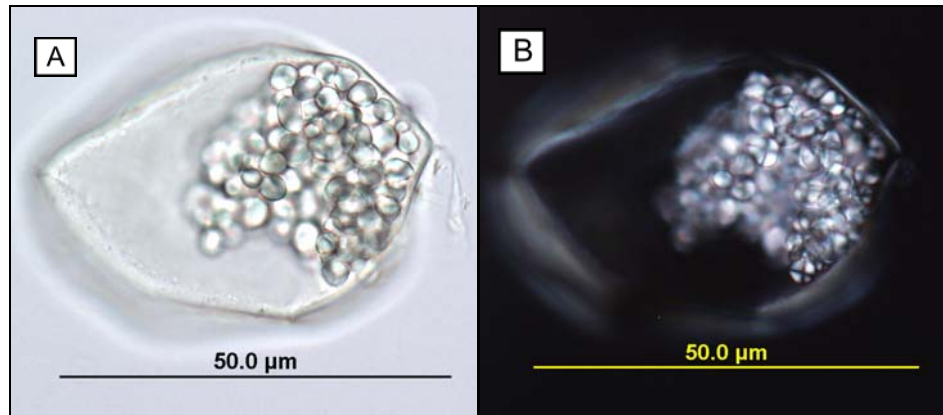


Fig. 8.5 Starch grains from *Typha latifolia* located within a sac viewed under PPL (A) and XPL (B).

Starch grains observed in the tubers of *Nymphaea odorata* ssp. *tuberosa* included both elongated and bell-shapes, frequently in semi-compound form. These starch grains were observed in clusters within sacs, similar to that of the *Typha latifolia* starch. Several of these starch grains are unique, including the bell-shaped starch grain with a single facet and containing shoulders. These starch grains can be viewed in Fig. 8.6. *Nymphaea odorata* ssp. *tuberosa* contained larger and more elongated starch grains than those produced by *Nymphaea odorata*.

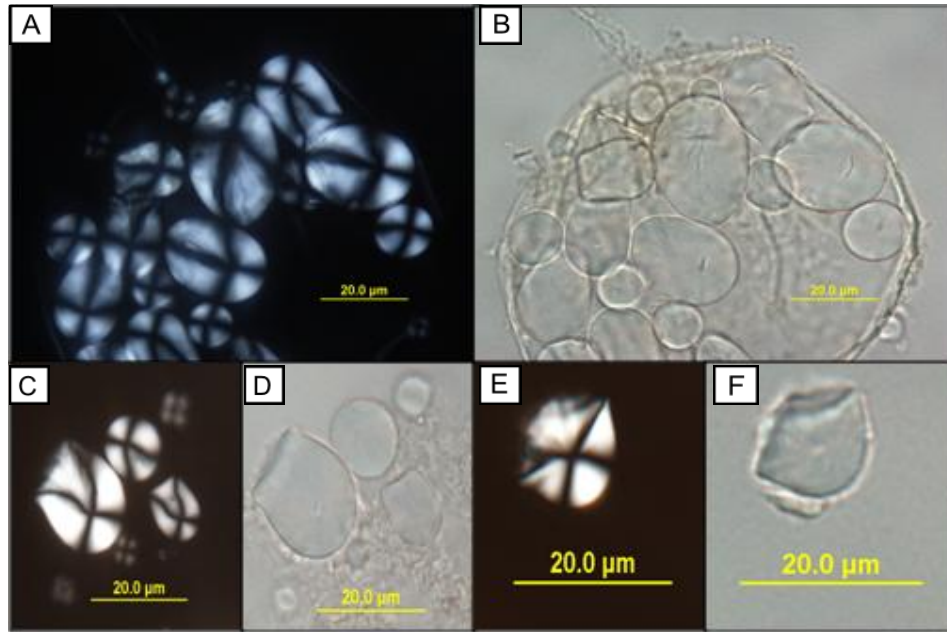


Fig. 8.6 Examples of starch grains produced by *Nymphaea odorata ssp. tuberosa*. Starch grains still located in a large sac viewed under XPL (A) and PPL (B). Bell shaped starch grain under XPL (C) and PPL (D). A multi-faceted bell-shaped starch grain under XPL (E) and PPL (F).

The morphology of the starch grains differed from species to species. For instance, while *Psoralea esculenta* produced large (<30 μ m) multi-faceted bell-shaped starch grains, starches from other tuber-bearing plants produced elongated starch grains. A common trait observed within all species was the presence of circular starch grains with no diagnostic features. Additionally, semi-compound and compound starch grains were common in most tuber starch grains (see Appendix).

Peltandra virginica produced both elongated and bell-shaped starch grains. The elongated species included extinction crosses that transected the mid-line and were also parallel to the midline of the starch grains (Fig. 8.7). These starch grains commonly exhibited highly visible lamellae. These starch grains varied widely in size with the bell-

shaped starch grains ranging from 10-15 μ m in diameter and the elongated starch grains ranging 20-35 μ m. It is also important to note that a high amount of raphides were found in the *Peltandra virginica* starch samples.

The starch grains produced by *Lilium philadelphicum* were also very large with some grains exceeding 30 μ m. Some of the starch grains produced in the tubers of this species were similar to those found in *Nymphaea odorata* ssp. *tuberosa* but, however, were square rather than oval in shape. Other types produced by this tuber were also distinct from other types analyzed in this study. *Lilium philadelphicum* produced large starch grains that were irregular in shape and in the nature of extinction cross (Fig. 8.7). The extinction crosses of these starch grains were irregular with multiple 'arms' exhibited.

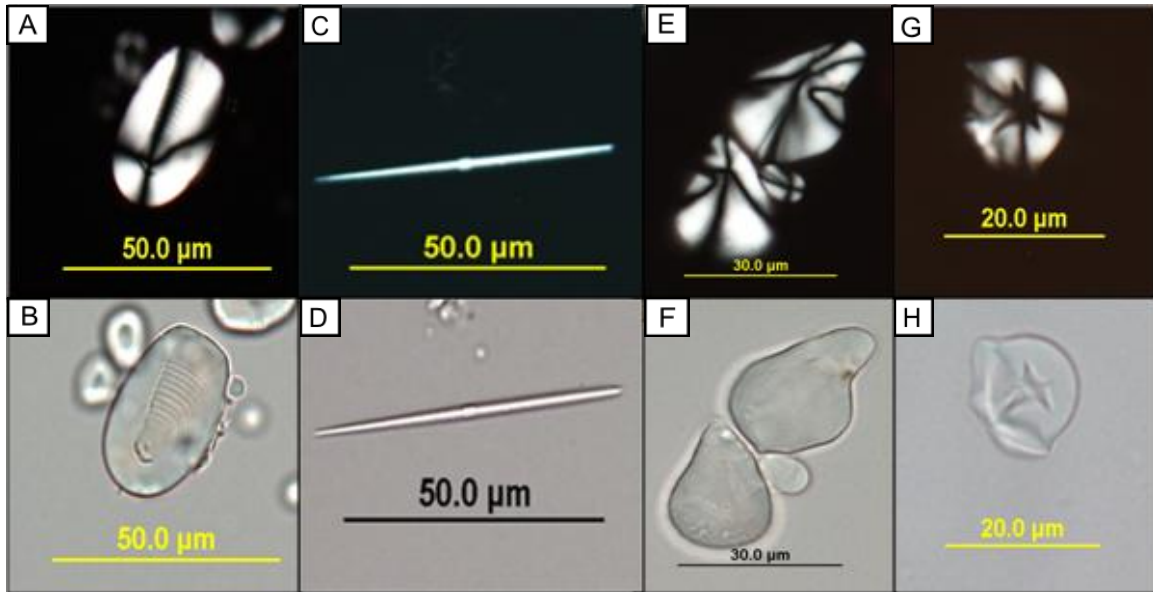


Fig. 8.7 Examples of starch grains and raphides produced by other tubers. Elongated starch grain with highly visible lamellae from *Petlandra virginica* under XPL (A) and PPL (B). A raphide found within the *Petlandra virginica* starch sample under XPL (C) and PPL (D). *Lilium philadelphicum* starch grains under XPL (E) and PPL (F). Multi-faceted bell-shaped starch grain from *Psoralea esculenta* under XPL (G) and PPL (H).

8.1.5 ‘Confusers’

The last group of plants that was analyzed included plants that posed as possible ‘confusers’ with previously mentioned wild and domesticated plants. These plants included *Hordeum jubatum* (foxtail barley), *Heracleum lanatum* (cow parsnip), *Perideridia gairdneri* (yampa), *Maranta arundinacea* (arrow root/exotic), *Arisaema triphyllum* (jack in the pulpit), *Claytonia caroliniana* (broad-leaved spring beauty), *Lomata foeniculaceum* (desert biscuit-root), *Ozmyriza longistylis* (smooth sweet-cicely), *Sparagenium eurycarpus* (giant burr-reed), *Symplocarpus foetidus* (skunk cabbage) and *Platanthera dilata* (tall white bog-orchid). These plants were chosen after the original analysis of selected economic plants due to their similarities in starch grains produced.

However, it is important to note that these ‘confusers’ are also edible, and have been noted to have been collected for subsistence. While *Maranta arundinacea* (arrow root) was included in this study due to the “confusing” starch grains that it produces, this species is native to lowland Tropic regions of South America, and exotic to the Northern Plains. Therefore starch identifications of this plant in the archaeological samples may rather represent a tuber native to the Northern Plains that has yet to be identified based on starch grains and subsequently identified as Unknown Root/Tuber.

Hordeum jubatum, was analyzed due to similarities in starch morphology with that of bean starch grains. Within the starch grains observed, 47 elongated starch grains (10-15µm) and 15 angled starch grains (5µm) were noted that were similar in morphology to the ones produced by bean species. Within *Caltha palustris* assemblages, 10 types of elongated starch grains (10µm) similar to those produced by beans were noted during analysis. An important difference is the size of these starch grains. While beans (*Phaseolus vulgaris* and *Phaseolus lanatum*) produce elongated starch grains that are quite large, elongated starch grains produced by *Hordeum jubatum* rarely exceed 20µm. Another key difference is the presence of grain cracking and compound starch grains, which are characteristics that were not observed in *Hordeum jubatum*. Similar to *Hordeum jubatum*, *Perideridia gairdneri* also produces starch grains that may be confused with bean. These elongated starch grains are also significantly smaller in length and width and are generally more angular.

Other plants such as *Maranta arundinacea*, and *Arisaema triphyllum*, produce starch grains that are similar to squash species and other wild plant species that were analyzed. *Maranta arundinacea* produced a large amount of bell shaped starch grains that

were quite similar to starch grains found in squash and *Nymphaea odorata* ssp. *tuberosa* species. *Arisaema triphyllum*, *Claytonia caroliniana*, *Lomatium foeniculaceum* and *Ozmyrhiza longistylis* produce multi-faced bell shaped starch grains that may be confused with squash or *Psoralea esculenta*. While the squash starch grains may be difficult to differentiate, the bell-shaped starch grains produced by *Psoralea esculenta* are generally larger and more robust than their confusing counterparts (Fig. 8.8). *Sparanganium eurycarpum* also produces starch grains that are bell shaped but are quite small, rarely exceeding 10µm in diameter.

Platanthera dilata produces starch grains that are very large and has both elongated and compound forms. These starch grains may be confused with those produced by *Nymphaea odorata* ssp. *tuberosa* but are generally thinner. *Platanthera dilata* also produces angled elongated starch grains that may be confused with bean. However, the extinction cross, lack of cracking, and overall shape is vastly different. The compound species, however, were not observed in other plant taxa in this study and may be included as a diagnostic starch grain type.

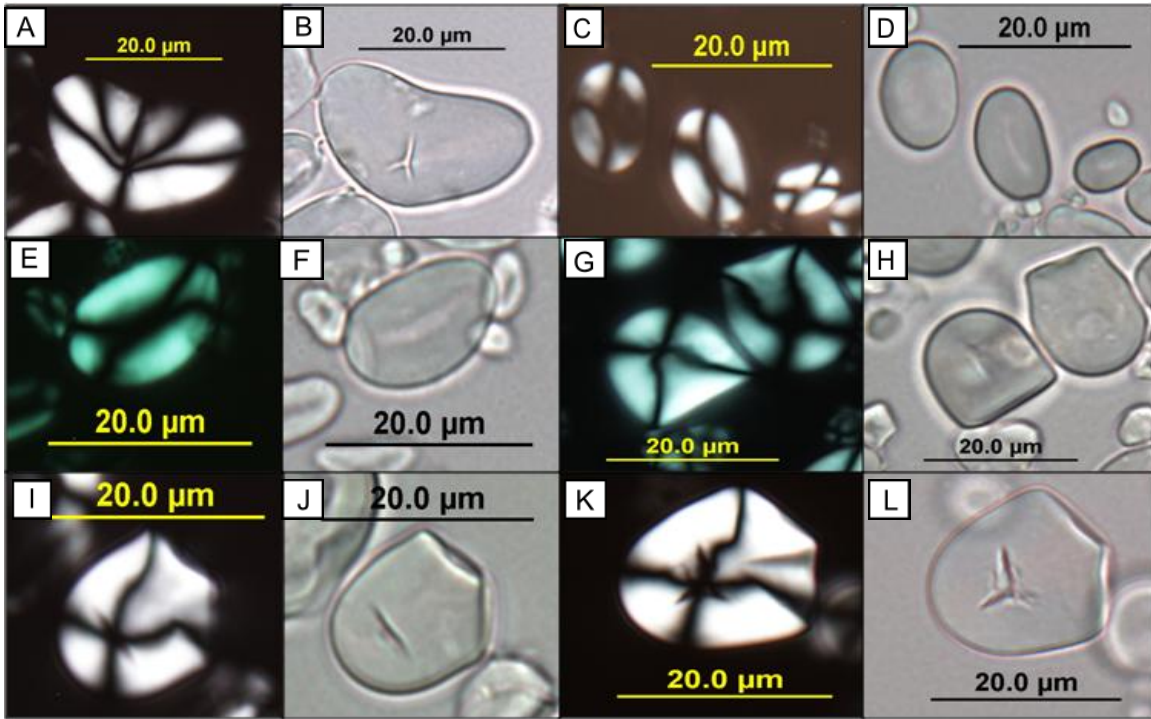


Fig. 8.8 Examples of starch grains that may be confusers with key economic plants. Elongated *Platanthera dilatata* starch grain under XPL (A) and PPL (B). Elongated starch grains from *Hordeum jubatum* viewed under XPL (C) and PPL (D). Elongated starch grains from *Peridia gardneri* viewed under XPL (E) and PPL (F). Bell-shaped starch grains produced by *Claytonia caroliniana* viewed under XPL (G) and PPL (H).

8.2 Archaeological Results

8.2.1 Sample Sizes from Carbonized Food Residue and Stone Tool Residue

Avonlea pottery yielding sufficient amounts of carbonized food residue was obtained from the Miniota, Broadview, Lebret, Garratt, Avonlea, Sjovold, and the Remembrance sites (Fig. 8.9). Overall, the amount of residue obtained was more than sufficient to allow

multiple analyses to be completed. Sites such as Miniota contained very thick encrustations of carbonized residue (see Fig. 6.6 of Chapter 6).

The amount of residue observed at the Miniota site presented the opportunity to obtain direct AMS dates from the carbonized food residue. Samples from three separate vessels averaging 70 mg were sent to Beta Analytic for AMS Analysis. These results are presented in Table 8.2.

The two Avonlea ceramic types that were studied included parallel grooved ceramics, and net impressed ceramics. In comparison, the net-impressed vessels contained residue primarily on the interior of the vessels as opposed to the parallel grooved vessels where residue was seldom found in the interior but rather the exterior surfaces of the ceramics. Although this study involved a small sample of Avonlea wares, this trend was noted in all samples analyzed in this study.

Only a few stone tool samples were acquired for this study (Fig. 8.10). This was due in large part to the small number of lithics identified (by the excavators) as being involved in plant processing. Stone tools were acquired from the Gull Lake site and the Sjovold site. FCR from a cooking feature at the Sjovold site was also obtained. The residue obtained through all the removal phases can be observed in Table A.1 of the appendix.

Three soil samples were obtained from the sites chosen in this study. These samples included a soil sample from the Avonlea site and two soil samples from a possible midden feature at the Miniota site. The soil samples from the midden feature at the

Miniota site contained a large amount of carbonized material, ash, and carbonized faunal remains.

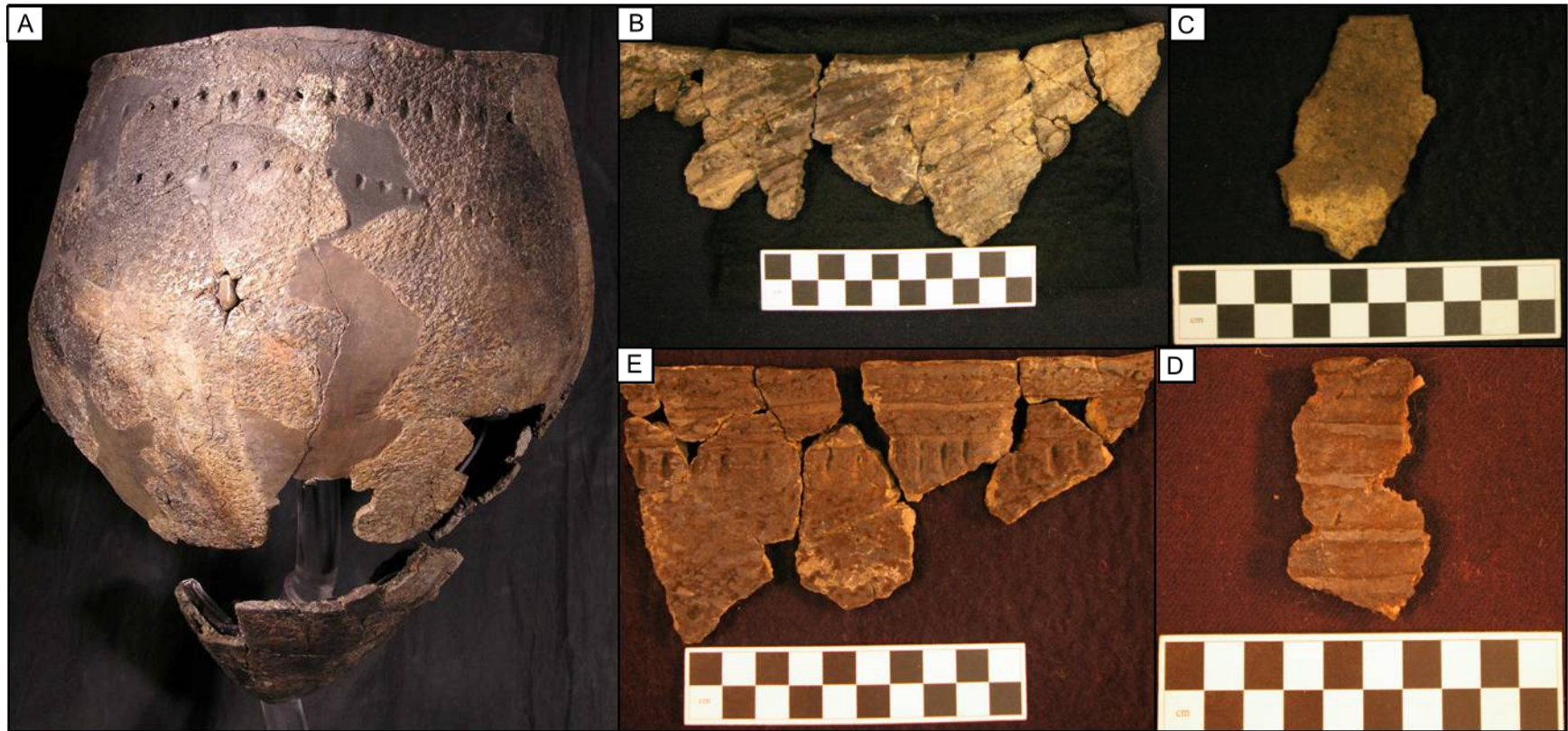


Fig. 8.9 Examples of Avonlea vessels examined in this study. The ‘Miniota Vessel’ (A), Vessel G from the Sjøvold site (B), a large net-impressed rim sherd from the Broadview site (C), Vessel 1 from the Garratt site (E), and a large parallel grooved rim sherd from the Avonlea site (D).



Fig. 8. 10 Photographs of the stone tools processed and analyzed in this study. ‘Hammer stones’ S-2 1999 (A) and S-1 2562 (C) from the Sjøvold site. ‘Chipping anvil’ S-3 2464 (B) from the Sjøvold site. Bell-shaped pestles 1294 (D) and 2024 (F) from the Gull Lake site. A possible metaté recovered from the Gull Lake site (E). A large FCR fragment from an Avonlea hearth feature from the Sjøvold site (G).

8.2.2 Contamination Tests

In order to ensure and identify any possible sources of contamination that may be present in the laboratory, slides containing silicon jelly were placed throughout the lab for 12 days. This process was completed multiple times during this research. At no point were any plant microfossils observed on the slides, thus eliminating the possibility of airborne contamination of archaeological samples in the laboratory.

8.2.3 Miniota site (EaMg-12) Results

8.2.3.a Starch and Phytolith Content of Carbonized Food Residue

Phytoliths were analyzed from 5 separate vessels from the Miniota site. Diagnostic ‘wavy-top’ rondel phytoliths produced in the cobs of maize were recovered in all samples analyzed (Fig. 8.11). Not only were ‘wavy-top’ rondels found in all samples, but in most samples multiple examples of this diagnostic phytolith was observed. These samples also yielded cross-shaped phytoliths similar to those produced in the leaves of maize (Iriarte *et al.* 2004). Although these cross-shaped phytoliths do not provide a positive confirmation of maize, they do support the rondel evidence and are in keeping with the presence of maize in the residue. Two of the carbonized samples contained diagnostic rondels produced by *Zizania*. As for other diagnostic phytoliths, phytoliths

produced in the rinds of squash were recovered in one of the carbonized samples.

Although this scalloped-shaped phytolith was highly fragmented, the remaining portion of the phytolith was sufficient to provide identification.

As with the phytolith content, a tremendous number of starch grains were observed all samples analyzed from this site. These starch grains were mostly located in large gelatinous masses and included both domesticated and wild starch types. A large amount of the starch grains observed in these samples contained damage likely from cooking. These starch grains appeared swollen, exhibited little birefringement, and were stained by 'trypan blue' or 'Congo red.' All but one sample yielded diagnostic maize starch grains (8.12). This lack of maize starch in the one sample can likely be explained by the amount of damaged starch grains (via cooking) that were observed, which may have limited the opportunity to identify maize starch grains. Bean (*Phaseolus vulgaris*) starch grains were also observed in the Miniota residue (Fig. 8.14). Only one sample yielded evidence of possible squash starch. Wild species that were identified in the residue based on starch morphology (see descriptions above) included *Psoralea esculenta*, *Nymphaea odorata* ssp. *tuberosa*, *Acer negundo*, *Quercus macrocarpa*, *Amelanchier alnifolia*, *Prunus virginiana*, *Prunus pensylvanica*, and *Prunus nigra*. Also found within the carbonized food residue from the Miniota site were a large amount of raphides intermixed with large gelatinized starch grain clusters. Raphides are common among many wild plants such as *Typha latifolia* and *Peltandra virginica*. Raphides appear as long needle-shaped calcium oxalate structures and are inedible.

Other important microfossils that were identified in the residue included possible maize pollen (Fig. 8.13). Two of the residue samples contained possible maize pollen.

This pollen evidence supports the phytolith and starch data for maize. It is unlikely that these pollen grains are the result of modern contamination since *Zea* pollen is large and heavy and does not travel far from the source plant.

8.2.3.b Results from Soil Samples

In total, two soil samples were analyzed for phytoliths, starch, and other microfossils from the Miniota site. Similar diagnostic ‘wavy-top’ rondels and cross shaped phytoliths were found in both samples. In addition, diagnostic maize starch and *Zea* pollen was also recovered in both samples. Both squash phytoliths and possible squash starch grains were identified in both soil samples. However, unlike the carbonized food residue, these samples yielded no evidence of bean (*Phaseolus vulgaris*) starch. Wild starch types were identified in the soil samples and included *Psoralea esculenta*, *Maranta arundinacea* (Unknown Root/Tuber), *Arisaema triphyllum*, *Nymphaea odorata* ssp. *tuberosa*, and *Acer negundo*.

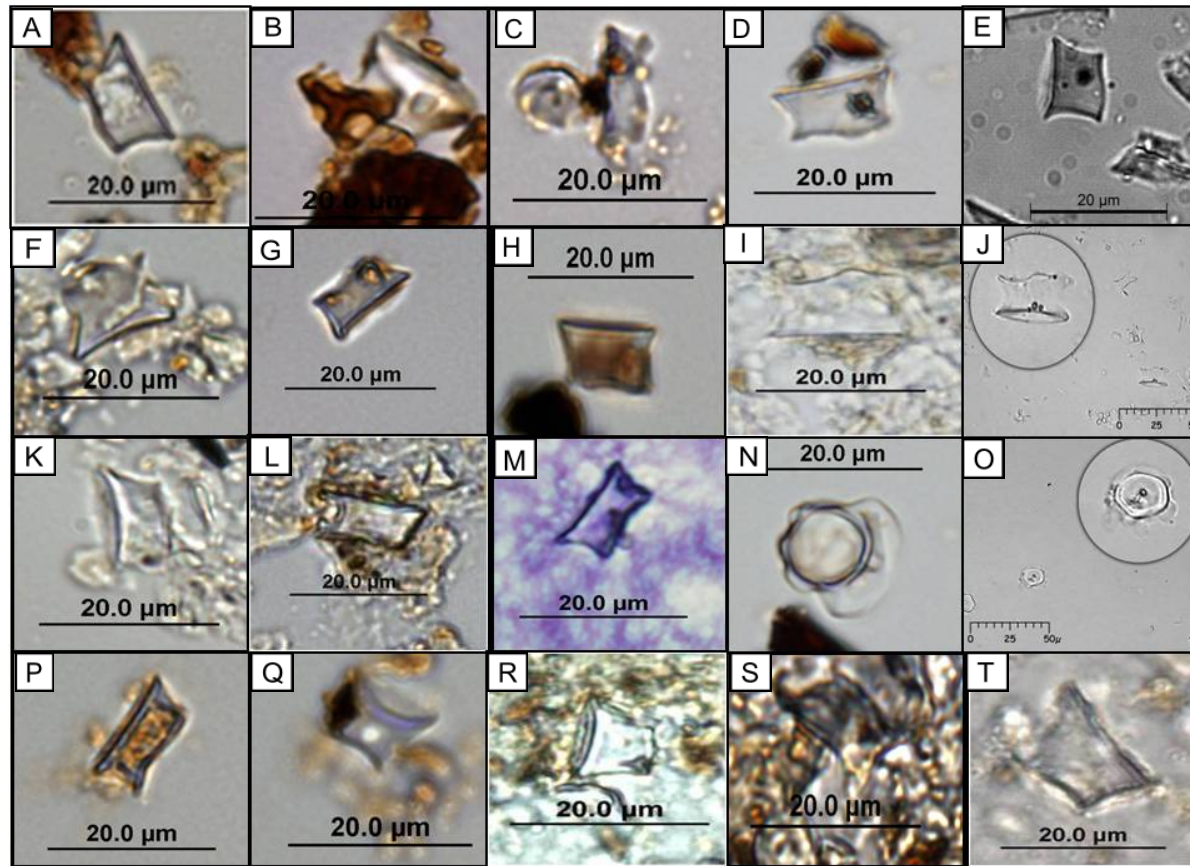


Fig. 8.11 ‘Wavy-top’ Rondel Maize phytoliths recovered from Avonlea carbonized food residue, stone tools, FCR, and soil samples. Comparative ‘wavy-top’ rondel phytoliths (E,J) (McKey *et al.* 2010; Pearsall *et al.* 2003) and ‘Ruffle-Top’ rondel phytolith (O) (Pearsall *et al.* 2003). ‘Wavy-top’ rondels from carbonized food residue at the Miniota site (A,D), Lebret site (B, C), Avonlea site (G), Garratt site (P,Q), Remembrance (M), and Sjovold site (H). ‘Ruffle-Top’ rondel phytolith recovered from the Lebret site (N). ‘Wavy-top’ rondel phytoliths recovered from stone tools at the Sjovold site (F,S). ‘Wavy-top’ rondel phytolith recovered from FCR at the Sjovold site (L). ‘Wavy-top’ rondel phytoliths recovered from soil samples acquired from the Miniota site (I,K,T) and the Avonlea site (R).

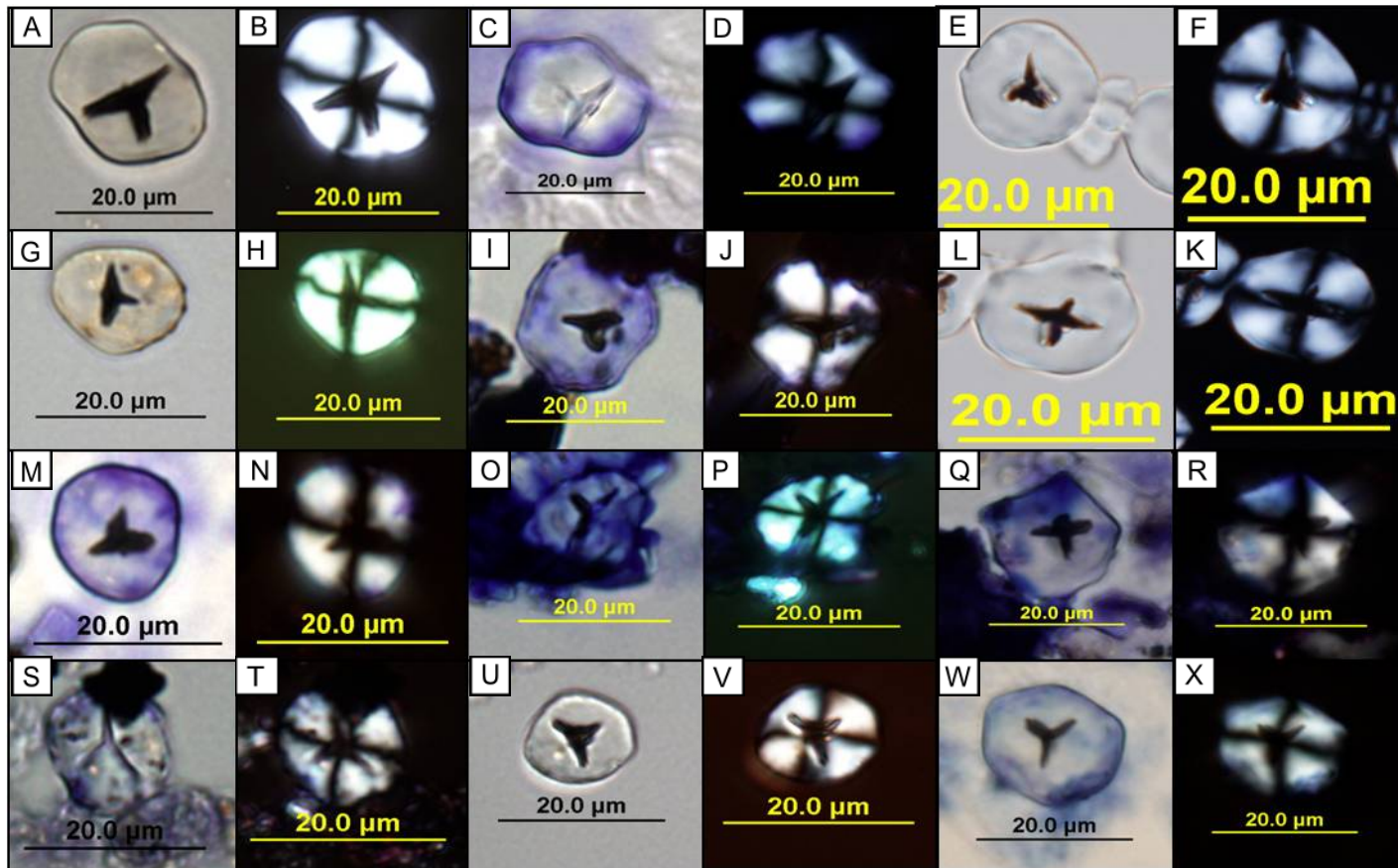


Fig. 8.12 Examples of *Zea mays* ssp. *mays* starch grains identified in Avonlea contexts viewed under XPL and PPL. Comparative *Zea mays* starch grains from Mandan corn (E-F, L-K). Mays starch grains recovered from Avonlea carbonized food residue from the Miniota site (A-B, G-H), Broadview site (Q-R), Garratt site (I-J), and the Avonlea site (M-N). *Zea mays* phytoliths recovered from Avonlea stone tools at the Sjøvold site (S-T) and Gull Lake site (O-P, U-V, W-X). *Zea mays* starch grain recovered from FCR at the Sjøvold site (C-D).

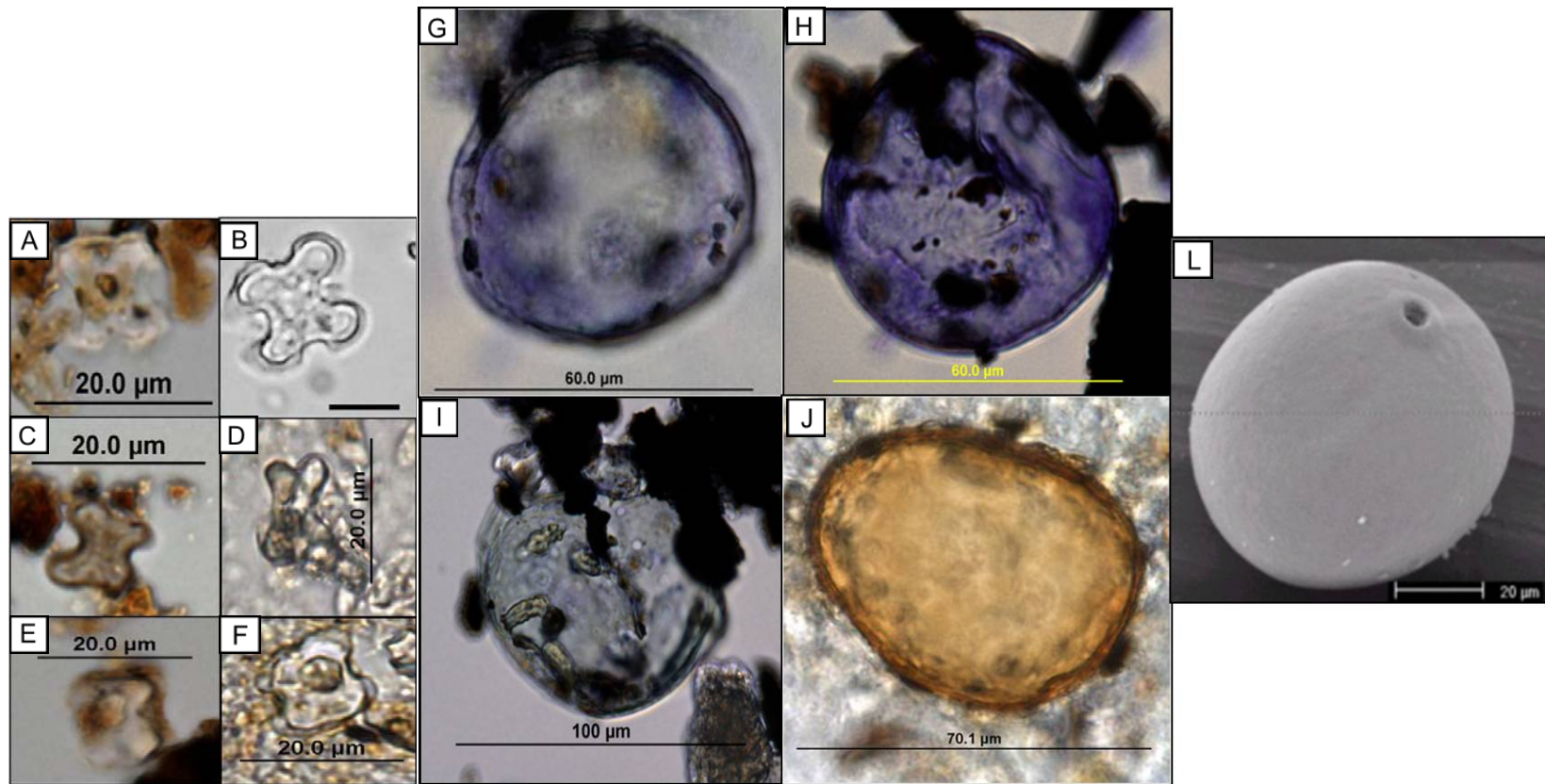


Fig. 8.13 Examples of possible cross-shaped phytoliths and pollen grains produced by *Zea mays ssp. mays* from Avonlea contexts. Cross-shaped phytoliths recovered from carbonized food residue from the Miniota site (A,C) and Garratt site (E). Cross-shaped phytolith recovered from Miniota soil sample (D) and FCR from the Sjøvold site (F). Possible *Zea* pollen recovered from carbonized food residue from the Miniota site (I,G) and Avonlea sites (H). Possible *Zea mays ssp. mays* pollen recovered from soil samples from the Miniota site (J). Comparative examples of both cross-shaped phytoliths (Iriarte *et al.* 2004) (B) and modern *Zea mays ssp. mays* pollen (www.biologie.uni-regensburg.de)(L).

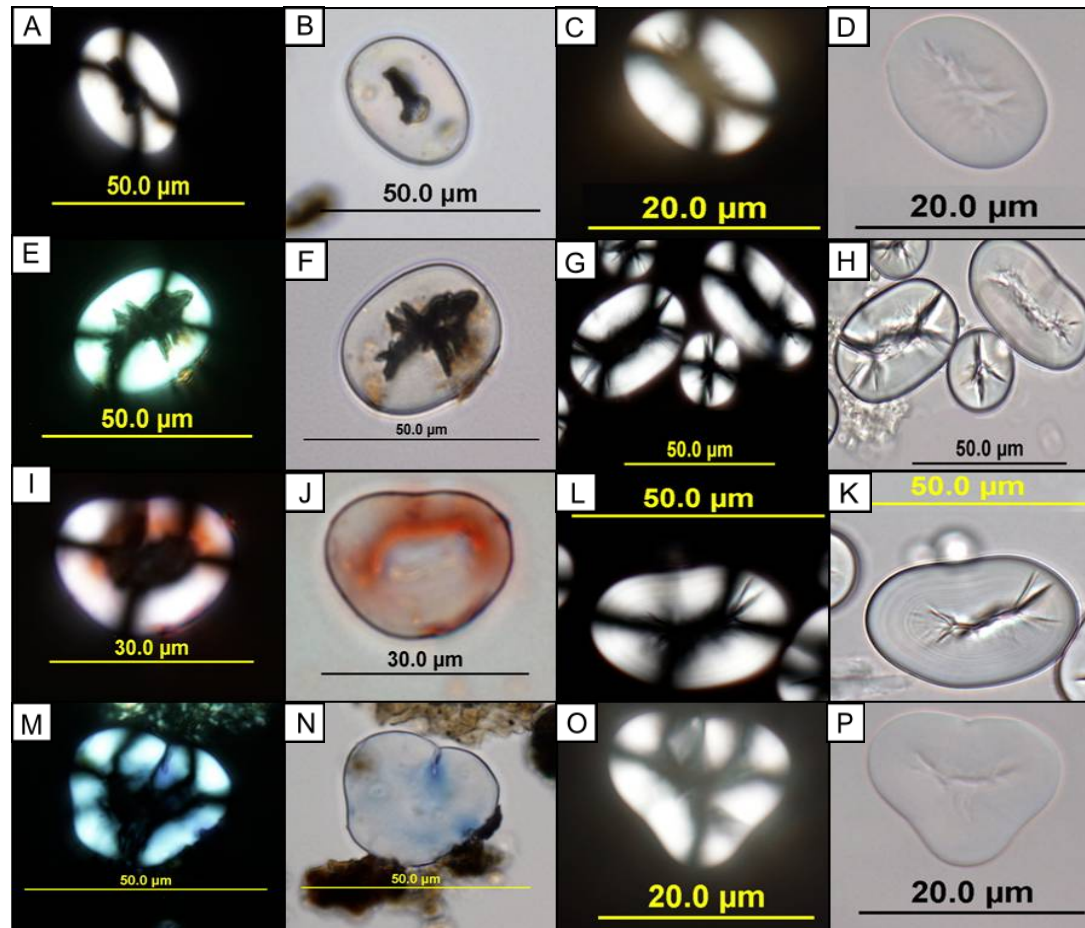


Fig. 8.14 Examples of comparative and archaeological *Phaseolus* sp. bean starch grains viewed in XPL and PPL. Elongated bean starch grain observed in carbonized food residue from the Broadview site (A-B), Garratt site (E-F), Sjevold site (I-J), and a compound bean starch grain from the Miniota site (M-N). Comparative examples of bean starch grains from White Navy Bean (C-D), Red Kidney Bean (G-H), Pinto bean (L-K), and White Lima bean (O-P).

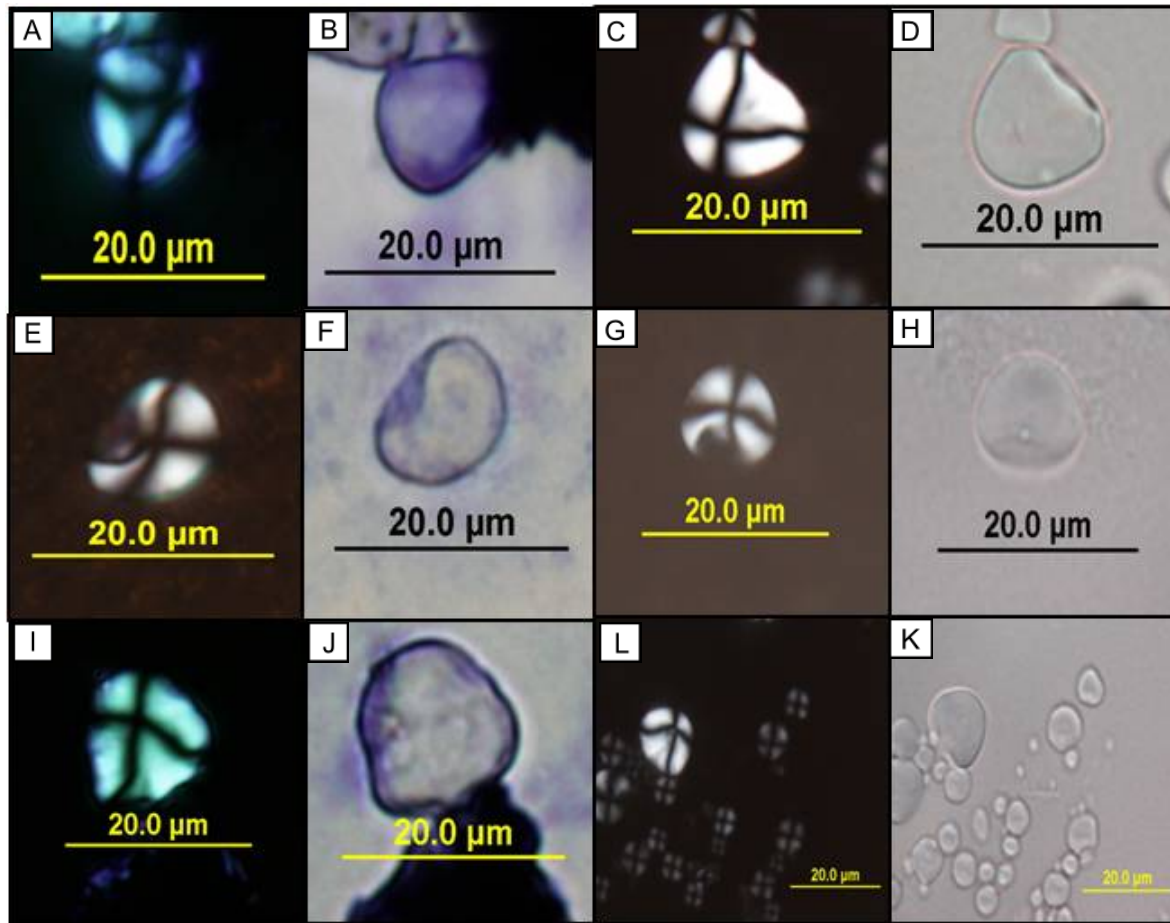


Fig. 8.15 Examples of possible squash starch grains recovered from Avonlea food residue viewed under XPL and PPL. Bell-shaped starch grains recovered from the Garratt site (A-B, E-F) and the Avonlea site (I-J). Comparative bell-shaped starch grains from *Cucurbita pepo* ('Acorn' squash) (C-D), *Lageneria sp.* ('Common Gourd') (G, H), and *Cucurbita maxima* ('Buttercup' squash) (L-K).

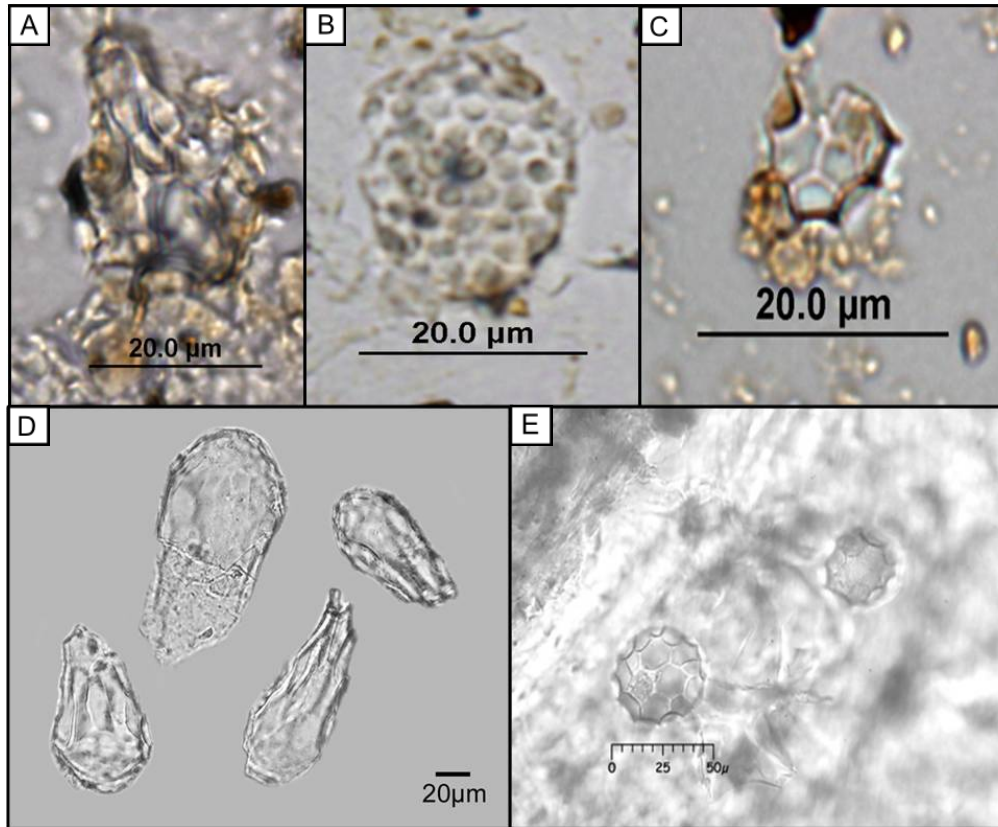


Fig. 8.16 Examples of possible *Cucurbita* sp. phytoliths recovered from the Miniota site. Possible scalloped phytoliths recovered from Miniota soil samples (A,B). Possible damaged scalloped phytolith recovered from carbonized food residue from the Miniota site (C). Comparative examples of scalloped *Cucurbita* sp. phytoliths D (Piperno 2006) and E (www.missouri.edu/~phyto/).

Table 8.2

Diagnostic Plant Microfossils Observed in the Miniota Site Carbonized Food Residue and Soil Samples.

Site	Sample	Phytoliths			Starch Grains		Pollen
		<i>Zea mays</i> Rondel	<i>Zizania sp.</i> Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus</i> <i>vulgaris</i>	<i>Zea</i>
Soil Samples							
Miniota	XU 13 SW	7	0	7	6	0	1
Miniota	XU 13 SE	9	0	5	3	0	1
Food Residue							
Miniota	M3	2	1	0	10	18	1
Miniota	M6	3	0	0	3	0	0
Miniota	M2	5	1	1	5	0	0
Miniota	M5	5	0	0	5	1	1
Miniota	Vessel	3	0	0	0	2	0

8.2.3.c AMS Dating of Avonlea Food Residue from the Miniota Site

A total of three residue samples from a minimum of two vessels were sent to BETA analytic for AMS dating. Approximately 70 mg of carbonized residue food from each individual sample was sent for analysis. These dates are presented in table 8.3. The dates from these vessels support the date on charcoal of 565 to 880 AD (Beta 58908) that was obtained by Landals (1995) (Reimer *et al.* 2009).

Table 8.3

Results from AMS Dating of Carbonized Food Residue

Sample Data	Measured Radiocarbon Age	Conventional Radiocarbon Age	2 Sigma Calibrated Range
Beta - 296295	1230+/- 30 BP	1260 +/- 30 BP	AD 670 to 810
Beta - 296296	1240+/- 30 BP	1300 +/- 30 BP	AD 660 to 770
Beta - 296297	1230+/- 30 BP	1300 +/- 30 BP	AD 660 to 770

8.2.4 Broadview site (EmBp-6) (Carbonized Food Residue)

Unlike the residue observed from the Miniota site, limited carbonized food residue was found adhering to the Broadview site Avonlea ceramics. Despite this, microfossils were still recovered from all samples. All of these samples contained *Zea mays* ssp. *mays* ‘wavy-top’ rondels (Fig. 8.11). Cross-shaped phytoliths, similar to those found in maize, were also identified in the residue. In addition, one of these samples contained diagnostic *Zizania* sp. rondels (see descriptions in Surette 2008; and Yost and Blinnikov 2011).

Diagnostic maize starch grains were identified in two of the three samples. Bean starch was also identified in two of the three samples (Fig. 8.14). Wild starch grains were also recovered; these were identified as coming from *Quercus macrocarpa*, *Amelanchier alnifolia*, *Prunus virginiana*, and *Prunus nigra*.

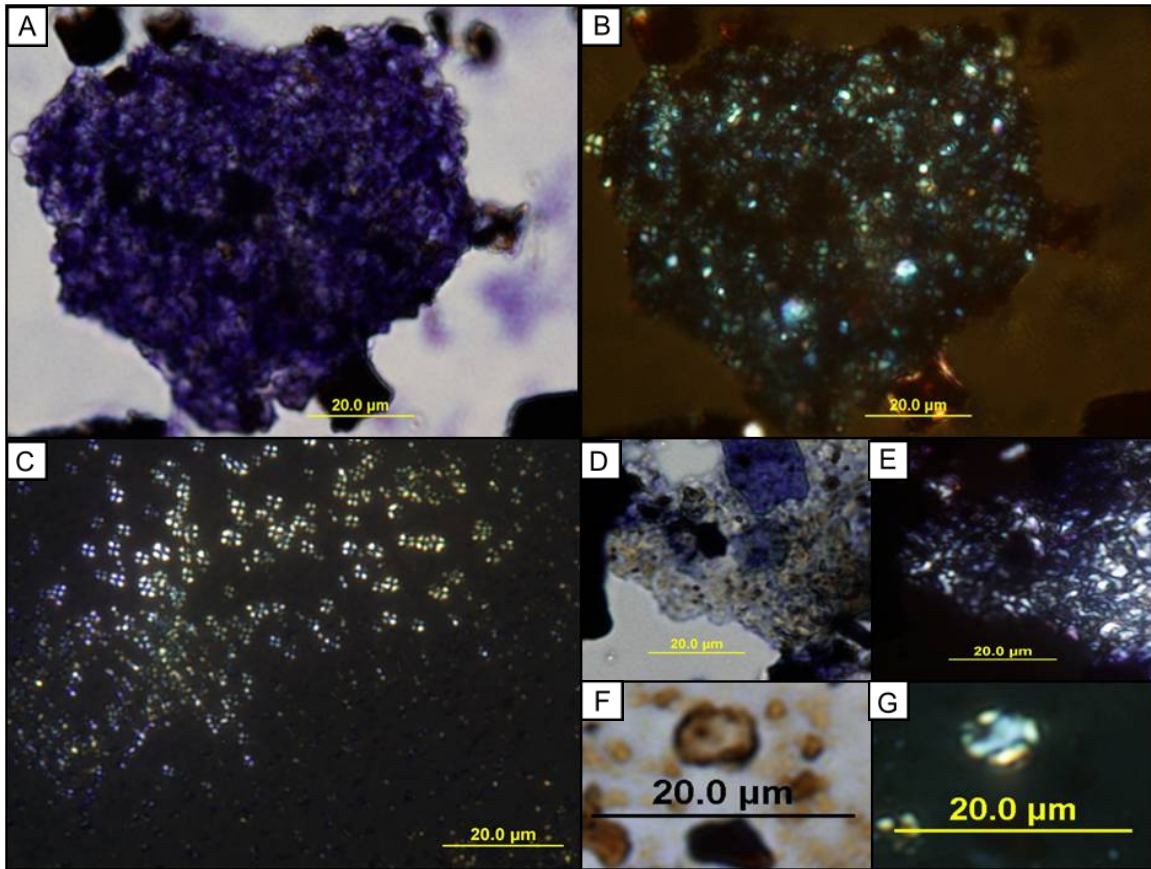


Fig. 8.17 Examples of large clusters of possible berry starch grains and a possible *Prunus* starch grain viewed in both XPL and PPL. Large cluster of berry starch grains recovered from carbonized food residue from the Broadview site (A-B). Possible *Prunus* sp. starch grains recovered from carbonized food residue from the Lebret site (C). Berry starch grain cluster observed in the Garratt site residue (D-E). *Prunus* sp. starch grain recovered from the Miniota site residue (F-G).

Table 8.4

Diagnostic Plant Microfossils Observed in the Broadview Site Carbonized Food Residue Samples.

Site	Sample	Phytoliths			Starch Grains	
		<i>Zea mays</i> Rondel	<i>Zizania sp.</i> Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>
Broadview	1359 Rim	1	0	0	2	7
Broadview	1492 Body	2	1	0	0	3
Broadview	1574 Body	3	0	0	1	0

8.2.5 Lebret Site EeMw-25 & 26 (Carbonized Food Residue)

In general, large quantities of residue were observed to be adhering to the Lebret site ceramics, suggesting multiple cooking events. Both ‘wavy-top’ and ‘ruffle-top’ maize phytoliths were identified in the samples analyzed (Fig. 8.11). In addition, possible maize phytoliths were also recovered. Diagnostic *Zizania sp.* rondels were also recovered in all samples.

Further evidence of domesticated plants at this site was provided by the presence of maize, bean, and squash starch grains. Additional evidence of maize was also observed in the identification of a possible maize pollen grain recovered from the Lebret residue. Starch from squash was only present in one of the samples. *Hordeum jubatum*, *Maranta arundinacea* (Unknown Root/Tuber), *Nymphaea odorata* ssp. *tuberosa*, *Osmirhiza longistylis*, *Quercus macrocarpa*, and *Prunus nigra* represented the wild starch grains that were present in the residue.

Table 8.5

Diagnostic Plant Microfossils Observed in the Lebret Site Carbonized Food Residue Samples.

Site	Sample	Phytoliths			Starch Grains		Pollen
		<i>Zea mays</i> Rondel	<i>Zizania</i> sp. Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>	<i>Zea</i>
Lebret	Lv. 12 XU 8	3	1	0	2	5	0
Lebret	R-2-68 SEQ	7	1	0	1	1	1
Lebret	R-8 Body Lv. 15	4	1	0	8	2	0

8.2.6 Avonlea site EaMg-1

8.2.6.a Starch and Phytolith Content of Carbonized Food Residue

The Avonlea site generally yielded smaller amounts of residue per sherd compared to the other sites examined. Much of this residue, furthermore, was found adhering to the exterior of the sherds; this ‘exterior-only’ residue was noted in all parallel grooved vessels analyzed. Fortunately, these low amounts of initial residue did not affect phytolith counts because the minimum count (250) was obtained for all samples. The Avonlea samples all yielded positive results for maize in the form of diagnostic ‘wavy-top’ rondels (Fig. 8.11). Two of these samples yielded *Zizania* sp. phytoliths while one

sample yielded possible *Zizania* sp. phytoliths. A possible maize pollen grain was also recovered in the residue at the Avonlea site as well.

Maize starch was identified in the carbonized food residue from the Avonlea site. Other domesticated plants identified based on starch characteristics included bean and squash. Wild species that were identified included *Psoralea esculenta*, *Nymphaea odorata* ssp. *tuberosa*, *Platanthera dilatata*, *Amelanchier alnifolia*, and *Prunus virginiana*. The Avonlea 'Big Pot' yielded a large amount of wild starch grains likely produced by *Nymphaea odorata* ssp. *tuberosa*. This sample had a high level of starch preservation as a large amount of starch grains were still visible in their semi-compound forms and also remained within large sacs. *Typha latifolia* and *Nymphaea odorata* ssp. *tuberosa* starch grains were observed still within large sacs, as seen in the modern comparative material (Fig. 8.18).

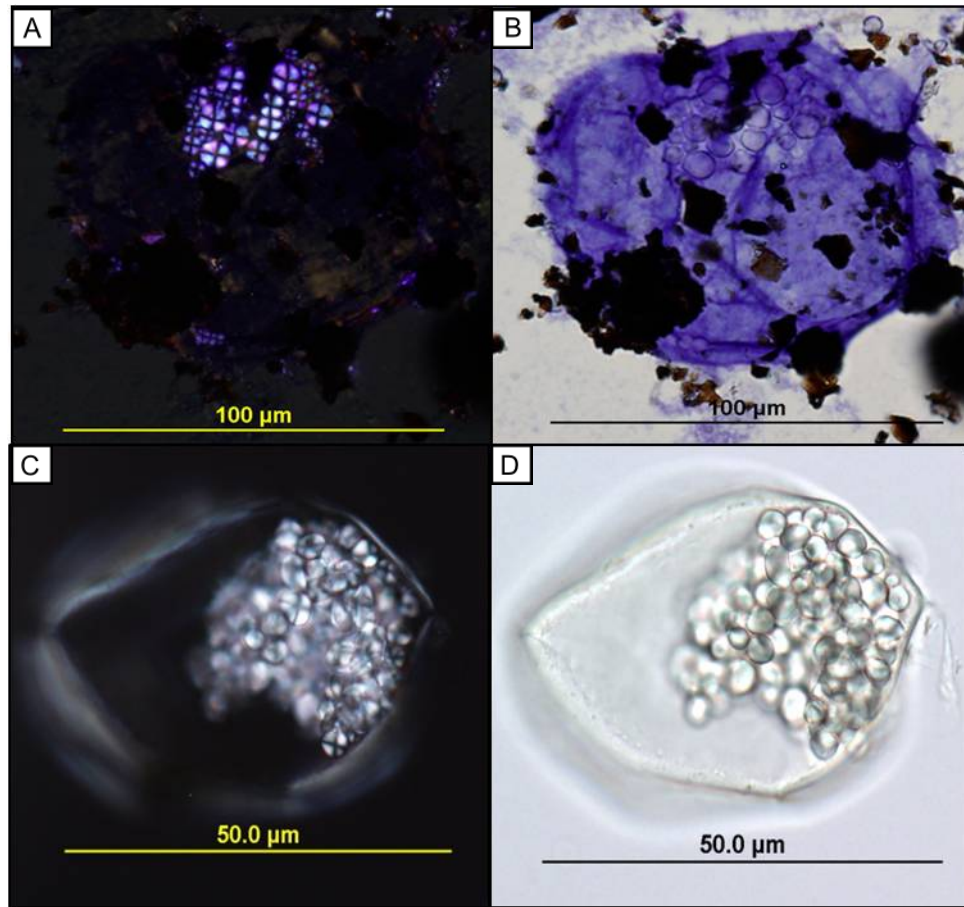


Fig. 8.18 Example of an intact sac containing possible *Typha latifolia* starch grains recovered from carbonized food residue from the Avonlea site viewed under XPL and PPL (A-B). Modern example of a large sac containing *Typha latifolia* starch grains (C-D).

8.2.6.b Soil Sample Results

One sample of soil/matrix was obtained from the Avonlea site and analyzed for microfossil content. This sample was associated with ceramic remains recovered during the 1985 excavation of the site. This soil sample was taken from matrix surrounding a parallel grooved ceramics. Diagnostic ‘wavy-top’ rondels were recovered from this

sample in addition to those recovered in the Avonlea carbonized food residue. Possible maize and *Zizania* sp. rondels were also recovered. Unlike the soil samples from the Miniota site, very few diagnostic microfossils were recovered from the Avonlea soil sample. However, a single diagnostic maize starch was recovered from the soil sample. Another plant that was identified was *Nymphaea odorata* ssp. *tuberosa*.

Table 8.6

Diagnostic Plant Microfossils Observed in the Avonlea Site Carbonized Food Residue and Soil Samples.

Site	Sample	Phytoliths			Starch Grains		Pollen
		<i>Zea mays</i> Rondel	<i>Zizania</i> sp. Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>	<i>Zea</i>
Soil Samples							
Avonlea	Soil Sample	4	0	0	2	0	0
Food Residue							
Avonlea	2382	3	1	0	0	0	0
Avonlea	1965	2	1	0	1	0	0
Avonlea	Big Pot	2	0	0	11	8	1

8.2.7 Garratt site EcNj-7 (Carbonized Food Residue)

The two samples analyzed from the Garratt site contained little amounts of residue but again provided sufficient phytoliths to allow interpretation. Not only were a large amount of phytoliths present, but also some of these were located *in situ*, held within plant structures. Similar to the Miniota site, a high amount of gelatinized starch grains were observed. The Garratt samples both contained diagnostic ‘wavy-top’ phytoliths as well as cross shaped phytoliths similar to maize. A large amount of positive *Zizania* sp. rondels were recovered in both residue samples (Fig. 8.19). The Garratt samples contained the highest amount of *Zizania* sp. phytoliths of all samples in this study.

Diagnostic starch grains of maize and bean were recovered in both samples from the Garratt site. Possible Squash starch grains were also observed in the residue. Wild plants that were identified included *Claytonia caroliniana*, *Nymphaea odorata* ssp. *tuberosa*, *Sparangium eurycarpum*, *Osmorhiza longistylis*, and *Prunus virginiana*.

Table 8.7

Diagnostic Plant Microfossils Observed in the Garratt Site Carbonized Food Residue Samples.

Site ID	Sample	Phytoliths			Starch Grains	
		<i>Zea mays</i> Rondel	<i>Zizania</i> sp. Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>
Garratt	V1	5	4	0	2	6
Garratt	V2	4	5	0	11	5

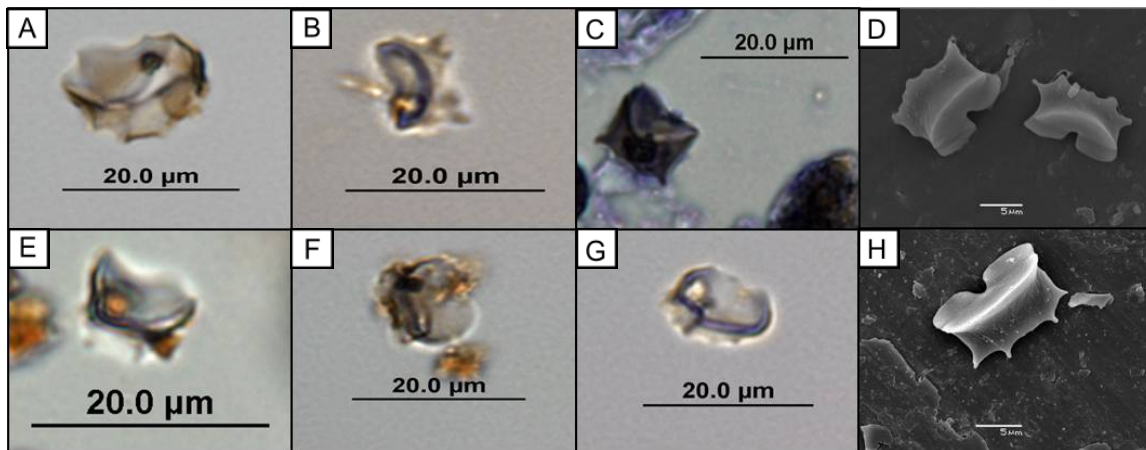


Fig. 8. 19 Examples of *Zizania* sp. rondel phytoliths recovered from Avonlea stone tools and carbonized food residues. Multi-spiked indented rondels recovered from carbonized food residue from the Miniota site (A) and Garratt site (B,E,F,G). Multi-spiked indented rondel recovered from stone tool residue from the Gull Lake site (C). Comparative Scanning Electron Microscope (SEM) examples of *Zizania* sp. rondel phytoliths (D,H) (Taken by Surette 2008).

8.2.8 Remembrance Site (EjNq-19) (Carbonized Food Residue)

Diagnostic ‘wavy-top’ phytoliths were recovered from a single parallel grooved rim sherd. Although the total weight of the residue analyzed was quite small, phytolith counts were achieved. In addition to ‘wavy-top’ phytoliths, possible maize starch grains were also recovered. Unfortunately, these starch grains did not exhibit any diagnostic traits to enable a confident identification.

Contrary to the results found in the phytolith sample, the starch sample did not yield microfossil evidence of maize. However, identifiable starch grains produced by *Psoralea esculenta* and *Platanthera dilatata* were observed.

Table 8.8

Diagnostic Plant Microfossils Observed in the Remembrance Site Carbonized Food Residue Samples.

		Phytoliths			Starch Grains	
Site ID	Sample	<i>Zea mays</i> Rondel	<i>Zizania sp.</i> Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>
Remembrance	Rim	2	0	0	0	0

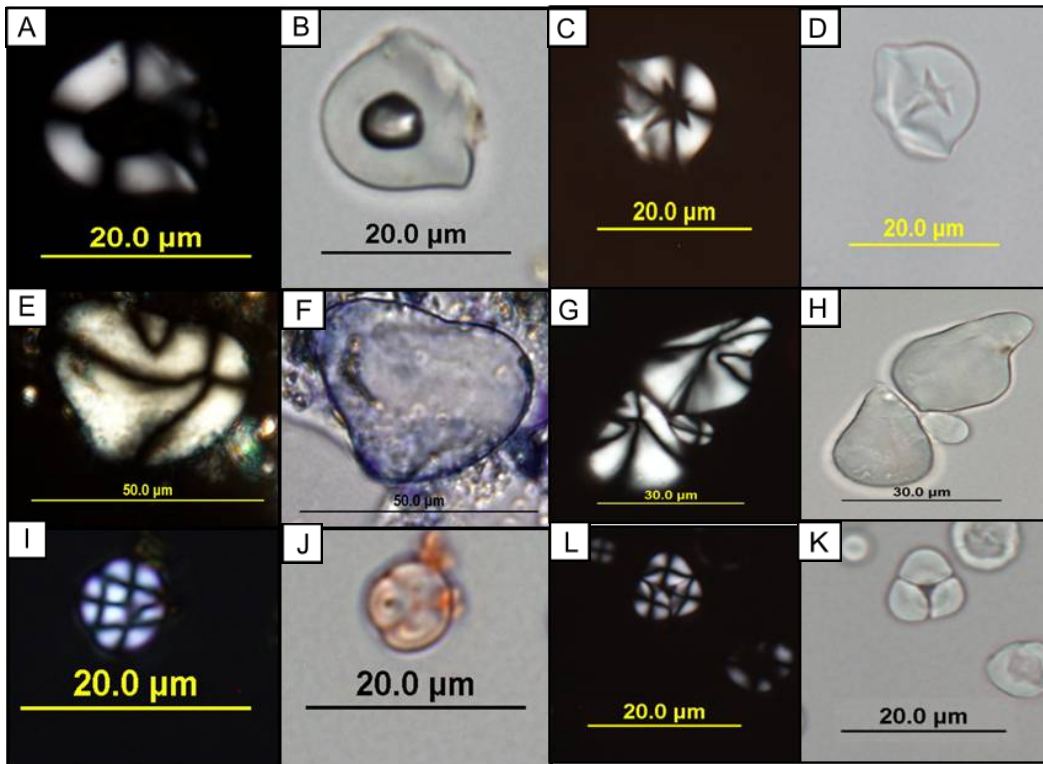


Fig. 8. 20 Examples of starch grains from wild plants found in Avonlea food residue. Specimens shown under XPL and PPL. Possible *Psoralea esculenta* starch grain observed in the Remembrance site carbonized food residue (A-B). Modern example of *Psoralea esculenta* starch grain (C-D). Possible *Lilium philadelphicum* starch grain recovered from stone tool residue from the Gull Lake site (E-F). Modern examples of *Lilium philadelphicum* starch grains (G-H). Possible *Acer negundo* semi-compound starch grains observed in the Miniota site carbonized food residue (I-J). Modern example of *Acer negundo* semi-compound starch grains.

8.2.9 Sjovold Site (EiNs-4)

The Sjovold site provided the opportunity to analyze residue from three different archaeological/behavioral contexts. This included carbonized food residue from two ceramic vessels, stone tools from two occupation layers, and a large fragment of FCR (fire-cracked rock) from a cooking feature.

8.2.9.a Carbonized Food Residue Analysis

The earliest vessel consisted of a net-impressed vessel that was highly fragmented. The second vessel was from a later context, and consisted of a very large, partially reconstructed, parallel-grooved vessel.

Maize ‘wavy-top’ phytoliths were recovered from both vessels (see Table 8.10). Other diagnostic phytoliths included *Zizania* sp. rondels that were also found in both vessels. Both vessels from the Sjovold site contained numerous identifiable starch grains. Maize starch grains were observed in residue from both vessels. Starch grains from bean and squash were observed from the residue at the Sjovold site. Bean starch grains were recovered in both samples, while squash was recovered only in the later Avonlea vessel. Wild plant starches were also observed in the later parallel grooved vessel. These wild plants included *Psoralea esculenta*, *Lomatium foeniculaceum*, *Claytonia caroliniana*, *Nymphaea odorata* ssp. *tuberosa*, and *Sparangium eurycarpum*. In the earlier net-impressed vessel, starch grains from *Prunus virginiana* were the only wild starches identified. The lack of identifiable wild starches from the earlier sample may be explained by the high amounts of gelatinized and damaged starch grains that were observed.

8.2.9.b Starch and Phytolith Content of Stone Tool Residue

In total, three stone tools from the Avonlea layers excavated at the Sjovold site were selected for analysis. These tools were selected based on visible evidence of wear on the surfaces of the stone tools. Two of these were from layer 6 (S-1 and S-2), while only one (S-3) was available from the earlier layer 7. These stone tools were identified by (Dyck and Morlan 1997) as hammer stones and chipping anvils primarily used for flint knapping. However, this interpretation is not consistent with the results of my microfossil analyses, as discussed below.

Of the three stone tools, maize phytoliths were recovered from all stone tools examined. Lithic artifact #2562 contained 'wavy-top' phytoliths in both the wet brush and sonicated samples, artifact #1999 yielded 'wavy-top' maize phytoliths from all processing stages/subsamples, while stone tool #2464 yielded 'wavy-top' maize phytoliths in both the wet brush and sonicated samples. Other than maize, scalloped shaped squash phytoliths were observed in a sonicated sample obtained from stone tool #2562.

The stone tools also yielded identifiable starch grains. On stone tool #2562, maize starch grains were observed in the dry brush and wet-brush stages. Stone tool #1999 yielded maize starch grains in the wet brush and sonicated samples, while stone tool #2464 contained maize starch grains in the wet brush sample. Diagnostic bean starch grains were also observed in all of the samples from the Sjovold stone tools. Stone tool #2562 contained significant amounts of diagnostic bean starch grains in all three sample

stages while the other two samples contained bean starch in the dry brush and sonicated samples. Stone tool #2562 also contained possible squash starch grains. The wild starch grains that were observed in the residue from the stone tools were solely from tuberous plants. These plants included *Psoralea esculenta*, *Nymphaea odorata* ssp. *tuberosa*, *Plantathera dilatata*, and *Caltha palustris*. It is important to note that there was a high amount of starch grains exhibiting signs of mechanical wear or damage compared to gelatinized starch grains. In comparison to the carbonized food residue results, the stone tool samples contained a higher amount of starch grains exhibiting signs of mechanical wear (Table 8.9). This trend was observed in all stone tool samples. One exception to this trend was associated with the bell shaped pestle (1294) from the Gull Lake site. This artifact yielded more gelatinized than mechanically damaged starch grains. However, this pestle shows signs of heating (Kehoe 1973), so the gelatinized starch grains likely derived from this heating event.

Table 8.9.

Number of gelatinized and mechanically worn archaeological starch grains identified in each Avonlea samples.

Borden	Site	Sample ID	Gelatinized Starch	Mechanical Wear	Total Microfossil Count
Stone Tools					
EiNs-4	Sjovold	FCR Wet Brush	10	9	316
EiNs-4	Sjovold	FCR Sonicated	9	0	303
EiNs-4	Sjovold	S-1 2562 Dry Brush	2	5	12
EiNs-4	Sjovold	S-1 2562 Wet Brush	11	21	85
EiNs-4	Sjovold	S-1 2562 Sonicated	5	11	266
EiNs-4	Sjovold	S-2 1999 Dry Brush	0	3	263
EiNs-4	Sjovold	S-2 1999 Wet Brush	0	5	281
EiNs-4	Sjovold	S-2 1999 Sonicated	0	20	335
EiNs-4	Sjovold	S-3 2464 Dry Brush	1	3	49
EiNs-4	Sjovold	S-3 2464 Wet Brush	3	2	282
EiNs-4	Sjovold	S-3 2464 Sonicated	3	3	261
EaOd-1	Gull Lake	1294 (25) Dry Brush	5	4	122

EaOd-1	Gull Lake	1294 (25) Wet Brush	42	27	351
EaOd-1	Gull Lake	1294 (25) Sonicated	5	8	265
EaOd-1	Gull Lake	2024 Dry Brush	2	7	55
EaOd-1	Gull Lake	2024 Wet Brush	2	11	286
EaOd-1	Gull Lake	2024 Sonicated	10	3	91
EaOd-1	Gull Lake	2323 Sonicated	2	25	368
Food Residue					
EaMg-12	Miniota	M3 Rim	339	2	684
EaMg-12	Miniota	M6 Rim	226	6	505
EaMg-12	Miniota	M2 Rim	586	10	1107
EaMg-12	Miniota	M5 Rim	1354	4	1876
EaMg-12	Miniota	Entire Vessel	1900	3	2226
EbMp-6	Broadview	1359 Rim	387	0	1138
EbMp-6	Broadview	1492 Body	237	0	500
EbMp-6	Broadview	1574 Body	90	0	347
EeMw-26	Lebret	R-2-68 SEQ	35	20	320
EeMw-25	Lebret	R-8 Body Lv. 15	53	0	1746
EeMw-26	Lebret	Lv. 12 XU 8 NEQ	37	1	761

EaNj-1	Avonlea	2382 Rim	6	0	457
EaNj-1	Avonlea	1965 Rim	0	3	711
EaNj-1	Avonlea	Big Pot	315	10	537
EcNj-7	Garratt	Vessel 1	456	0	308
EcNj-7	Garratt	Vessel 2	75	11	459
EiNs-4	Sjovold	Vessel F	414	4	310
EiNs-4	Sjovold	Vessel G	72	21	345
EjNq-19	Remembrance	Rim	28	3	525

8.2.9.c FCR (Fire-Cracked Rock) Residue Samples

The FCR sample from the Sjovold hearth feature was only exposed to wet brush and sonicated sampling due to its fragility. However, maize ‘wavy-top’ rondels were recovered in both wet brush and sonicated samples. In addition to maize phytoliths, maize starch grains were also observed in both samples. Similar to the starch results found from the stone tool residue, bean starch grains were also found from the FCR samples. Also, wild starch grains from *Lilium philadelphicum* and *Nymphaea odorata* ssp. *tuberosa* were observed.

Table 8.10

Diagnostic Plant Microfossils Observed in the Sjovold Site Carbonized Food Residue and Stone Tools/FCR Samples (DB = Dry Brush, WB = Wet Brush, and SN = Sonicated).

Site	Sample	Phytoliths			Starch Grains	
		<i>Zea mays</i> Rondel	<i>Zizania sp.</i> Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>
Food Residue						
Sjovold	Vessel F	8	1	0	3	7
Sjovold	Vessel G	4	1	0	6	4
Stone Tools						
Sjovold	FCR WB	3	0	0	9	2
Sjovold	FCR SN	1	0	0	8	8
Sjovold	S-1 2562 DB	0	0	0	1	1
Sjovold	S-1 2562 WB	1	0	0	4	4
Sjovold	S-1 2562 SN	2	0	2	0	5
Sjovold	S-2 1999 DB	1	0	0	0	1
Sjovold	S-2 1999 WB	3	0	0	3	0
Sjovold	S-2 1999 SN	4	0	0	1	22
Sjovold	S-3 2464 DB	0	0	0	0	3
Sjovold	S-3 2464 WB	1	0	0	1	0
Sjovold	S-3 2464 SN	1	0	0	0	2

8.2.10 The Gull Lake site EaOd-1 (Stone Tool Residue)

The Avonlea layers at the Gull Lake did not contain any ceramics. However, stone tools were recovered and analyzed as part of this study. Two bell-shaped pestles and a single flat stone were analyzed for plant residue. Bell shaped pestle #2024 was

recovered from one of the earliest layers at the Gull Lake site and associated charcoal provided an approximate date of AD 50 (1900 +/- 65 BP).

The residue obtained from the bell-shaped pestles contained a high amount of visible calcium carbonate crystals that limited the visibility of plant microfossils. Bell-shaped pestle #1294 did, however, yield maize phytoliths in both the wet brush and sonicated samples while bell shaped pestle #2024 only yielded maize rondel phytoliths in the wet brush sample. A possible metaté (#2323) also contained maize rondel phytoliths in the sonicated residue sample. *Zizania* sp. rondel phytoliths were also observed in the sonicated sample of bell-shaped pestle #1294.

Maize starch grains were present in both of the bell shaped pestles as well. In bell-shaped pestle #1294, maize starch grains were observed in the dry brush and wet brush stages while the second pestle (#2024) yielded a high amount in the dry brush and sonicated stages. The sample obtained from the flat stone artifact contained the highest amount of maize starch grains observed in all of the samples in this study. This sample also contained numerous diagnostic maize starch grains. Similar to the results found in the stone tools analyzed from the Sjøvold site, bean starch was present in both pestle residues. Bell shaped pestle #2024 yielded bean starch in both the wet brush and sonicated samples while the #1294 pestle contained little amounts of bean starch in the dry and wet brushed samples. No bean starch grains were recovered in the metaté residue. Starch grains similar to those produced by *Nymphaea odorata* ssp. *tuberosa*, *Peltandraica virginica*, and *Arisaema triphyllum* represented the wild starch grains recovered from the bell shaped pestle samples. The appearance of starch grains solely from plants bearing

tubers is a trend that is documented in this site, similar to the results found at the Sjovold site.

Table 8.11

Diagnostic Plant Microfossils Observed in the Gull Lake Site Stone Tool Residue Samples (DB = Dry Brush, WB = Wet Brush, and SN = Sonicated).

Site	Sample	Phytoliths			Starch Grains	
		<i>Zea mays</i> Rondel	<i>Zizania</i> sp. Rondel	<i>Cucurbita</i> sp.	<i>Zea mays</i>	<i>Phaseolus vulgaris</i>
Stone Tools						
Gull Lake	1294 (25) DB	0	0	0	2	1
Gull Lake	1294 (25) WB	2	0	0	10	2
Gull Lake	1294 (25) SN	1	1	0	0	0
Gull Lake	2024 DB	0	0	0	3	0
Gull Lake	2024 WB	1	0	0	0	4
Gull Lake	2024 SN	0	0	0	7	8
Gull Lake	2323 SN	2	0	0	24	0

8.2.11 Possible Robust Globular Phytoliths

One type of unknown phytolith that was able to be confidently identified in the carbonized food residue samples from the Miniota (n=3), Garratt (n=3), Broadview, Avonlea (n=2), Lebret (n=1), and Sjovold (n=3) sites (Fig. 8.21). These phytoliths were

similar to the robust irregular phytoliths described by Pearsall *et al.* (2003).

Distinguishing features of these phytoliths are long speculate projections, a 3-d globular surface, smooth-visible body, heavily silicified, and between 20 to 50 μm in size (Pearsall *et al.* 2003). Robust globular phytoliths are known only in maize and teosinte, and are produced in the fruit case, glumes, cupules, and other portions of the inflorescence (Pearsall *et al.* 2003). The unknown phytoliths observed in these samples contained all of these features and may provide further supporting evidence of maize.

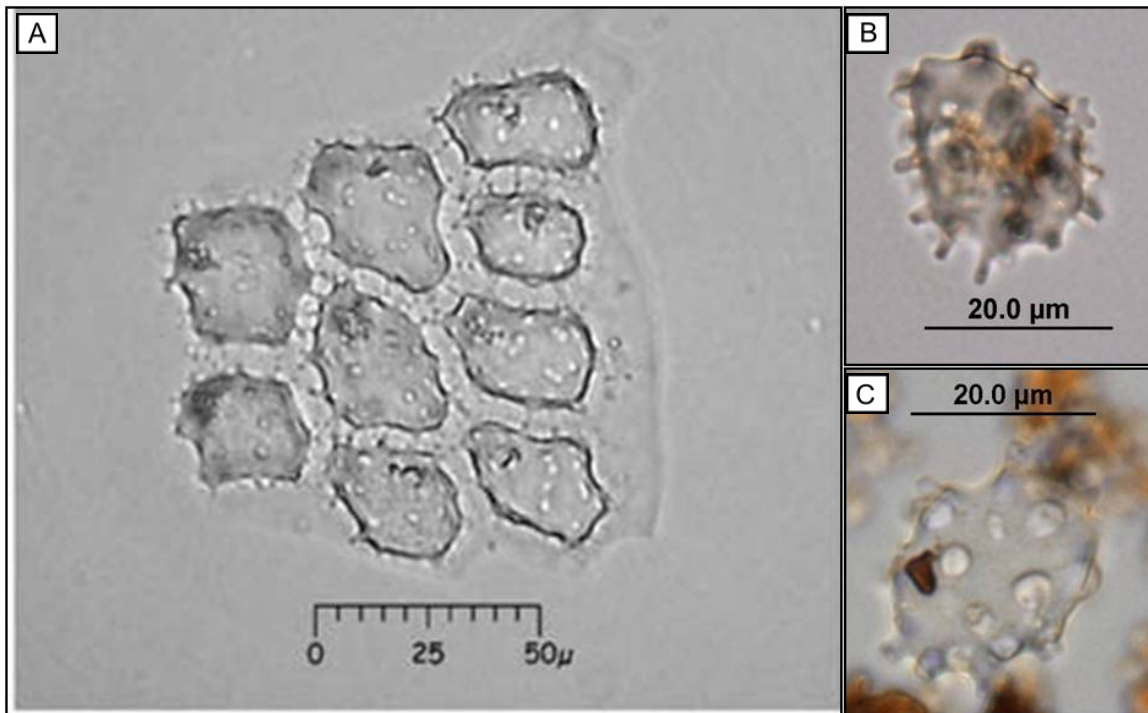


Fig. 8.21 Robust globular body phytoliths of maize. Comparative section of robust globular body phytoliths produced in maize (A) (Pearsall *et al.* 2003). Possible robust globular phytoliths found in the carbonized food residue from the Miniota site (B) and the Garratt site (C).

CHAPTER 9

INTERPRETATIONS

9.1 Introduction

Interpretations of my research results are provided in the following four sections. First, the possibility of contamination is discussed in order to identify the antiquity of the microfossils identified in these theses. This is followed by a discussion of the plants identified in Avonlea contexts, including both domesticated and wild species. Following this section, the possible sources (trade, small-scale horticulture, or a combination of the two) for the domesticated plants will be presented. Finally, the importance of these results for cultural historical interpretation of the Northern Plains, Central Plains, and Eastern Woodlands is discussed.

9.2 Contamination Issues

Previous archaeological investigations at Avonlea sites have yielded no macrobotanical evidence of domesticated plants, yet the plant microfossil evidence at the eight Avonlea sites examined here indicates the presence of both wild and domesticated plants. Could the presence of maize micro-remains on these artifacts be the result of recent contamination?

Contamination in the field may consist of recent domesticated and wild plant microfossils penetrating older cultural levels at archaeological sites. However, studies by Haslam (2006) and Therin (1998) show that starch microfossils move very little in soils and remain in or near to the original layers of deposition. Although these studies have not been able to test these results on a longer time-scale, these experiments indicate that pre-excavation contamination of artifacts by modern starch is of little or no concern. Further evidence against surface contamination is provided by the location and depth of the cultural materials analyzed in this study. The majority of the Avonlea site components, with the exception of the Broadview site, have well-defined stratigraphy consisting of multiple cultural and non-cultural layers. In many cases the archaeological deposits are located well below surface. At the Miniota site, for example, the Avonlea materials are located approximately two metres below surface (Landals 1995). It seems highly unlikely that modern starch and phytoliths from New World crops would filter through two metres of fine-grained sediment and penetrate all food residue samples with a large quantity of contaminants in a short period of time. I also note that absence of starch from Old World cultigens (e.g., wheat and barley) on the material examined argues against the possibility of recent contamination by this means.

Another source of contamination may occur through the handling of artifacts in the field. Although this is very difficult to address because many of these sites were excavated over 20 years ago, there is no reason to expect that normal artifact handling would result in the deposition of large numbers of maize starch grains and phytoliths on Avonlea artifacts. Improper handling of artifacts usually involves the transfer of food materials, plasticine or other modern materials from archaeologists to artifacts. The main

problem to this scenario is that this would only result in the deposition of starch onto samples. Maize phytoliths, for example, are only produced in edible portions such as the cobs. Therefore, the presence of numerous maize phytoliths reduces the likelihood of this form of contamination.

The possibility of contamination within the carbonized food residue is especially unlikely since it provides a 'protected environment' for organic microremains (Evershed 2008; Oudemans and Boon 1991; Patrick *et al.* 1985). In addition, most ceramics are cleaned after excavations in laboratory settings. Furthermore, the radiocarbon dates from the Miniota site food residue all yielded tightly overlapping dates with standard deviations of +/- 30 cal BP. If modern carbon contaminated these samples, it would be unlikely that three dates from three separate vessels would be nearly identical and with such a small standard deviation. For these reasons, I reject the possibility that the plant microfossils identified in my samples represent modern contamination.

9.3 Plants Identified In Avonlea Contexts

9.3.1 Wild Plants

The results of microbotanical analysis of Avonlea artifacts indicate a wide variety of wild plant starches in the archaeological samples. Although it is possible that some of these starch grains and phytoliths were ‘inherited’ from the matrix, this seems unlikely due to the documented use of these plants (Shay 1980), and for reasons stated above. Based on my microfossil analyses, possible wild plants that were found in Avonlea contexts include *Psoralea esculenta* (Indian breadroot), *Platanthera dilatata* (tall-white bog orchard), *Lomatium foeniculaceum* (desert biscuit-root), *Claytonia caroliniana* (broad-leaved spring beauty), *Hordeum jubatum* (foxtail barley), *Peltandra virginica* (green arrow arum), *Nymphaea odorata* (white pond-lily), *Nymphaea odorata* ssp. *tuberosa* (white pond-lily), *Sparanganium eurycarpum* (giant bur-reed), *Osmyriza longistylis* (smooth sweet-cicely), *Quercus macrocarpa* (bur oak), *Acer negundo* (Manitoba maple), *Corylus americana* (American hazelnut), *Amelanchier alnifolia* (Saskatoon), *Prunus nigra* (Canada plum), *Prunus virginiana* (chokecherry), *Prunus pensylvanica* (pincherry), and *Typha latifolia* (cat-tail). The wild plant identifications are made with caution due to the need for further research based upon a more extensive comparative collection. Identifications of starch grains similar to those produced by exotic *Maranta arundinacea* (arrow root) were limited to unknown root/tuber and therefore require further research into native root/tuber species of the Northern Plains. Although it is possible that future analyses will suggest that these wild plant identifications may be false positives, a large

number of comparative plants analyzed (n=45) in this thesis support the interpretation of a diverse assemblage of wild plants in the Avonlea cultural materials.

Although it is clear that Avonlea groups consumed many wild plants, the proportional contribution of these plants to the diet is difficult to determine based on the microfossil evidence. Problems due to differential preservation and the uncertainty over the number of cooking events represented make interpretations difficult. The identification of an analytical approach to identifying the number of cooking events and plants being consumed from carbonized food residue needs to be developed in order to resolve this issue. Re-occurring plant taxonomic representation in the Avonlea samples indicates that some of these plants were frequently targeted by Avonlea groups. For example, starch grains from *Prunus* sp., *Nymphaea odorata*, *Quercus macrocarpa*, and *Psoralea esculenta* were found in Avonlea materials from multiple sites.

The growth seasons of these wild plants can be used to interpret Avonlea subsistence activities. For instance, aquatic (i.e. *Nymphaea odorata*, *Platanthera dilata*, *Claytonia caroliniana*) and terrestrial (i.e. *Psoralea esculenta*, *Peltandra virginica*, *Lomata foeniculaceum*) tubers are collected in the late fall-early spring (Peterson 1977) when the tuber/rhizome offered the greatest yield. Berry producing plants such as *Prunus* sp., ripen in September-October (Peterson 1977) and therefore are collected during this period. *Amelanchier alnifolia* ripens from June to September (Peterson 1977) and can be collected during this season. Similar to berries, Acorn varieties, including *Corylus americana* and *Corylus cornuta* are collected in the mid-summer to early-fall (July-September) when they mature. These plants may have also been dried and stored for use during winter months, as suggested by the Miniota site, which was occupied during the

winter to early spring (Landals 1995). By looking at when these plants were collected historically, it is apparent that the majority of the wild plants identified in this thesis would have been collected in the summer to early fall months, depending on the growing season. Therefore, it is likely Avonlea groups were collecting wild plants during the late-summer/early fall, and furthermore, preparing these plants for immediate and future use during the winter months. Analysis of both ceramic residue and stone tools also led to subtle insight into how these plants were processed.

Several similarities and differences are observed between the microfossil content of carbonized (pottery) and non-carbonized (stone tool) residues. Firstly, the starch component of most of the samples was composed of both domesticated and wild plants. This was present in most stone tool and ceramics samples, with some variations in the types of plants present. For instance, samples that were from sites located in the modern Aspen Parklands typically contained more berry starch grains whereas plains samples contained a higher number of larger tuber starch grains. This is expected given larger populations of edible berry-producing plants in the Aspen Parkland region (see Chapter 2). Although the exact location of modern Aspen Parklands during Avonlea times may not reflect current locations, one may interpret these findings to suggest ecological consistency of the Aspen Parklands during Avonlea and modern times. However, this remains tentative until future research can be completed on the Avonlea complex and other groups residing in Saskatchewan and Manitoba.

Regarding carbonized food residue, it is important to note that the parallel-grooved vessels examined in this thesis contained higher amounts of ‘tuber-like’ starch grains compared to the net-impressed vessels, which contained more berry starch. This

observation is made with caution, considering the possibility that the smaller berry starch grains may not have survived in the parallel-grooved samples. However, this may be an indication of plant selection by these parallel-grooved and net-impressed producing Avonlea groups. Avonlea net-impressed ceramics are typically recovered in eastern and northern Avonlea areas, (Southwestern Manitoba and Central Saskatchewan) while parallel grooved vessels are found in central Avonlea areas (Southern Saskatchewan and Montana) (see Fig. 9.7). It is important to note that the locations of these Avonlea ceramic regions are confined to the Aspen Parklands (net-impressed) and Mixed-Grass Prairie (parallel grooved).

The idea that differences in wild plants identified in the food residue reflecting regionalization of plant use is made with caution due to the small sample size of parallel grooved vessels from only three sites (Avonlea, Sjovold, and Remembrance). Of these sites, it is also important to note that the Remembrance site and the Sjovold site both are located in geographically overlapping net-impressed and parallel grooved regions. In addition to small sample size, the residue identified does not necessarily reflect local plants being consumed. The Avonlea tradition consisted of mobile groups, therefore the residue identified in this thesis may reflect plants collected at number of locations other than the archaeological site from which the pottery was recovered. Therefore interpretations of intracultural differences within the Avonlea complex are tentative. While it is likely that these choices were dependent on the natural environment (i.e. locally available plants), this does re-enforce the importance of plants to the palaeodiet in both ecoregions. In both Aspen Parkland and Mixed-Prairie regions, Avonlea groups were actively collecting and consuming available plants.

Also of interest is that stone tools collected from the Sjovold and Gull Lake sites contained tuber starch grains and no berry starch grains. In contrast, the ceramic residue contained both tuber and berry starch grains. This could be the result of differential preservation. However, studies have shown that smaller starch grains are more likely to be preserved (Haslam 2004). It may also be assumed that smaller starch grains would have a higher chance of survival since they may fit deeper into lithic micro-fissures. Micro-fissures have been identified as a possible ‘safe-haven’ for starch grains, protecting them from deterioration over time (Barton 2007). This lack of small berry-like starch grains may suggest berries were not prepared with stone tools but rather added to cooking vessels without modification. The presence of the larger starch grains, as well as maize starch, indicate that these stone tools were most likely used to prepare tubers and domesticated plants. Further evidence of this is provided in the conditions of the starch grains recovered from the stone tools. Both gelatinized and non-gelatinized starch grains exhibiting signs of mechanical wear were found in all of the stone tools samples (See Results Table 8.9) (Fig.7.11). It is likely that these damaged starch grains were the result of grinding and crushing by the stone tools. This may have been done to prepare these tubers into a flour-like substance, which could have been used later in the year, or, to prepare tubers and domesticated plants for cooking. Preparation of wild tubers into flour has been documented in plants such as *Peltandra virginica*, *Psoralea esculenta*, as well as indigenous cultigens of the Eastern Woodlands and Central Plains (i.e. *Chenopodium* sp., *Iva Annuua*) (Adair 1988; Messner and Schindler 2010; Peterson 1977).

Similar signs of mechanical wear on starch grains have been identified by Barton (2007), Lamb and Loy (2005), and Zarrillo (2008). Barton (2007) identified gelatinized

starch grains on the surface of stone and wooden implements from Australia and hypothesized that such starch grain damage was the result of cooked materials being mechanically processed. Thus, cooking probably explains the presence of gelatinized starch grains on Avonlea stone tools. Research by Barton (2007) indicated the use of stone and wooden implements to prepare already-cooked foods through analysis of residue and ethnographic accounts. Although the cooking of these starch grains on the stone tools may have occurred after deposition, as a result of location near a hearth (e.g., stone tool #1294 Gull Lake site) or natural fires, the processing of cooked foods seems the more likely explanation for these starch grains since most of these tools were not found near these contexts or exhibiting signs of heating. Supporting evidence of repeated processing of these plants is visible in the presence of numerous raphides in the samples.

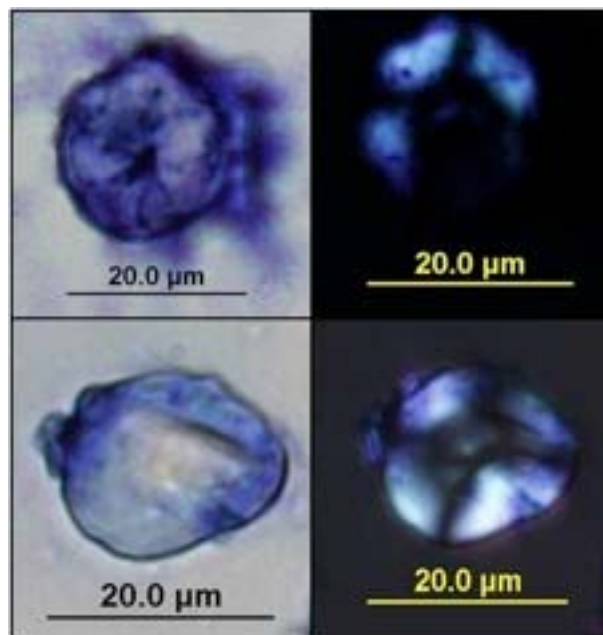


Fig.9.1 Photomicrographs of a gelatinized starch grain (Top left and right) and a starch grain exhibiting signs of mechanical wear (Bottom left and right). Both starch grains were from the bell-shaped pestle (# 2024) from the Gull Lake site. Specimens are stained with trypan blue.

Numerous raphides were found in samples from the Miniota (Fig. 9.12) and Lebret sites, providing further evidence for plant processing and preparation techniques. Raphides are composed of calcium oxalate and are needle-like in shape. Raphides are themselves inedible, but are contained in some plant storage organs. *Peltandra virginica* and *Typha latifolia* tubers are examples of plants that produce these inedible microfossils. Messner and Schindler (2010) provide evidence of plant use and preparation of *Peltandra virginica* by indigenous groups. Specific cooking and preparation techniques were noted to reduce the amount of these raphides and therefore make the highly nutritious plant edible. One of these techniques included extensive cooking of the plant material to remove the raphides. This technique may have been employed at the Miniota and Lebret sites since a large amount of gelatinized starch grains were found in the samples containing raphides. It is likely that the site occupants were extensively cooking plant materials containing raphides in an effort to make the plant palatable. This implies an extensive knowledge regarding the selection and preparation of wild plants for subsistence. Although a significant amount of literature has been published on preparation of faunal remains, very few examples (Adair 2003) are available regarding plant preparation strategies used by Avonlea groups. This represents a significant contribution to the understanding of Avonlea, and also Northern Plains, life-ways.

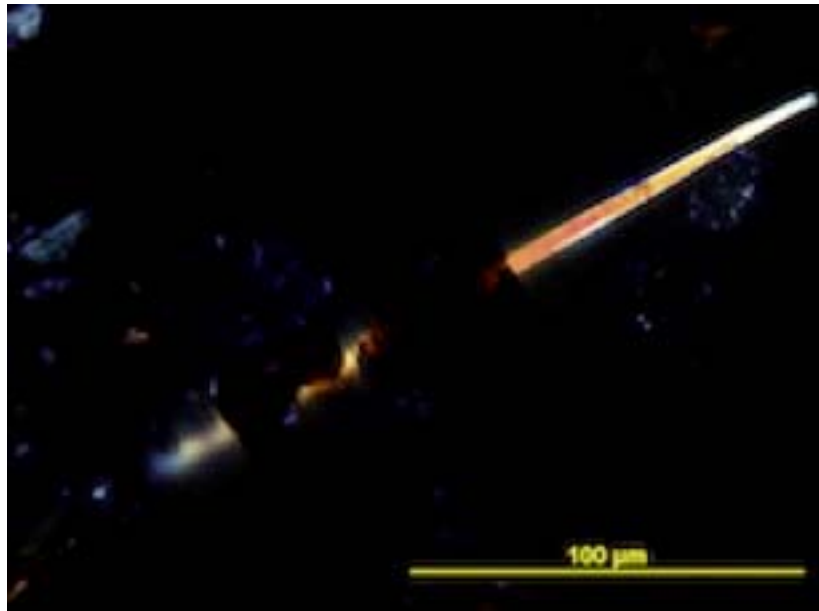


Fig.9.2 Example of a raphide observed within the carbonized food residue from the Miniota site.

The presence of intact plant tissues containing phytoliths or starch grains is also worth noting. For instance, at the Garratt site, portions of phytoliths were observed still contained within plant materials. It would seem likely that if the site occupants were intensively processing plant materials prior to cooking, it would reduce the chances of observing intact portions of plant microfossil structures. This may be interpreted as either a lack of intensive processing of plants or a relatively large plant number of plants being processed, thereby increasing the chances of seeing these intact portions.

Evidence for wild plant consumption on the Northern Plains was difficult to interpret, based on the current level of research that has been completed (Zarrillo and Kooyman 2006). Detailed summaries of wild edible plants and documented uses (Shay 1980) have been generated through ethnographic research, but due to the fragile, organic

nature of these plant foods, little is left for archaeologists to enable identification.

However, this research indicates that a wide variety of plants from multiple environmental contexts (etc. Aspen Parkland and Mixed-Grass Prairie) were collected, prepared with stone tools, and cooked in ceramics during the Avonlea period. These individuals also had extensive knowledge of how to prepare plants to make them palatable. It is clear that the plant component of Avonlea diet was diverse, with varying combinations of indigenous wild plants as well as southern cultigens and wild rice.

While the total contribution of these plants contributed to the diet is difficult to determine, the wide variety of plants – both domesticated and wild – suggests that plants contributed a significant portion of the overall subsistence of Avonlea groups. It suggests a broad foraging pattern, similar to that identified by Smith and Walker (1988) and Meyer and Walde (2009) within faunal assemblages. While interpreting faunal remains from the Lebret site, Smith and Walker (1988) proposed that Avonlea groups might not have been as selective as originally proposed (Kehoe 1973), but rather practiced subsistence strategies based on the collection of seasonally abundant resources as part of a bison-oriented strategy. The initial inclusion of domesticated plants was likely to support this broad foraging pattern. If these individuals were involved in small-scale cultivation, then some reallocation of time within the seasonal foraging cycle would have been required to maintain these crops. However, if these individuals used a mobile farming strategy (discussed further in section 9.4.2.d), this required time would be short term, and not limiting regular broad foraging patterns. The analysis of the food residue of this site also led to the identification of a wide variety of wild rice and domesticated

species as well as other wild plants. This variable plant component ‘fits’ within this strategy proposed by Smith and Walker (1988).

9.3.2 Grasses (Rondel Phytoliths)

An important category of plant remains is rondel phytoliths, which are only produced by grasses. Several of types of rondel phytoliths are characteristic of key economic plants such as maize and wild rice. It is important to note that, although maize and wild rice produce diagnostic rondels, they also produce an abundance of ‘non-diagnostic’/generic rondels that are found in many other plants. This is especially true for carbonized food residue samples where there is a reduced chance that these grass microfossils were ‘inherited’ from the surrounding matrix. Of the carbonized food residue samples examined, rondel phytoliths represent a mean of 21.25% of the total phytoliths observed, with a range between 10 to 31%. In the stone tool samples, rondels contributed from 0 to 33.3% of the total phytoliths identified, with a mean of 15.7%. In this case, the likelihood of some phytoliths being ‘inherited’ from the surrounding environment is higher than in the carbonized food residue samples. This is due to a lack of a carbonized food residue that may act to shield microfossils from external contamination. However, similar to starch preservation on stone tools, phytoliths may also become trapped in the micro-fissures of stone tools (Barton 2007; Lui *et al.* 2010; Perry 2004) and be protected from cross-contamination. This rondel count suggests that these stone tools had been used to process grasses, possibly maize. It is important to note that this is further verified by the identification of diagnostic maize phytoliths, which will

be discussed in the following paragraphs. However, due to the presence of naturally occurring phytoliths in soil, interpretation of these 'generic' rondel phytoliths is made with caution. In summary, phytolith analysis yielded evidence of grasses in carbonized food residue, stone tool residue, and soil samples. The following sections details the specific grasses found in these contexts and their archaeological significance.

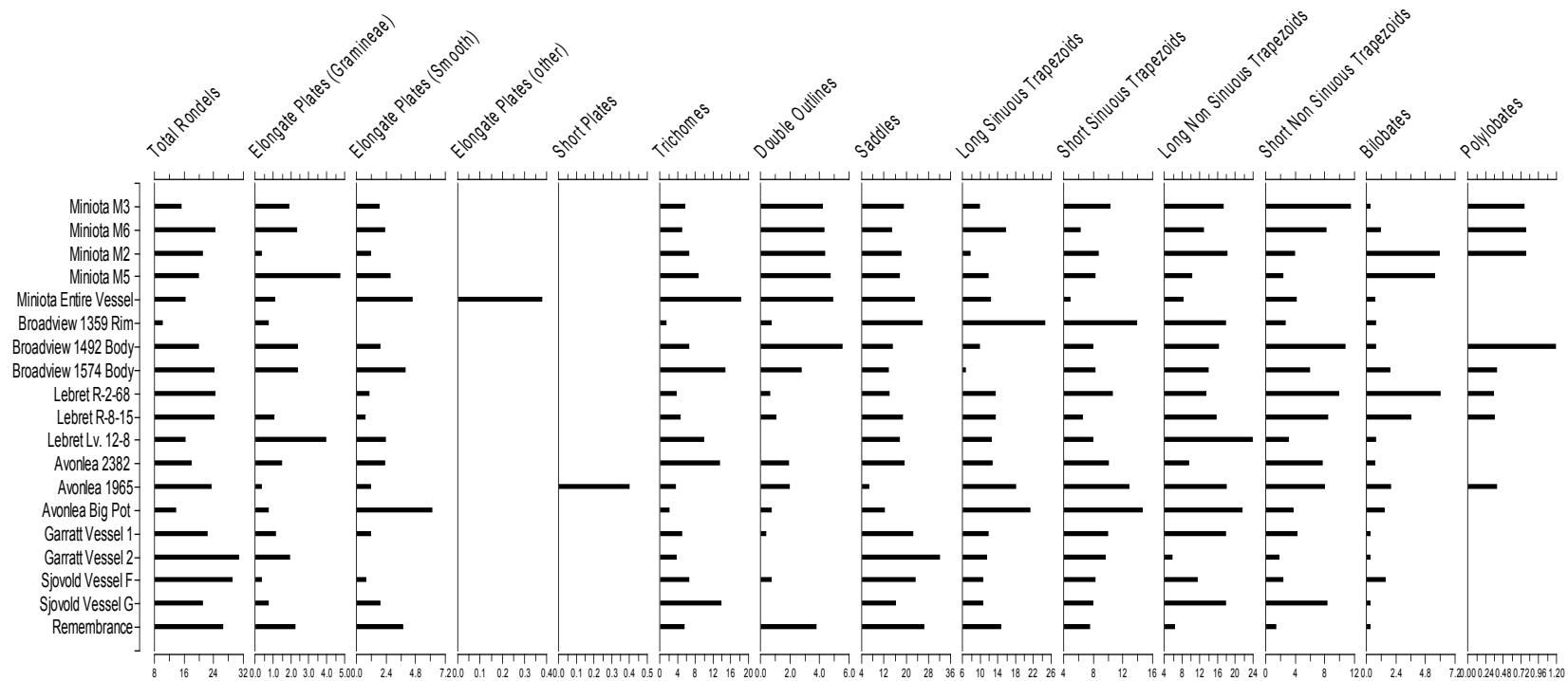


Fig. 9.3 Phytolith results from Avonlea carbonized food residue samples (Miniota, Broadview, Lebre, Avonlea, Garratt, Remembrance and Sjovald sites). Values are percentages of the total number of phytoliths counted per sample (250).

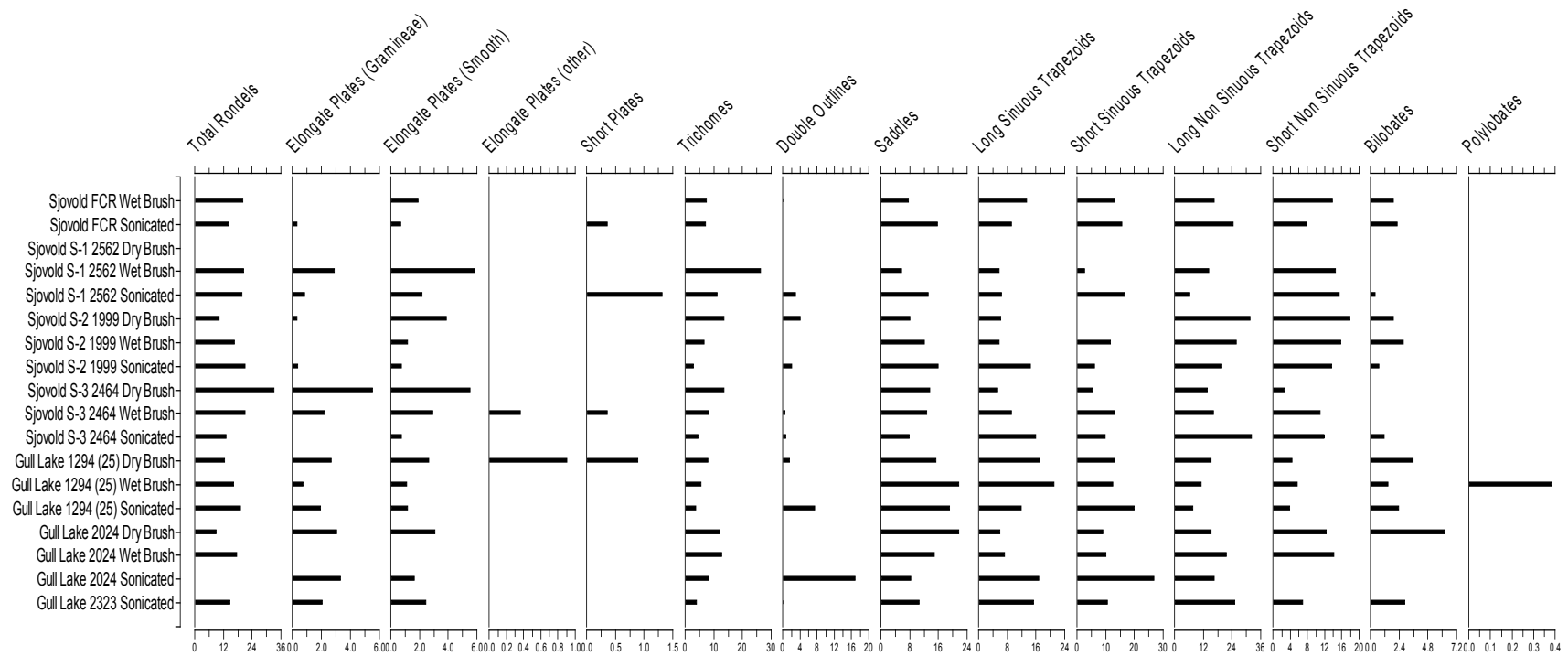


Fig. 9.4 Phytolith results from Avonlea stone tool samples (Sjøvold and Gull Lake sites). Values are percentages of the total number of phytoliths counted per sample (250).

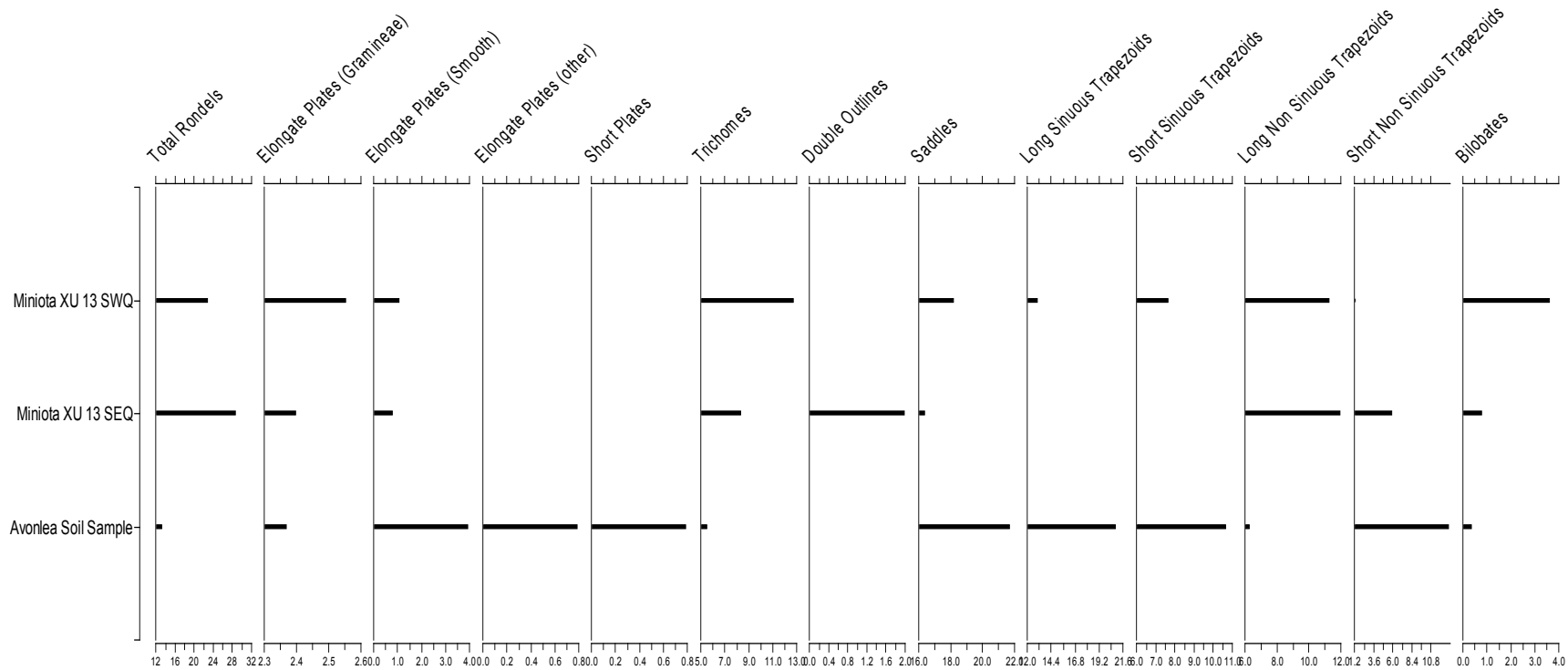
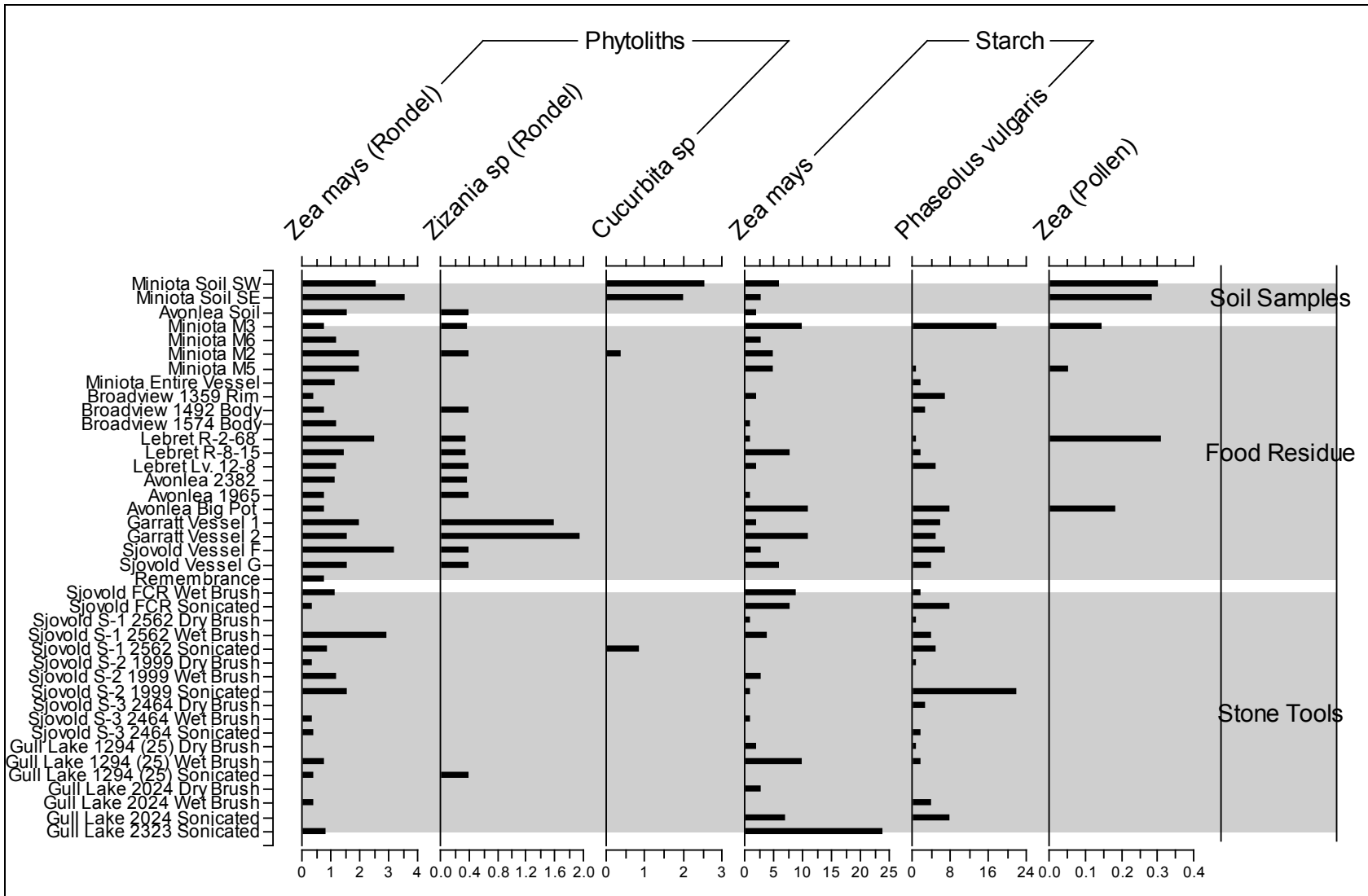


Fig. 9.5 Phytolith results from Avonlea soil samples (Miniota and Avonlea sites). Values are percentages of the total number of phytoliths counted per sample (250).

9.3.3 Maize

The carbonized food residue recovered from pottery, stone tools, FCR, and soil samples analyzed all yielded evidence of maize (see Fig.8.6 of Chapter 8). Specifically, every sample was positive for wavy-top rondel phytoliths, and many samples also yielded evidence of maize starch (see Fig. 9.6). These numbers are significant considering maize produces multiple rondel types, and only the wavy-top and ruffle-top types are considered diagnostic (Pearsall *et al.* 2003). Maize cross phytoliths and possible pollen was also identified. In most of the samples analyzed, multiple forms of maize microfossils were present, and in some cases in multiple contexts.

Because maize phytoliths were found in all of the Avonlea sites that I examined, this plant must have been widely consumed across a broad area of the Northern Plains during this time (Fig. 9.7). The northernmost sites yielding maize are the Remembrance and Sjovold sites, located near the southern edge of the Boreal Forest in central Saskatchewan (Fig. 9.7). The most westerly site considered in this study was the Gull Lake site, which is located in southwestern Saskatchewan (Fig. 9.7). The Miniota site was the most easterly site, located in the Aspen Parklands of Southwestern Manitoba (Fig. 9.7).



9.6 Important microfossil results from soil, food residue, and stone tool analysis. Phytolith values are the percentage of the total phytoliths counted for each sample (n=250), while starch values represent each individual grain counted. Pollen values are percentages of the total microfossils counted in each sample.

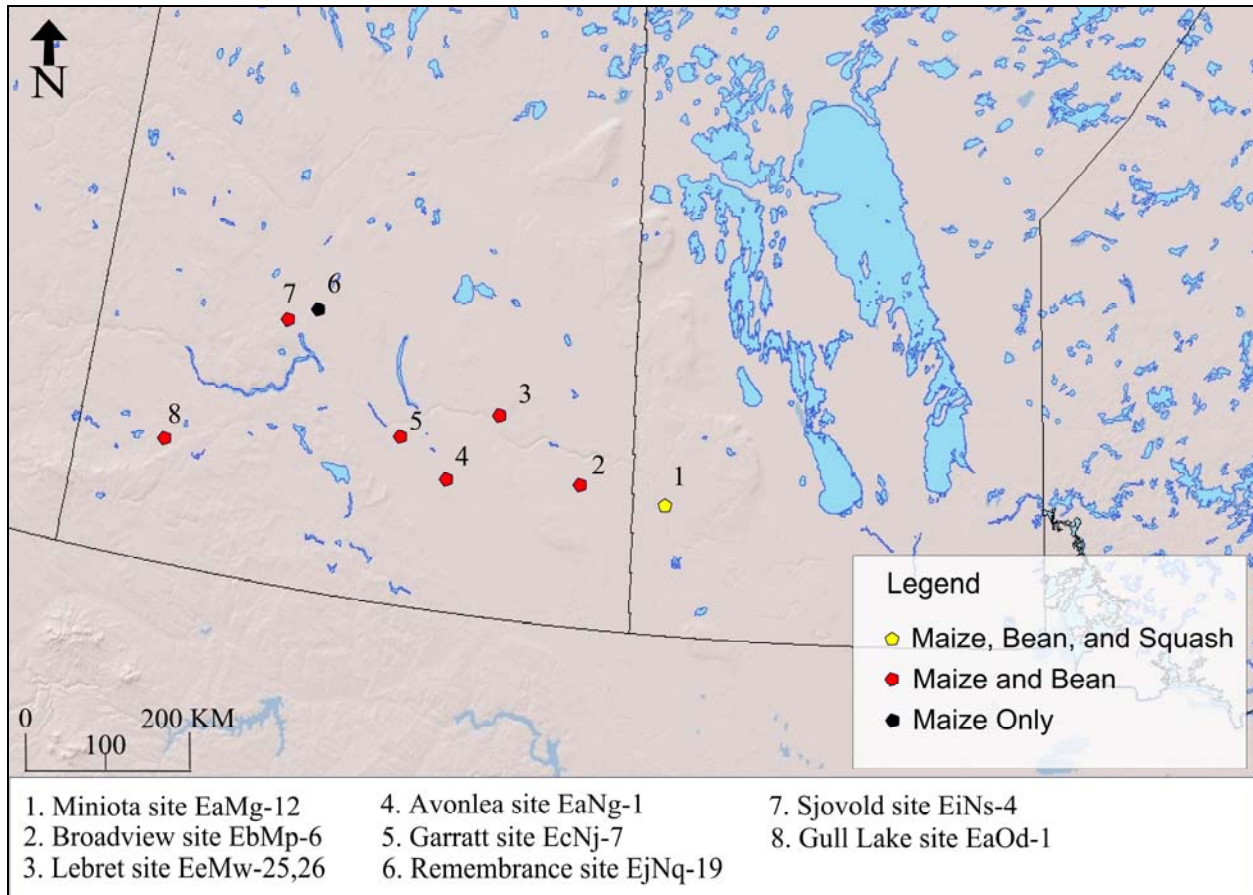


Fig. 9.7 Distribution of Avonlea sites examined in this thesis with identifications of domesticated plants found at each site.

9.3.4 Implications of the Antiquity of the Avonlea Sites Examined

This research reveals some of the earliest evidence for maize and bean consumption on the Northern Plains. Radiocarbon dates from the Avonlea sites considered in this thesis are summarized in Table 7.1. The Sjovold and Avonlea dates, while they do fall within the Avonlea time frame, do not contain tight Sigmas, and therefore, the use of these dates to infer the appearance of maize is avoided. However, dates from the Miniota, Garratt, Gull Lake, and Remembrance site provide can be considered more precise.

Table 9.1.

Radiocarbon dates from archaeological sites yielding Avonlea materials that were analyzed in this thesis. Radiocarbon ages were calibrated using INTCAL09 database (Reimer *et al.* 2009).

Site	Lab Number/Source	Material	Radiocarbon Age	2 σ Calibrated Age
Miniota	Beta – 296295 (This Study)	Food Residue	1230+/- 30 BP	AD 670 to 810
Miniota	Beta – 296296 (This Study)	Food Residue	1240+/- 30 BP	AD 660 to 770
Miniota	Beta – 296297 (This Study)	Food Residue	1230+/- 30 BP	AD 660 to 770
Avonlea	S-2623 (Klimko 1986)	Bone Collagen	1565 +/- 205 BP	AD 18 to 893*
Garratt	S-406 (Morgan 1978)	Bone Collagen	1450 +/- 70 BP	AD 431 to 679
Garratt	S-408 (Morgan 1978)	Bone Collagen	1280 +/- 60 BP	AD 653 to 881
Remembrance	Beta – 270674 (Norris 2009)	Bone Collagen	1100 +/- 40 BP	AD 880 to 1020
Sjovold	S-1762 (Dyck and Morlan 1997)	Bone Collagen	1380 +/- 200 BP	AD 224 to 1042*
Sjovold	S-1763 (Dyck and Morlan 1997)	Bone Collagen	1380 +/- 190 BP	AD 247 to 1024*
Gull Lake	S-256 (Kehoe 1973)	Charcoal	1900 +/- 65 BP	44 BC to AD 252
Gull Lake	S-149 (Kehoe 1973)	Bone Collagen	1220 +/- 80 BP	AD 663 to 972

* Indicates inaccurate 2 Sigma calibrated radiocarbon dates.

At the Gull Lake site, stone tools from multiple Avonlea layers were analyzed. The earliest date at this site was obtained from charcoal directly associated with a bell-shaped pestle in Layer 34 that was analyzed in this thesis. This charcoal sample provided a date of 1900 +/- 65 cal. 44 BC to AD 252 (S-256). Since this date was obtained from charcoal, it may be older than the age of the occupation. However, Layer 24 (which overlies the stratum containing radiocarbon sample S-256) yielded a date from bone collagen (S-149) of 1220+/-80 BP cal. AD 663 to 972. Bell-shaped pestles located in these levels were analyzed and both yielded positive evidence of maize starch and phytoliths. However, the later date from Layer 24 still falls within the Avonlea complex and indicates that Layer 34 was deposited prior to the calibrated date of AD 663 to 972.

Two radiocarbon dates were also obtained from the Garratt site, a small Avonlea campsite in central Saskatchewan. These yielded 2σ calibrated age ranges from AD 431 to 679 and AD 653 to 881. Ceramics located directly within these dated Avonlea layers at the Garratt site also yielded positive evidence for maize. Similarly, a date on bone collagen from the Avonlea layer at the Remembrance site ranged from AD 880 to 1020 (Beta 270674). Food residue from a vessel obtained from this site (Remembrance) also yielded evidence for maize.

Further evidence for early use of maize on the Northern Plains was found at the Miniota site. Radiocarbon dates obtained from food residue from three separate vessels found at the Miniota site yielded 2σ ages ranging from AD 660 to 810 (Table 9.1). The food residue from two of these vessels was also analyzed for plant microfossils and yielded positive evidence for maize. These maize remains were directly associated within dated materials, providing positive confirmation of maize at the Miniota site between approximately AD 700 and 800.

The radiocarbon dates found in the above sites all were directly located within levels that contained Avonlea ceramics, stone tools, soil samples, and FCR that was analyzed in this thesis. In some sites such as Gull Lake, Garratt, and Miniota, multiple dates were obtained and all fell within the previously accepted timeframe of the Avonlea complex (AD 300 to 1100). These sites, however, predate the previously accepted date for the dispersal of maize in many areas of the Northern United States (Adair 2003; Hart *et al.* 2002; Smith 1992c; Smith and Cowan 2003). As summarized by Smith and Cowan (2003), the conventional view is that maize arrived on the Northern Great Plains sometime around AD 800 to 1000. After this arrival, maize and other domesticated plants become widely dispersed and in some cases become dietary staples associated with the development of sedentary village life-ways. However, this research shows that maize and other domesticated plants were widespread on the Northern Plains prior to this

predicted dispersal, and therefore, it is likely that these cultigens, and associated cultural activities appeared earlier in the Central Plains and Eastern Woodlands.

9.3.5 Beans (*Phaseolus vulgaris*)

Domesticated bean starch grains were recovered from cultural materials at all Avonlea sites except for the Remembrance site. This indicates a wide dispersal and use of *Phaseolus* within the Avonlea complex. These starch grains were recovered from carbonized food residues, stone tools, and FCR from a cooking feature (see Fig. 9.6). Although bean starch grains were recovered from numerous contexts and multiple sites, no bean phytoliths were recovered. This may suggest only bean seeds were present at the sites rather than the pods, which are the only source of bean phytoliths. Another possibility may be low numbers of bean phytoliths that may have limited the chances of observing these phytoliths within a typical count size (n=250). Regardless, this research confidently indicates the inclusion of beans, along with maize, into the subsistence strategies of Avonlea groups, likely as a means to supplement hunting activities.

Beans are nutritionally complementary to maize (Adair 1988; Hart *et al.* 2003). Specifically, although maize is insufficient in the amino acids lysine and tryptophan, these are contained in beans (Adair 1988). This has been identified as one of the main reasons maize and bean were predominantly found together in agricultural villages in the Eastern Woodlands and Central Plains. Previous microbotanical residue studies addressing the Northern Plains and Boreal Forest (Boyd and Surette 2010; Boyd *et al.* 2006, 2008) have also yielded evidence of beans. Therefore, the evidence recovered in this thesis supports these earlier identifications and

also indicates a greater role of beans in the subsistence strategies of many groups residing in the Northern Plains and Boreal Forest. Although evidence for beans were found in most Avonlea sites, contemporaneous Laurel sites that were examined yielded little evidence of this plant (Boyd and Surette 2010). This may indicate that Laurel groups were trading for small amounts of beans, therefore limiting identifications of this cultigen.

It has been argued that domesticated bean (*Phaseolus vulgaris*) was available later than maize among groups living on the Great Plains. Adair (2003) estimates that beans were consumed on the Central Plains by at least AD 950 to 1200, shortly after it was locally available in the US Northeast (AD 750) (Hart *et. al* 2002). However, my carbonized food residue analysis indicates that beans were consumed alongside maize on the Northern Plains by at least AD 660 to 810 (Miniota site), and perhaps as early as AD 431 (Garratt site). In the stone tool samples from the Gull Lake site, beans starch grains were also observed on the early pestle (#2024), approximately dated to 44 BC to AD 252 (S-256). Therefore, this cultigen was very likely consumed earlier on the Central Plains and Eastern Woodlands than scholars have previously estimated. This cultigen may have been ‘missed’ in previous archaeobotanical remains due to poor preservation of macroremains. Other explanations for why this cultigen may have been missed includes the type of preparation involved to cook beans or a limited use of this cultigen which would reduce the chances of its appearance in the archaeological record (Fritz 2011).

Thus, the microfossil evidence recovered from Avonlea sites indicates use of maize and bean earlier than anticipated on the Northern Plains. However, this study incorporated plant microfossils analysis in multiple contexts rather than macro-botanical remains. Plant microfossils survive a wider variety of conditions, are produced in large quantities, and can provide positive

identifications of domesticated plant groups. In this context, plant microfossil analysis has been shown to provide subtle insight into past plant-use unavailable through conventional means.

9.3.6 Squash (*Cucurbita pepo*)

Confident identification of squash was less frequently made than maize and beans on the Avonlea materials addressed in this thesis. However, squash was present at the Miniota, Lebret, Garratt, Avonlea, and Sjovold sites. With the exception of the Miniota site, the evidence for squash at these sites is only in the form of starch grains. Therefore, because starch from squash is highly variable and similar to types produced in some wild species (see Chapter 8), presence of this plant in Avonlea sites cannot be determined with certainty. Squash phytoliths, furthermore, are produced in the stem and rind (Bozarth 1987), which are inedible, and are therefore unlikely to be found in cooking residue. Importantly, however, squash phytoliths were observed at the Miniota site (see Fig. 9.6). Thus, at this site at least, maize was consumed alongside its other ‘sisters’, beans and squash.

Other sites where all three cultivated plants were consumed together may include Sjovold, Garratt, Lebret, and Avonlea. The relatively high numbers of squash phytoliths recovered from the Miniota midden (in contrast to the cooking residues) may record squash refuse (rind and stems) in this feature. This would explain why there were squash phytoliths in the soil but very little in the carbonized food residue—i.e., the rinds would have been removed prior to cooking. The historic practice of cooking both with, and without, the rinds has been noted by Buffalo-bird-woman (Wilson 1917), Gilbert Wilson’s Hidatsa informant.

9.3.7 Wild Rice (*Zizania* sp.)

The presence of wild rice at all of the Avonlea sites, except for the Remembrance site, indicates the importance of this key economic plant for Avonlea groups. Frequently, wild rice has been suggested as a ‘prime mover’, promoting the expansion of woodland groups such as Laurel and Blackduck into Boreal Forest regions (Buchner 1979; Rajnovich 1980). Similar to beans, wild rice also provides a nutritional compliment to maize (Hart *et al.* 2003; US Department of Agriculture 2002). Although wild rice starch was not identified, the phytoliths observed provide a confident identification. Wild rice may have been acquired by Avonlea peoples through three different scenarios. The first involves the local collection of wild rice by Avonlea groups, the second involves trade with northern/eastern groups, and the last scenario is a combination of trade and local collection.

The distribution of wild rice throughout the Aspen Parklands region occupied by the Avonlea complex is unknown during this period. However, presently in southern Manitoba, wild rice is found in deep water areas of the western-banks of portions of the Red River (Moodie 1991). Moodie (1991) reports no mention of wild rice during historic times although some reports were noted on the Red River in Minnesota. Wild rice was also noted during historic times in the Assiniboine River, further west near Brandon House. Hudson’s Bay Company trader Fidler stated in 1820 that “...there are a number of small lakes East of Brandon House that produce Rizina aquatic or Wild Rice a few years ago an Indian sowed some in 2 or 3 places on the south side the Assinniboyne which grew and multiplied where water is too deep or the seasons too dry slender crops brought to maturity (Fidler 1820:fol.16).” Based on this evidence, local collection of wild rice during Avonlea times cannot be ruled out. Furthermore, it may be

possible that some Avonlea groups were locally collecting wild rice in the southern areas of the Boreal Forest in Saskatchewan. However, the limited archaeological evidence recovered in these areas (Meyer and Walde 2009) permits only speculation. Northernmost Avonlea sites, such as the Gravel Pit site (FhNa-61) (Meyer and Walde 2009) and Yellow Sky (FjOd-2) (Meyer *et al.* 1988), are both located within the southern Boreal Forest of north-central Saskatchewan, allowing the local collection of wild rice, if available.

Another possible source for wild rice may have been through trade from northern Laurel groups, where previous residue analysis has recovered wild rice phytoliths (Surette 2008; Boyd and Surette 2010), or from southern Elk Lake groups (Thompson 2000; Thompson *et al.* 1995) (Fig. 9.7). The existence of trade is difficult to document, but connections have been hypothesized between Avonlea and southern Elk Lake and northern Laurel traditions. For instance, Norris (2007) identified similar traits in net-impressed ceramics between Avonlea and Elk Lake wares suggesting a connection between the groups. Alternatively, interaction between Avonlea and Laurel components is suggested by the co-recovery of Laurel and Avonlea pottery at several sites in Saskatchewan (Meyer and Walde 2009). Therefore, the origins of wild rice into the Avonlea complex is difficult to interpret since there are multiple equally likely scenarios involving trade with surrounding Non-Avonlea groups or local collection. Future research is necessary to further trace the dispersal or use of wild rice.

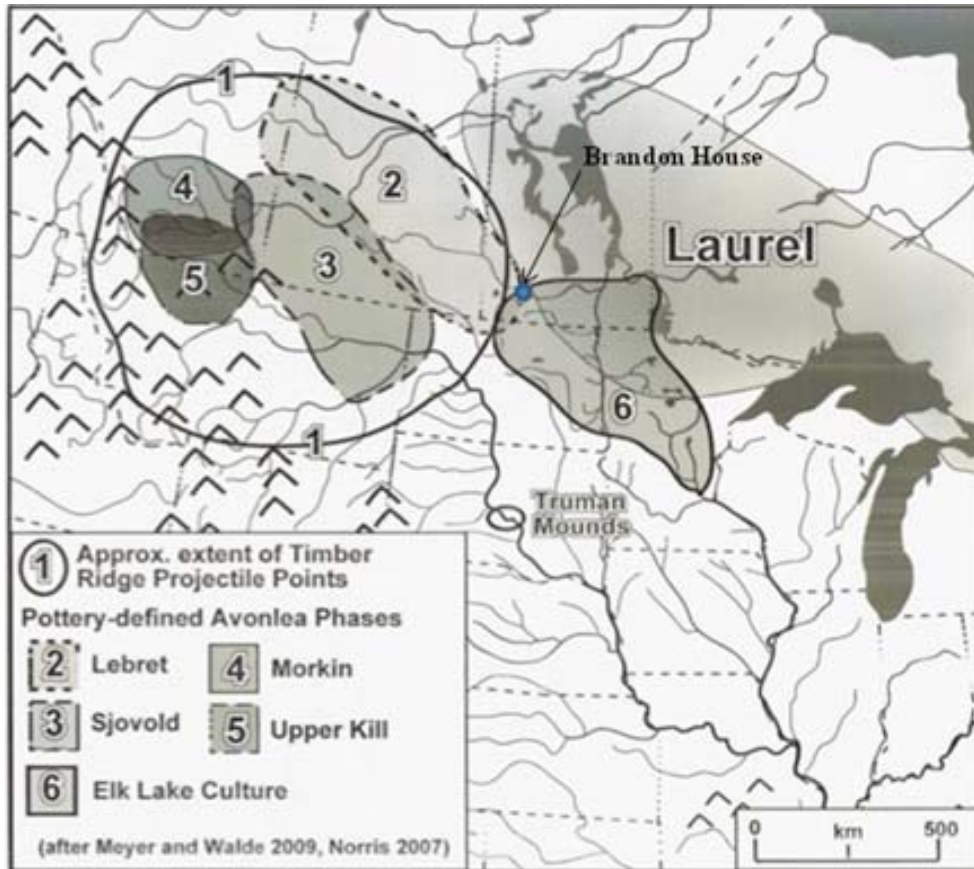


Fig. 9.8 Distribution of the Avonlea complex and other contemporaneous archaeological traditions and historic sites.

9.4 Pathways of Domesticated Plants

Considerations regarding the origins and dispersal of domesticated plants into and within the Avonlea Complex need to be further discussed. Possible scenarios include trade, small-scale horticulture, or a combination of both. The means by which these plants arrived remains uncertain and, thus, requires future research into the Avonlea complex and contemporaneous southern archaeological complexes.

9.4.1 Trade

Evidence of long-distance trade networks has been identified from Avonlea sites by previous researchers (Dyck and Morlan 1997; Landals 1995; Meyer and Walde 2009; Peck 2011). At the Miniota site, dentalium shells were recovered from the Avonlea layers (Landals 1995). These shells are typically native to the west coast of British Columbia and were highly valued status and exchange items. Also, approximately 74% of the lithics found at this site were composed of Knife River flint, which is sourced to west-central North Dakota (Landals 1995). Similarly, exotic lithics at the Broadview (Landals 1995), Avonlea (Klimko 1985a), and Sjøvold (Dyck and Morlan 1997) sites have been identified and interpreted as trade items. Given the evidence of long-distance trade of non-perishable items between Avonlea and other groups on the Great Plains and beyond, it is possible that maize and other plants were also acquired through this means.

Further evidence of interactions and shared cultural affiliation with other groups is noted in the form of ceramics produced by Avonlea groups. It has been hypothesized that both net-impressed and parallel grooved ceramics may have originated with 'southern' pottery-producing areas. Norris' (2007) analysis of Avonlea net-impressed ceramics suggested a connection with Elk Lake groups found primarily in Minnesota (Figure 9.7). Meyer and Walde (2009) propose a similar scenario, and suggest linkages between Avonlea parallel grooved ceramics and those deriving from the Truman Mounds of South Dakota (Newman 1960) (Figure 9.7). Thus, some have suggested these southern areas as origin points for the net-impressed and parallel grooved ceramics later found in Avonlea contexts (Meyer and Walde 2009; Peck 2011). Although there are similarities in these ceramic styles, this may reflect cultural influence rather than affiliation.

However, this still enforces that a connection existed between Avonlea and these southern areas (Minnesota and South Dakota). These southern groups were in closer association Middle Missouri and Eastern Woodland groups, who were likely practicing horticulture and extensive trade. It is therefore feasible that these groups in Minnesota and South Dakota would likely been able to access domesticated crops from these areas. Similar connections to southern areas have been suggested regarding projectile point morphologies. It has been argued that projectile points associated with Elk Lake Culture, such as those from Petuga (21ML11) (Bleed 1969) and Vineland Bay (Morgan 1978) sites in Minnesota, appear similar to those found in Avonlea contexts. At the Vineland Bay site, these 'Avonlea-like' projectile points were recovered in association with Elk Lake net-impressed ceramics (as reported by Morgan 1978). Similar ceramics and projectile points found in Minnesota and South Dakota furthers the connection of Avonlea with southern areas.

Further evidence of influence has been argued through the Hopewell Interaction Sphere (Syms 1977). This system involved the spread of Hopewellian influence from Ohio and Illinois including the ceramics, trade items, mortuary practices, and settlement patterns into associated autonomous groups (Mason 1970, 2002; Syms 1977). Some suggest that this system of influence greatly affected northern groups, including Laurel (Mason 1970) and Avonlea (Morgan 1978), although Wright (1999) indicates little involvement with Laurel. However, identifications of maize within Laurel contexts (Boyd and Surette 2010) offers indications of some influence on Laurel from the more southerly Middle Woodland groups. The spread of Hopewellian influence across much of North America demonstrates the capability of long-distance trade to accommodate the early dispersal of domesticated plants. The presence of maize and other

domesticated cultigens within the Avonlea contexts provides further evidence of a connection between Avonlea groups and Middle Woodland areas.

Evidence of interaction between northern/Boreal groups, such as Laurel, has also been identified by archaeologists. At the Gravel Pit site, Avonlea ceramics have been found in close association with Laurel materials (Meyer and Walde 2009). Unlike many other sites in the region, the stratigraphy is well defined at the Gravel Pit site with no evidence of mixing of cultural layers. The ceramics recovered at this site also contain blending of both Laurel and Avonlea ceramic traits. This has been viewed by some (Hanna 1983; Klimko 1985b; Meyer *et al.* 1988) as evidence of interaction between northern Laurel groups and Avonlea.

Further evidence of trade is indicated by the location of Avonlea taxonomic groups. Major Avonlea taxonomic groups, proposed by Meyer and Walde (2009), are located over major transportation corridors such as the Missouri, Assiniboine, Qu'Appelle, and South Saskatchewan rivers (see Fig.7.7). Furthermore, Klimko (1985a) plotted the location of Avonlea sites yielding radiocarbon dates, and noted that earlier Avonlea sites occurred in the southeast and then decreased in age as one moved west. Thus, it has been suggested that Avonlea groups spread westward onto the Northern Plains from the southeast. It is important to consider this as the result a possible archaeological sampling bias, since only discovered sites are mapped. Regardless, these areas would provide Aspen Parkland environments in midst of prairie and easily accessible transportation. It is possible that these transportation routes would provide efficient dispersal of domesticated plants to Avonlea groups inhabiting the Northern Plains. Maize and beans are both light-weight, easily stored, and provide valuable sources of nutrition that would be desirable for Northern Plains groups during the Avonlea period. Archaeological evidence in the form of non-perishable exotic items being found in Avonlea contexts has already

been identified as signs of long-distance trade. Given this evidence, it is reasonable to expect that some cultivated plant foods may have also been acquired by Avonlea peoples through trade. However, the microbotanical evidence also lends support to the idea that these foods were grown by Avonlea peoples themselves.

The results of this research indicate that maize and other domesticated plants were present at widely dispersed Avonlea sites and found in multiple behavioral contexts. This suggests that Avonlea groups had regular access to these cultigens, possibly through trade with unidentified food-producing populations. Furthermore, a lack of bean phytoliths may indicate that only the seeds were present at the site rather than the entire pods. This may also be the result of a sample bias, since bean phytoliths are less likely to be found in food residue unless the pods were cooked. The lack of *Cucurbita* sp. phytoliths in the micro-botanical residues, (produced in the inedible portions of the plant) (Bozarth 1987), also indicates that it might have been acquired through exchange rather than local production.

At the Miniota site, a possible wintering site, evidence of maize and other cultigens was recovered from the ceramic residue and the soil samples. The carbonized food residue may be misleading due to an inability to decipher when the domesticated plants were consumed and the exact amount these plants contributed to the palaeodiet. However, the soil samples from a midden feature support the presence of domesticated plants at the Miniota site during its occupation. This indicates that not only was maize present, but since this is possible wintering site, this group would have had to obtain enough maize to generate a surplus. This interpretation is made with caution considering it cannot be ruled out that this site may have been occupied in other seasons, such as the late summer. This surplus may have either been obtained through

interactions with nearby horticultural groups through trade, or through small-scale horticulture by this particular Avonlea group.

9.4.2 Small-Scale Production of Maize by Avonlea Groups

It has been argued that the microfossil content of carbonized food residue on Laurel pots (Boyd and Surette 2010) may reflect long-distance trade of cultivated plants between temperate and subarctic North America. This interpretation was based on conventional chronologies of the dispersal of maize, which suggested maize was acquired through trade only. In this study Boyd and Surette (2010), report few Laurel sites contained maize rondels and the highest amount of maize rondels found within Laurel samples was two, or 0.8% of a typical 250 count (Fig. 9.8). In addition, total rondel counts were above 20% in only a few Laurel samples. In contrast, all Avonlea samples were positive and in some cases, such as the Sjøvold site (Vessel F), diagnostic rondel phytoliths composed almost 3.5% of the total phytolith sample. It is also important to note that rondel counts reached 20% of the total phytoliths counted in at least one sample from every site examined (Fig. 9.9). Total rondel counts are useful since rondel phytoliths are produced only by grasses, such as maize and wild rice. While domesticated plants produce diagnostic rondels, these plants also produce non-diagnostic rondels. Therefore, a lack of diagnostic rondel phytoliths may be the result of this type being missed during a 250 phytolith count. Therefore, through comparison of total rondel counts, it may be possible to infer the relative abundance of these plants. For example, if a sample contains a high number of rondels it may suggest the inclusion of these economically important grasses. The presence of rondel phytoliths within carbonized food residue samples is due to the inclusion of grasses, some of which may have been

maize and wild rice, into the cooking contents. Therefore, a high amount of rondels identified in carbonized food residue supports the idea that these economic grasses were included in the pot.

This trend is also present when comparing wild rice microfossils between Avonlea and Laurel sites. For instance, wild rice was only found in one of the Laurel sites and it composed 0.4% of a 250 phytolith count. In Avonlea, we see that wild rice is present at all sites except for the Remembrance site and the highest amount found was in the Garratt site where wild rice contributed 2% of the total phytolith count.

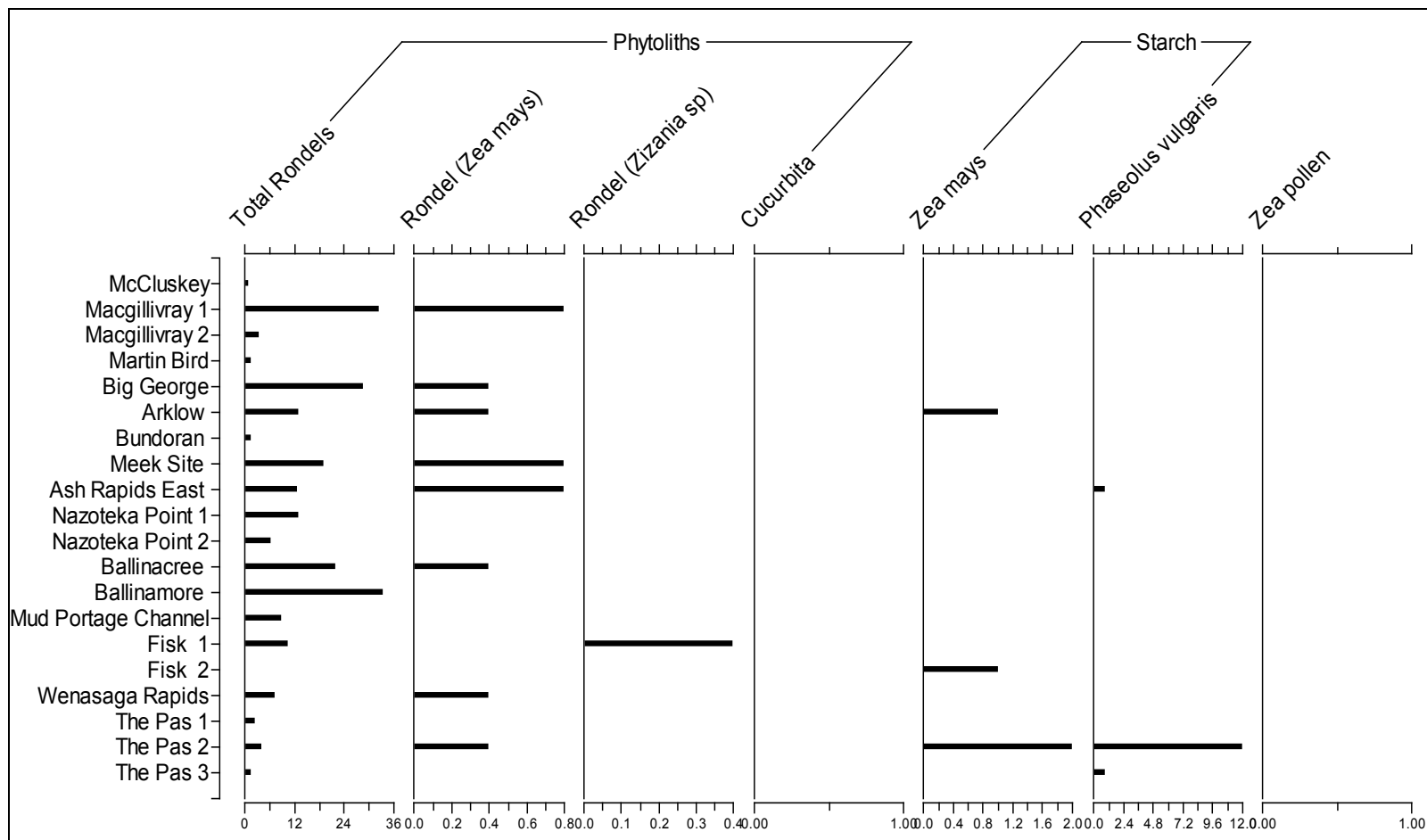


Fig. 9.9 Important diagnostic plant microfossil counts and percentages from Laurel vessels (data from Boyd and Surette 2010). Phytolith data displayed as a percentage of total phytoliths counted (250) while starch grains represent individual counts.

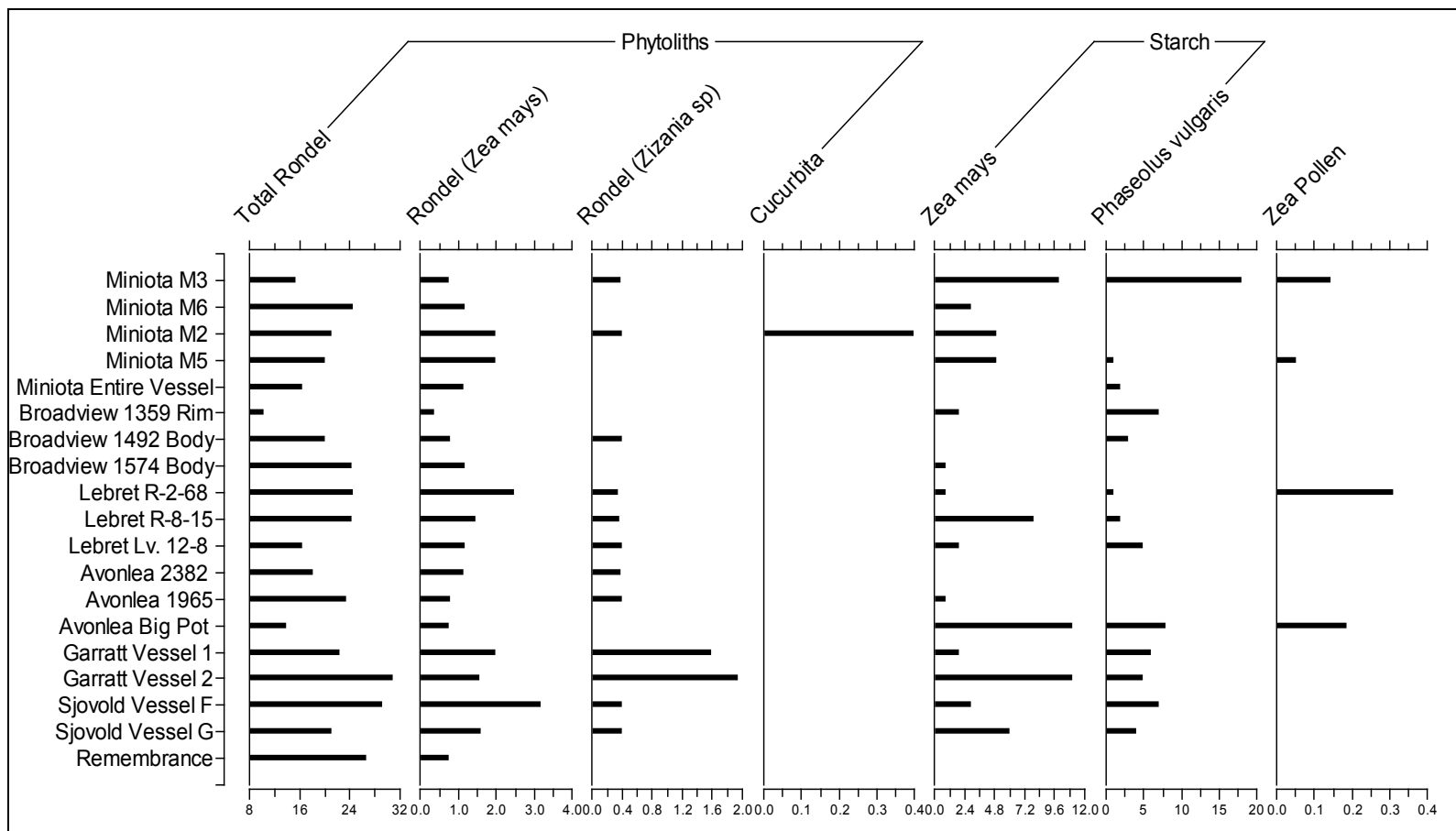


Fig. 9.10 Important diagnostic plant microfossil counts and percentages from Avonlea cultural materials. Phytolith data displayed as a percentage of total phytoliths counted (250) while starch grains represent individual counts.

It could be argued that this is the result of differential preservation or different cooking techniques between Avonlea and Laurel. However, these data reflect multiple sites, and multiple vessels within these sites, spanning a wide geographic area. Thus, this trend probably reflects differences in the importance of cultivated foods in the diet, with Avonlea peoples generally consuming larger quantities of maize and perhaps other cultigens. For instance, Laurel sites contained little evidence of beans, which may represent reduced access to this cultigen. This would explain the few positive results since Laurel may not have obtained beans regularly, unlike Avonlea groups.

Since Laurel and Avonlea are contemporaneous and located in adjacent environmental zones, it is possible that Laurel groups received maize through trade with Avonlea peoples. A suitable exchange item may have been wild rice, collected from the Boreal Forest, which has been identified in numerous Avonlea sites. This interpretation is made with caution since it is possible that Avonlea groups collected wild rice themselves during their seasonal round, which may have extended into the southern fringe of the Boreal Forest. However, archaeological evidence of interaction between groups has been suggested by many (Hanna 1983; Klimko 1985b; MacNeish 1958; MacNeish and Capes 1958; Meyer *et al.* 1988; Meyer and Walde 2009; Morgan 1978). Evidence of Avonlea/Laurel interaction was noted by Landals (1995), through examination of ground-stone celts, similar to Laurel types, recovered at the Miniota site. The timing of the Miniota site (AD 630 to 810) falls directly within the range with Laurel sites (Dawson 1983; Meyer and Hamilton 1994), such as The Pas site (Boyd and Surette 2010).

9.4.2.a Cob and Leaf Phytoliths from Avonlea Contexts

If traded, it is likely that only the maize kernels (or flour) would be traded in order to reduce bulk and weight. Ethnographic accounts of trade between aboriginal groups and Europeans during the historic period provide some insight into how this transaction occurred. In François-Antoine Larocques' 'Missouri Journal' (December, 1804) he notes the trading for items from Mandan villages and among these items obtained were "5 Bags Corn" (Moodie and Kaye 1969). Trading kernels would allow for more items to be carried over longer distances as opposed to the entire cobs. Additionally, Buffalobird-woman (Wilson 1917), a Hidatsa elder, noted that once harvest of maize was completed, the majority of the cobs were stripped of the kernels in preparation for storage. Removal of kernels for trade would reduce the chances of finding maize phytoliths (rondels and crosses). Interestingly, in the Avonlea samples considered, rondel phytoliths from maize were recovered in varying amounts at every site and in multiple contexts (Table. 9.2). Perhaps some rondels may have remained attached to the kernels after removal from the cob, and may be a source for the rondels recovered in the Avonlea materials. Although this accidental inclusion may be the case, research by Raviele (2011), has shown that maize phytoliths are more frequently deposited in food residues during the cooking of green maize cobs rather than the chance inclusion of chaff adhering to dried maize kernels. If the cooking of green corn was indeed the case, this would suggest that entire green cob portions, which are less likely to be traded-in, were locally grown by Avonlea groups examined in this study.

Table 9.2

Maize rondel phytoliths counts per site and amount recovered in each sample.

Site	Maize Rondel Phytoliths		
	Carbonized Food Residue	Stone Tool Residue	Soils
Miniota	18	N/A	16
Broadview	6	N/A	N/A
Lebret	14	N/A	N/A
Avonlea	7	N/A	4
Garratt	9	N/A	N/A
Remembrance	2	N/A	N/A
Sjovold	12	17	N/A
Gull Lake	N/A	6	N/A

Not only were maize crosses and rondels found in carbonized food residue, these microfossil types were also recovered from stone tools, FCR (fire-cracked rock), and soil samples. These phytoliths are produced in the cobs and leaves of maize, as discussed above. Although the phytolith evidence supports the presence of multiple maize portions at some of these sites, this is made with caution considering it is not known whether or not these portions were traded-in or locally grown.

9.4.2.b Evidence From Stone Tools Residues

As discussed above, the earliest bell-shaped pestle from Layer 34 (1900 +/- 65 cal. 44 BC to AD 252) recovered from the Gull Lake site yielded some of the earliest evidence of maize in this study. Comparative examples of this type of pestle were noted by Kehoe (1973) to be limited to Eastern Woodland groups. This stone tool, based on its shape and wear, is clearly designed to process food materials. The shape of other stone tools found at the Gull Lake site and the Sjøvold site were also apparently used for food preparation, including processing of domesticated plants. The results of the stone tool analysis compliments the plant identifications made based on the carbonized food residue analysis of Avonlea wares. Frequently, the presence of grinding implements has been used in conjunction with other archaeological remains (garden implements, structures, and macroremains) to identify small-scale production of maize (Schneider 2002; Zarrillo and Kooyman 2006). However, these stone tool results may also indicate the processing of maize and other domesticated plants that were acquired through trade.

9.4.2.c. *Zea* Pollen identified in Avonlea samples

Maize pollen was recovered from the soil samples and food residue from the Miniota site, and food residue from the Lebret and Avonlea sites. The recovery of *Zea* pollen within multiple contexts and multiple sites is important due to the characteristics

of *Zea* pollen. *Zea* pollen is large, heavy, and unlikely to be dispersed far from its point of origin (Fearn and Lui 1995). *Zea* pollen is considerably larger (70 to 90µm) than other grass pollen, such as wild rice (30 to 40µm) (McAndrews 1973). In addition to size, Geib and Smith (2008) outline that maize pollen is “exceedingly rare” on kernels or shucked ears and primarily contained to the husk portions enveloping the cob. Therefore finding maize pollen in carbonized food may provide evidence of non-husked ears of maize, which may be direct result of small-scale horticulture somewhere near the vicinity of the Miniota site. It is important to note, however, that this pollen may also have arrived to the Miniota site through trade, clinging to products traded in.

9.4.2.d Archaeological Evidence of Small-Scale Horticulture

The lack of unequivocal archaeological evidence of gardening – e.g., scapula hoes and other garden implements – may also be explained by a horticultural scenario. A mobile horticultural strategy would involve the planting of maize and other cultigens in one season followed by a dispersal of the groups away from the gardens and returning later in the year to harvest available yields (Chilton 1999; Graham 1994; Handsman 1995; Mulholland 1988). If these groups were mobile horticulturalists, there may be few signs of this lifestyle in the archaeological record, leaving little archaeological evidence of gardening. Archaeological excavation at the Miniota site yielded a scapula ‘paddle’ (Landals 1995) (Fig. 9.20). Another scapula ‘paddle’ was also recovered from the Sjevold site (Dyck and Morlan 1997), however, this was interpreted as a ceramic

production tool. Although the Miniota scapula was not available for analysis in this thesis, this paddle looks similar to other tools on the Northern Plains identified as scapula hoes (Grant 1961; Nicholson 1990; Wilson 1917). Until further research is completed, this interpretation should be considered speculative.



Fig. 9.11 Photograph of a bison scapula ‘paddle’ recovered from the Miniota site. Photo courtesy of Alison Landals.

9.4.3 Combination of Trade and Small-Scale Horticulture

The plant microfossil data indicated the acquisition of maize through at least trade, however, subtle lines of evidence, for example pollen, suggest the presence or close connection to entire maize plants. An equally likely explanation would be that Avonlea groups might have been involved in both trade and, at some sites, small-scale horticulture. This small-scale horticulture may have occurred at more southern Avonlea sites, such as the Miniota site, where pollen, signs of a surplus of cultigens, and additional possible horticultural evidence (scapula paddle) has been identified. The river-valley environmental setting for this site also is similar to those depicted by Buffalobird-woman (Wilson 1917). A combination of both trade and farming within the Avonlea complex explains the widespread dispersal of maize within multiple contexts and sites, multiple forms of phytoliths observed, possible pollen from the soil and ceramic samples, and lack of bean phytoliths and additional archaeological evidence of small-scale horticulture.

The Avonlea complex (AD 300 to 1100) occurs prior to the anticipated dispersal and a dietary importance of maize in the Central Plains and Eastern Woodlands around AD 800 to 1200. Evidence collected in this thesis identifies Avonlea groups as transitional forager-farming groups, trading and possibly farming domesticated plants in order to supplement wild food procurement strategies. As previously mentioned, the wild plant data obtained in this research indicates a broad foraging pattern. However, if individuals were participating in cultivation of maize in small amounts, this cultivation would have been completed in order to supplement broad foraging patterns.

9.5 Domesticated Plants and their Importance to Northern Plains Groups

The adoption of maize and other domesticated plants is often regarded as a key event in the history of indigenous societies. Although maize was likely a dietary staple, and grown by numerous groups on the Central Plains and Eastern Woodlands around AD 800 to 1000, how this dietary transition occurred has been difficult to identify. This may be due to transitional forager-farming groups that were not defined by characteristics typical of horticultural societies (e.g. scapula hoes, storage pits, sedentary living), yet were involved in the acquisition of small amounts of maize and other cultigens through trade or small-scale mobile horticulture. This leaves little archaeological evidence behind for us to track. However, recent plant microfossil studies provide new insight into food procurement transitions, previously unavailable through conventional techniques (Boyd and Surette 2010; Boyd *et al.* 2006, 2008).

Evidence from the Avonlea sites suggests the dispersal of maize and other domesticated plants by at least AD 660 to 810, and perhaps as early as AD 50, in the northernmost regions of the Great Plains. Previous evidence from the Laurel ceramics also supports this earlier dispersal. Boyd and Surette (2010) identified microfossil evidence of maize in Laurel food residue as early as AD 500, in areas of the Boreal Forest. Therefore, maize and other domesticated plants must have been dispersed throughout the Eastern Woodlands and Central Plains well before previously anticipated in order to accommodate dispersal throughout the Northern Plains and areas of the Boreal Forest.

During this period prior to AD 800 to 1000, maize is expected to have been infrequently used in the Central Plains and obtained through trade, however, this early widespread dispersal in the Avonlea and Laurel areas indicates that maize and other domesticated plants must have been more widely distributed in the Central Plains and Eastern Woodlands, and in some instances grown by mobile foraging-farming groups. Therefore, established networks were available to widely disperse maize, and other cultigens, from southern areas practicing horticulture, well before originally anticipated.

Similar to the timing of maize, my results show that *Phaseolus vulgaris* was consumed on the Northern Plains by ~AD 700, which is earlier than previous estimates for the Central Plains (AD 900 to 1200), and contemporaneous with its first appearance in the US Northeast (AD 700) (Adair and Drass 2011; Hart *et al.* 2002). This provides further support for the inclusion of domesticated crops into the subsistence strategies of many groups much earlier than anticipated or this may suggest rapid dispersal of this cultigen around AD 700. Either of these scenarios is plausible however, future research is necessary to resolve this question. Beans are often thought to have arrived later into horticultural societies (Adair and Drass 2011; Hart *et al.* 2002), but this research has shown that beans were widespread on the Northern Plains, much earlier than anticipated.

The development of maize horticulture has been frequently identified as a key change in the development of North American indigenous groups. For instance, the development of the Plains Village Tradition (PVT) in areas of the Central Plains has been linked to the development and intensification of maize horticulture. This Plains village development involved a coalescence of mobile Woodland groups into more sedentary, often fortified, and village-forming societies practicing a mixed bison/maize horticulture

strategy by around AD 900 (Ahler 2007). Similar to the PVT, the Middle Missouri Tradition (IMMV and EMMV) involved a similar process, which has also been linked to maize (Anderson 1987; Lensink 1997, 1998). Tiffany (2007) proposes that maize horticulture was a primary ‘pull-factor’ towards more sedentary living. This transition resulted in a shift in focus from individual family groups to extended clans in order to maintain, harvest, disperse yields throughout the group, and trade items to external non-related groups (Tiffany 2007). This forager-farmer transition has been estimated to occur much later in the northern regions (i.e. North Dakota), sometime around AD 1200 (Ahler 2007). As previously indicated, my research suggests earlier use of these plants in the Central Plains and Eastern Woodlands. Therefore, since Central Plains and Eastern Woodland groups must have been more involved in maize activities much earlier, it may also be possible that cultural developments linked to the use of maize such as increased sedentism, coalescence, and increases in social complexity may have also began earlier.

The inclusion of maize and other domesticated plants in other foraging Woodland groups eventually led to the adoption of increased sedentary living, coalescence, and other PVT and MMV characteristics. Although archaeological evidence shows that Avonlea groups did not adopt these characteristics, my research indicates the acquisition, and possible growth, of domesticated plants to supplement wild foods. The inclusion of these domesticated plants foods, particularly those that are readily preserved and comparatively portable would provide a valued ‘buffer’ to supplement wild foods. This would be an important consideration during seasons of food shortage or unreliability.

The identification of maize within the Avonlea complex marks not a single occurrence of maize on the northern plains, but part of a reoccurring trend of maize use

on the Northern Plains. Comparison of this research with other studies completed in Manitoba by Boyd *et al.* (2006, 2008), and in Alberta by Zarrillo and Kooyman (2006), suggests a continual presence of maize in areas of the Northern plains from Avonlea times until proto-historic times. Figure 9.10 depicts Avonlea sites identified in this thesis to yield microbotanical evidence of maize and compares the results to Manitoba sites that have yielded additional evidence for maize. Although this represents only a small sample of Manitoba Woodland sites, plant microfossil evidence suggests the presence of maize in these areas of the Northern Plains, prior to and after AD 800 to 1000. This consistent presence of maize shows the importance of this cultigen to the Northern Plains populations and thus possibly indicates more complex social structures and inter/intra group interactions. At the very least, Northern Plains groups were involved in or had connection with long-distance trade networks, and in some cases may have practiced small-scale agriculture, which allowed for the widespread dispersal of this cultigen.

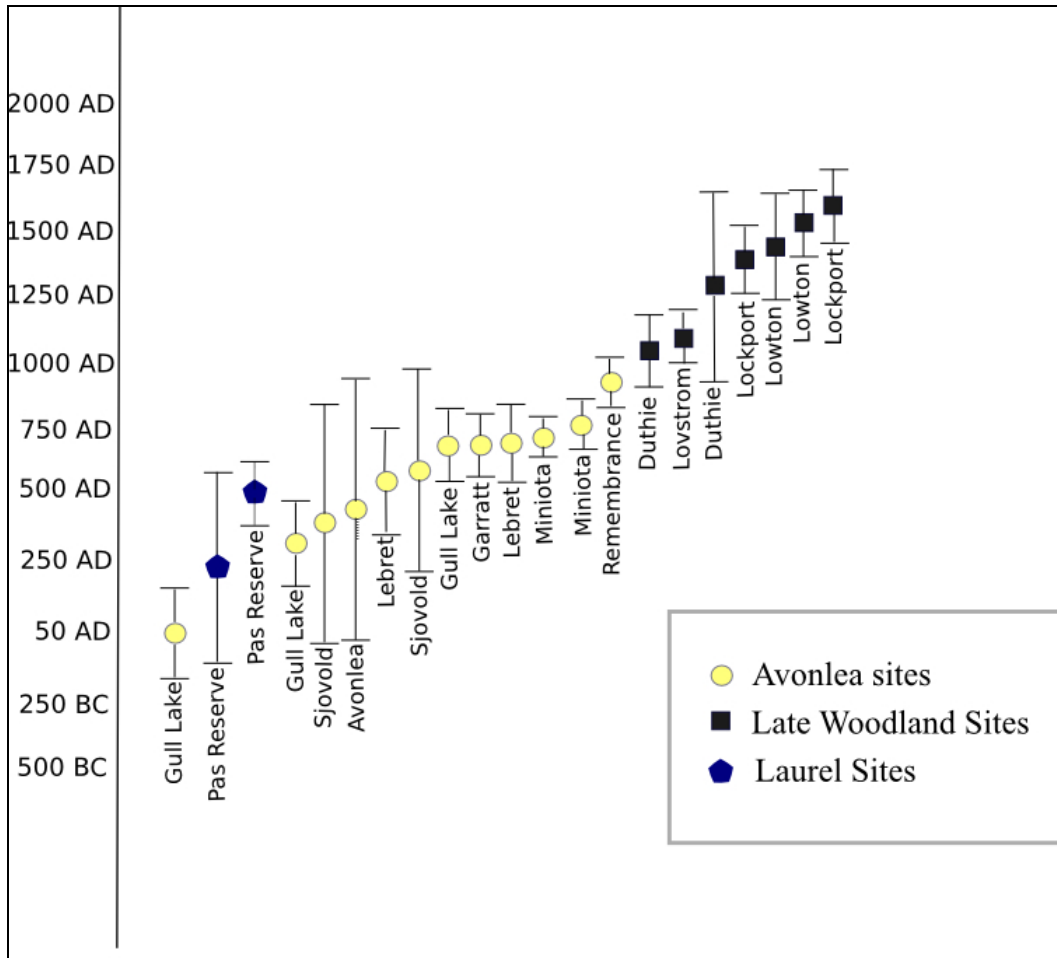


Fig.9.12 Graph plotting means and 2-sigma standard deviations of radiocarbon dates for Avonlea and other components in Manitoba and Saskatchewan that have yielded microbotanical evidence of maize. Non-Avonlea microfossil data obtained from: Boyd and Surette (2010); Boyd *et al.* (2006; 2008). Radiocarbon dates other than those reported in this thesis were obtained from the Canadian Radiocarbon Database (Morlan 2005).

Archaeological evidence from many Avonlea sites shows that these individuals were involved in long-distance trade. The presence of non-perishable items from British Columbia, northern Boreal Forest, and North Dakota indicate connections to surrounding cultural groups and also groups within the Avonlea complex. While the presence of these domesticated plants at least represents long-distance trade, subtle hints of small-scale

production of these plants requires further research into surrounding archaeological complexes, including the Elk Lake, Besant, and Sonota traditions.

Similarities in ceramic styles have been noted between Avonlea ceramics (parallel-grooved and net-impressed) and southern ceramic producing groups. Net-impressed vessels from the Avonlea complex have been found similar to Elk Lake wares found in Minnesota, which has promoted some to argue for cultural connections between them. Similarly, parallel-grooved vessels from the Avonlea complex have been shown to contain similar traits to vessels found at the Truman Mounds, in South Dakota. Similar projectile points have also been recovered in southern Elk Lake contexts as well.

This research indicates that influence from southern traditions, including Elk Lake and Truman Mound areas can not only be observed in Avonlea ceramics, but also through the plants that were incorporated into subsistence strategies. Evidence of maize and beans found in this study represent some of the earliest uses of these cultigens, far earlier and further dispersed as originally anticipated, by at least AD 660 to 810. This indicates that Avonlea groups were reliant on faunal resources, such as bison, but also collected and acquired, wild and domesticated plants for subsistence.

CHAPTER 10

CONCLUSION

The spread of maize, beans, and squash throughout North America marks a key shift in the development of past indigenous life ways that is often linked to the development of increasingly sedentary and more complex life ways in these groups. This sequence can be observed in the development of Plains Village economies of the Great Plains, where groups practiced a forager/farmer subsistence strategy prior to the adoption of more semi-sedentary horticulture (Ahler 2007; Bowers 1948; Smith and Cowan 2003; Tiffany 2007). Upon European contact, these cultigens were noted as dietary staples across much of the Eastern Woodlands and eastern Plains regions and available through expansive trade networks. Maize is may have been widespread as early as AD 800 to 1000 in the Eastern Woodlands and Central Plains (Adair and Drass 2011; Hart *et al.* 2002; Smith 1992c; Smith and Cowen 2003).

In areas outside of these centers of maize production, including the Northern Plains, very little is known regarding the use of domesticated plants, let alone the overall plant component of subsistence strategies of groups inhabiting these areas. These peripheral areas would be less involved in domesticated plant use (i.e. small amounts and trade), which would hinder the identification of domesticated plants in the archaeological record through conventional archaeological techniques. However, my research has shown that domesticated plants (maize and beans), were widespread throughout the Avonlea complex on the Northern Plains, and consumed alongside wild rice and other locally

collected plants. This evidence was found in carbonized food residue from 21 ceramic vessels, 7 stone artifact samples, and three soil samples obtained from eight widely dispersed Avonlea sites. The earliest evidence for maize in this study was found at the Gull Lake site (EaOd-1), the westernmost site examined (southwestern Saskatchewan), from a bell-shaped pestle where directly associated charcoal was dated to 1900 +/- 65 BP cal. 44 BC to AD 252 (S-256) (Kehoe 1973). Because maize phytoliths were found in all of the Avonlea sites that I examined, this plant must have been widely consumed across a broad area of the Northern Plains during this time.

Radiocarbon dates obtained from three carbonized food residue samples from the Miniota site yielded ages ranging from AD 660 to 810 (this study). These dates provide accurate timing of maize within the Avonlea period, which occurs earlier than originally anticipated for the Northern Plains. My results verify earlier documentation of maize by Boyd and Surette (2010). The discovery of maize within Laurel sites by at least AD 500 is also well before this expected widespread dispersal of maize in the Eastern Woodlands and Central Plains (Boyd and Surette 2010).

Additionally, the identification of domesticated beans (*Phaseolus vulgaris*) found in Avonlea cultural contexts predates the previously accepted arrival of these plants to the Central Plains (AD 950 to 1200) (Adair and Drass 2011) and Northeastern Woodlands (AD 750) (Hart *et al.* 2002). The earliest evidence of bean was recovered at the Garratt site, approximately dating to 1450 +/- 70 BP cal. AD 431 to 679 (S-406) (Morgan 1978) and this cultigen was likely widely dispersed within the Avonlea complex by at least AD 660 to 810, as seen at the Miniota site. These results may either suggest rapid dispersal of this cultigen or the methods employed in this thesis allowed for positive identifications

that were previously missed. Early evidence for this domesticated plant use on the periphery of the Great Plains highlights the effectiveness of employing plant microfossils and the need for future plant microfossil research to be completed into Early Woodland traditions.

In addition to maize and other domesticated plants, evidence of wild rice and other local wild plants were recovered from the Avonlea samples. A comparative starch key was generated from 45 wild and domesticated plant species in order to more securely identify plant taxa. In total, 300 starch grains were counted for each plant analyzed. These starch grains were then organized based on morphological features and size. When these starch grains were organized into morphological categories, a total of 573 starch grain types were identified. Although this comparative collection is only a small representation of total edible wild plants of the Northern Plains, this research enabled cautious identification of wild plants, which alone represents a significant contribution to palaeodietary research on the northern plains. More importantly, I observed no starch grains that would pose as 'confusers' to beans. This is significant since beans were likely cooked without the pods, where the diagnostic phytoliths are contained and therefore, would not be present in the residue. Identification of diagnostic bean starch grains provides another confident means to identify this cultigen. Thus, this finding is a significant contribution to future paleodietary research and provides verifications of past identifications of beans using starch (Boyd and Surette 2010; Boyd *et al.* 2006, 2008). Completion of comparative starch analysis is crucial to paleodietary analysis and allows for increased identifications of plants from archaeological contexts, which provides a

more holistic view of past subsistence. Further research into comparative starch analysis will only benefit future and past archaeological investigations.

Based on faunal recoveries, Smith and Walker (1988) hypothesized that some Avonlea groups based subsistence strategies upon seasonally abundant resources. My research compliments this scenario; by indicating that Avonlea groups participated in the collection of a diverse assemblage of wild plants during their seasonal round and supplemented this strategy with the acquisition of domesticated plants. The collection of wild plants likely occurred during the late-summer to early-spring, when the plants were mature. Evidence was also found indicating extensive cooking in order to make plants palatable, which provides subtle insight into the ecological knowledge that these individuals held regarding wild plant species. Furthermore, comparisons of residues between stone tools resulted in the identification of mostly domesticated plants and tubers on the stone tools, with very little evidence of berries. This suggests that these individuals were processing the tubers, in preparation for future use while the berries were added to cooking vessels with little preparation.

Wild rice was also found at many Avonlea sites indicating a widespread use of this economic plant. How Avonlea groups obtained this plant is difficult to confidently identify. Archaeological evidence has been found to suggest interaction with Laurel and Elk Lake groups (Meyer and Walde 2009), where evidence of wild rice has been found in carbonized food residue from both cultures (Boyd and Surette 2010; Thompson 2000) and both cultures are located in suitable wild rice growing areas. Although this may represent trade between Avonlea and these adjacent groups, it cannot be ruled out that

Avonlea groups locally collected wild rice from the southern Boreal Forest at some point during their seasonal round.

Similar to the arrival of wild rice into the Avonlea groups, the origins of the domesticated plants (maize and beans) are also difficult to interpret. The arrival of domesticated plants into the Avonlea complex can be interpreted as the result of trade, small-scale horticulture, or a combination of both. Archaeological evidence of established long distance trade networks (Landals 1995) suggests the acquisition of these cultigens at least through trade. However, other lines of evidence including the identification of possible maize pollen, amounts of diagnostic microfossils identified, the types of microfossils identified and their contexts, and archaeological recoveries at the Miniota site indicate more than just trade. Until further research is completed on more southern contemporaneous groups, the exact origins and nature of domesticated plant dispersal cannot be confidently identified.

The incorporation of maize into the Avonlea complex was not a unique event on the Northern Plains. Research completed by Boyd *et al.* (2006, 2008), the presence of maize on the Northern Plains was found in multiple sites from the Middle Woodland to Proto-historic times. This indicates that Northern Plains groups were regularly involved or influenced by southern PVT or Eastern Woodland Traditions, and in some cases, practicing small-scale horticulture.

Avonlea groups occupied the Northern Plains, utilizing multiple environmental zones, interacting with adjacent cultures, and completing a broad subsistence strategy based on seasonal abundance for approximately 800 years. We now know that knowledge

of the environment also extended to the use of a wide variety of wild and exotic domesticated plants that were incorporated into their subsistence strategies. The identification of maize and other domesticated plants, within the Avonlea complex represents a significant contribution to the understanding of the timing and dispersal of maize and other cultigens in the Central Plains and Eastern Woodlands. Evidence for maize and beans found in this thesis on the Northern Plains, within Avonlea contexts, predate the anticipated arrival and dispersal of these cultigens in many areas of the Eastern Woodlands and Central Plains. This research indicates that Avonlea groups were engaging in the acquisition and dispersal of maize, beans, squash, and wild rice, in order to supplement wild foods. This 'active' role of Avonlea groups allowed dispersal of these plants throughout the Northern Plains well before AD 800 to 1200.

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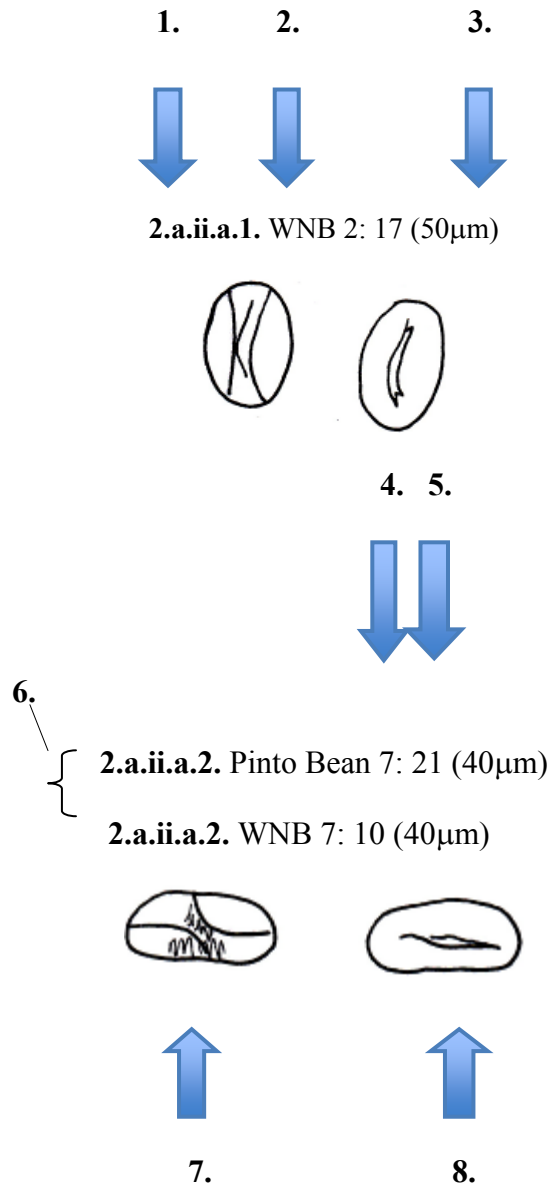
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APPENDIX

A.1 Guide To Comparative Starch Key

The following starch reference key was built in an effort to identify wild and domesticated plants through the use of starch grains. This key provides examples of starch morphotypes that were observed, counted, and depicted for future comparison. The starch morphotypes of the 45 plants were separated into seven classes: circular, elongated, bell-shaped, angular, irregular, compound, and basal. Also provided is a glossary of important descriptive terms used by the examiner in the development of this key. It is important to note that although these are examples of starch grains produced by plant species, using these starch grains as the sole species identifier should be made with caution.

Example:



Legend:

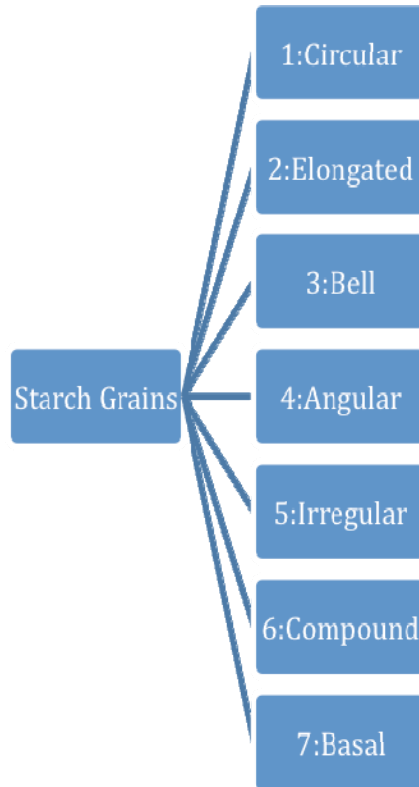
1. Starch Code
2. Short Form Plant ID
3. Size of the starch grain
4. Plant starch type within species
5. Count out of 300.
6. Represents starch morphotype number found in that particular species. (e.g. type 7 out of 25).
7. Depiction of starch under cross-polarized light.
8. Depiction of starch under plane-polarized light.

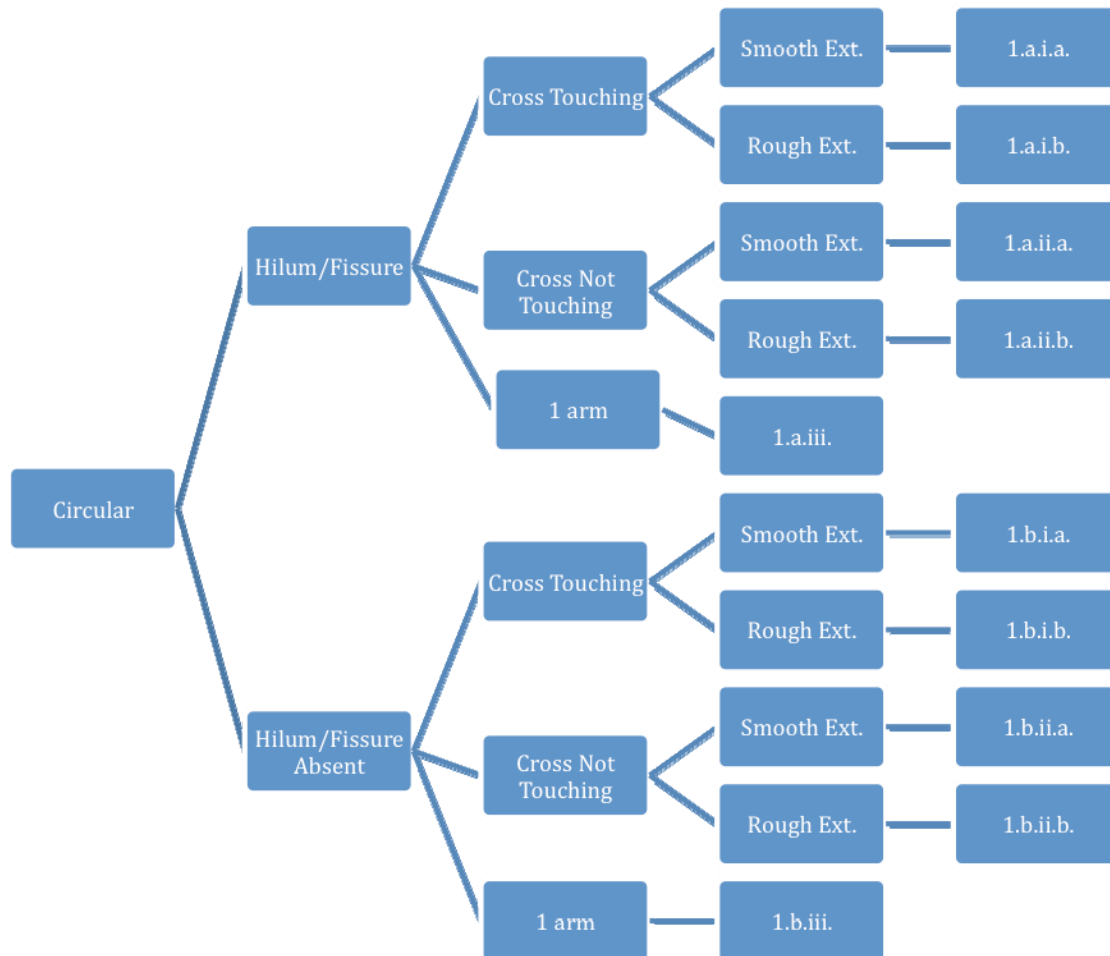
Table A. 1 Reference codes for plants analyzed in comparative study.

Scientific Name	Starch Reference Code
<i>Acer negundo</i>	Ace. neg.
<i>Amelanchier alnifolia</i>	Almer. alni.
<i>Arisaema triphyllum</i>	Aris. trip.
<i>Caltha palustris</i>	Calt. palu.
<i>Claytonia caroliniana</i>	Clay. caro.
<i>Corylus americana</i>	Cory. amer.
<i>Corylus cornuta</i>	Cory. corn.
<i>Cucurbita pepo</i> (Acorn)	Ac. Sq.
<i>Cucurbita maxima</i> (Buttercup)	Buttc. Sq.
<i>Cucurbita moschata</i> (Butternut)	Buttn. Sq.
<i>Cucurbita maxima</i> (Hubbard)	Hubb. Sq.
<i>Cucurbita maxima</i> (Kabosha)	Kabo. Sq.
<i>Cucurbita pepo</i> (Pumpkin)	Pumpkin
<i>Cucurbita pepo</i> (Zucchini)	Zucci. Sq.
<i>Heracleum lanatum</i>	Hera. luna.
<i>Hordeum jubatum</i>	Hor. juba.
<i>Lagenaria sp.</i> (Common Gourd)	Comm. Gour.
<i>Lilium philadelphicum</i>	Liliu. phila.
<i>Lomatium foeniculaceum</i>	Loma. foen.
<i>Maranta arundinacea</i>	Mara. arun.
<i>Nymphaea odorata odorata</i>	Nymp. odor.
<i>Nymphaea odorata ssp. tuberosa</i>	Nymp. tube.
<i>Osmorhiza longistylis</i>	Osmo. long.
<i>Peltandra virginica</i>	Pelt. virg.
<i>Perideridia gairdneri</i>	Peri. gair.

<i>Phaseolus vulgaris</i> (Black Turtle)	BTB
<i>Phaseolus vulgaris</i> (Green)	Gree. Bea.
<i>Phaseolus lunatum</i> (Lima)	Lima Bean
<i>Phaseolus vulgaris</i> (Pinto)	Pinto Bean
<i>Phaseolus vulgaris</i> (Red Kidney)	RKB
<i>Phaseolus vulgaris</i> (Romano)	Romano
<i>Phaseolus vulgaris</i> (White Navy)	WNB
<i>Phaseolus vulgaris</i> (Yellow Eyed)	YEB
<i>Platanthera dilatata</i>	Plan. dila.
<i>Prunus nigra</i>	Prun. nigr.
<i>Prunus pensylvanica</i>	Prun. pen.
<i>Prunus virginiana</i>	Prun. virg.
<i>Psoralea esculenta</i>	Psor. escu.
<i>Quercus macrocarpa</i>	Quer. macr.
<i>Sparangium eurycarpum</i>	Spar. eury.
<i>Symplocarpus foetidus</i>	Symp. foet.
<i>Typha latifolia</i>	Typh. lati.
<i>Viburnum opulus</i>	Vibu. opal.
<i>Zizania aquatica</i>	Ziza. aqua.
<i>Zizania palustris</i>	Ziza. palu.

A.2 Starch Reference Key for Archaeological Residue Analysis





Circular Shaped Starch Grains:
Hilum/Fissure Visible; Cross Not
Touching; Smooth: 1.a.ii.a

1.a.ii.a.1. Lima Bean 4: 25 (30µm)



1.a.ii.a.2. RKB 7: 18 (<20µm)



1.a.ii.a.3. As. Sq.23: 3 (15µm)



1.a.ii.a.4. Hubb. Sq.8: 3 (5-10µm)



Fissure

1.a.ii.a.5. BTB 4: 82 (20µm)



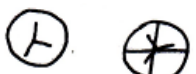
1.a.ii.a.6. Psor. escu. 17: 6 (20µm)



1.a.ii.a.7. RKB 4: 93 (10-15µm)



1.a.ii.a.8. Romano 2: 95 (25µm)



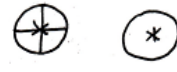
1.a.ii.a.9. Lima Bean 3: 83 (5-20µm)



1.a.ii.a.10. WNB 4: 85 (20-25µm)



1.a.ii.a.11. Loma. foen. 2: 80 (10-15µm)



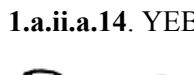
1.a.ii.a.12. As. Sq.11: 9 (10µm)



1.a.ii.a.13. Pinto Bean 3: 95 (25µm)



1.a.ii.a.14. Plan. dila. 4: 6 (15µm)



1.a.ii.a.14. YEB 4: 56 (10µm)



Hilum:

1.a.ii.a.15. Psor. escu.14: 33 (20µm)



1.a.ii.a.16. Comm. Gour. 3: 27 (15µm)



1.a.ii.a.17. Gree. Bea.2: 76 (10µm)



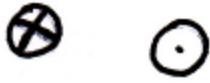
1.a.ii.a.17. Butc. Sq.11: 15 (10µm)



1.a.ii.a.18. Butc. Sq.5: 60 (5µm)



1.a.ii.a.19. As. Sq.5: 82 (<5µm)



1.a.ii.a.20. Butc. Sq. 24:1



1.a.ii.a.21. Buttn. Sq.12: 40 (10um)



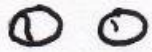
1.a.ii.a.22. Buttn. Sq.14: 2 (20um)



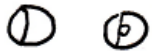
Circular Starch Grains: Fissure/Hilum Visible; 1 Arm:

1.a.iii.

1.a.iii.1. Prun. virg. 11: 5 (<5µm)



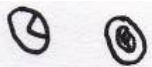
1.a.iii.2. Vibu. opal. 6: 20 (3-4µm)



1.a.iii.3. Amer. alni. 7: 12 (5µm)



1.a.iii.4. Prun. Nigr. 22: 1 (5um)



**Circular Shaped Starch Grains:
Hilum/Fissure Visible; Cross Not
Touching; Rough Exterior: 1.a.ii.b**

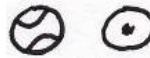
Curved:

1.a.ii.b.1. Prun. nigr. 4: 5 (5µm)

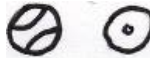
1.a.ii.b.1. Prun. penn. 8: 26(5um)



1.a.ii.b.2. Prun. nigr. 6: 140 (5µm)



1.a.ii.b.3. Prun. penn.1: 135 (5µm)



1.a.ii.b.4. Prun. virg.1: 149 (<5µm)



1.a.ii.b.5. Prun. penn. 2: 25 (<5µm)



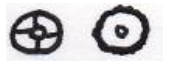
1.a.ii.b.6. Prun. virg. 3: 25 (5µm)



1.a.ii.b.7. Prun. virg. 5: 44 (<5µm)



1.a.ii.b.8. Prun. virg. 2: 23 (5µm)



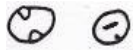
1.a.ii.b.9. Prun. penn. 7: 26 (<5µm)



1.a.ii.b.10. Vibu opal 1: 88 (3-4µm)

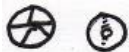


1.a.ii.b.11. Prun. nigr. 12: 11 (5um)



1 Arm Flat:

1.a.ii.b.12. Prun. nigr. 5: 5 (<5um)

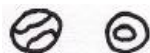


1.a.ii.b.13. Prun. nigr. 17: 16 (5um)



1.a.ii.b.14. Prun. virg. 17: 1 (<5um)

1.a.ii.b.14. Prun. nigr. 11: 25(5um)



1.a.ii.b.15. Amer. alni. 9: 41 (5um)

1.a.ii.b.15. Prun. nigr. 13: 10 (5um)



1.a.ii.b.16. Vibu. opal. 8: 15 (5um)



Irregular:

1.a.ii.b.17. Prun. nigr. 8: 17 (5um)



1.a.ii.b.18. Prun. nigr. 16: 4 (5um)



1.a.ii.b.19. Prun. nigr. 21: 1 (5um)



1.a.ii.b.20. Prun. pen. 4: 16 (<5um)



1.a.ii.b.21. Prun. pen. 5: 16 (<5um)



1.a.ii.b.22. Prun. pen. 12: 1 (<5um)



1.a.ii.b.23. Prun. virg. 10: 16 (5um)



1.a.ii.b.24. Prun. virg. 13: 1 (<5um)



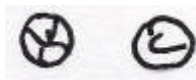
1.a.ii.b.25. Amer. alni. 8: 22 (5um)



1.a.ii.b.26. Prun. nigr. 10: 13 (5um)



1.a.ii.b.27. Prun. nigr. 19: 1 (5um)



1.a.ii.b.28. Prun. virg. 18: 1 (<5um)



Circular Shaped Starch Grains:

Hilum/Fissure Visible; Cross Touching;
Smooth; Not 90 Cross: 1.a.i.a

1.a.i.a.1. *As. Sq.*20: 1 (15µm)



1.a.i.a.2. *Hubb. Sq.*10: 12 (5-10µm)



1.a.i.a.3. *Ziza. palu.* 10: 5 (10-15µm)



1.a.i.a.4. *Clay. caro.* 5: 55 (15µm)



Circular Shaped Starch Grains:

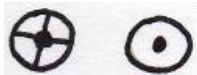
Hilum/Fissure Visible; Cross Touching;
Rough; 90 Cross:

1.a.i.b.

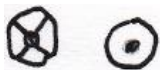
1.a.i.b.1. *Prun. nigr.* 1: 18 (<5µm)



1.a.i.b.2. *Prun. nigr.* 3: 26 (5µm)



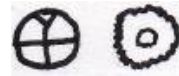
1.a.i.b.3. *Prun. nigr.* 9: 10 (5µm)



1.a.i.b.4. *Amer. alni.* 1: 10 (<5µm)



1.a.i.b.5. *Prun. virg.*9: 1 (<5µm)



1.a.i.b.6. *Amer. alni.* 5: 22 (<5µm)



1.a.i.b.7. *Vibu. opal.* 12: 2 (5µm)



Circular Shaped Starch Grains:

Hilum/Fissure Visible; Cross Touching;
Rough; Not 90 Cross:

1.a.i.b.9. *Prun. nigr.* 14: 3 (5µm)



1.a.i.b.10. *Prun. nigr.* 15: 5 (5µm)



1.a.i.b.11. *Prun. virg.*12: 1 (<5µm)



1.a.i.b.12. *Prun. virg.*16: 1 (<5µm)



**Circular Starch Grains: Fissure/Hilum
Not Visible; Cross Touching; Smooth
Exterior; 90 Cross:**

Straight: 1.b.i.a.

1.b.i.a.1. Ace. Ner.6: 73 (10µm)

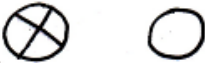


1.b.i.a.2. Symp foet 9: 35 (10µm)

1.b.i.a.2. Zucci. Sq. 11: 5 (10µm)

1.b.i.a.2. Osma long 2: 50 (10µm)

1.b.i.a.2. Hubb. Sq.6: 37 (10µm)



1.b.i.a.3. Aris. trip 3: 23 (10µm)



1.b.i.a.4. Hubb. Sq.3: 25 (5-10µm)



1.b.i.a.5. Pumpkin 5: 45 (5-10µm)

1.b.i.a.5. Nymph odor 4: 70 (5-10µm)

1.b.i.a.5. Spar eury 10: 17 (5-10µm)

1.b.i.a.5. Liliu. phila. 7: 48 (8µm)

1.b.i.a.5. Loma foen 7: 40 (5-10µm)



1.b.i.a.6. Pumpkin 6: 55 (5-10µm)



1.b.i.a.7. Calt. palu. 11: 25 (5µm)

1.b.i.a.7. Clay. caro. 12: 35 (5µm)

1.b.i.a.7. Kaba. Sq. 7: 62 (5µm)

1.b.i.a.7. Buttn. Sq.5: 143 (5µm)

1.b.i.a.7. Typh. lati.3: 105 (5µm)

1.b.i.a.7. Zucci. Sq. 6: 90 (5µm)



1.b.i.a.8. Ace. neg.12: 20 (<5µm)

1.b.i.a.8. Butc. Sq.9: 30 (<5µm)

1.b.i.a.8. Pelt virg 11: 42 (>5µm)

1.b.i.a.8. Aris. trip 16: 25 (2-3µm)

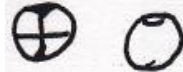
1.b.i.a.8. Spar eury 6: 25 (<5µm)

1.b.i.a.8. Comm. Gour. 9: 91 (<5µm)



Un-Straight Cross:

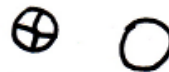
1.b.i.a.9. Hera luna. 6: 2 (<5µm)



1.b.i.a.10. Aris. trip 21: 4 (10µm)



1.b.i.a.11. Hord. juba.5: 50 (5µm)



1.b.i.a.12. Kaba. Sq. 15: 11 (15µm)



1.b.i.a.13. Mara arun 11: 10 (10µm)



Circular Starch Grains:

No Hilum; Cross Not Touching; Rough Exterior:

1.b.ii.b.

1.b.ii.b.1. Prun. virg. 7: 3 (5um)

1.b.ii.b.1. Vibu. opal. 10: 3 (5um)



1.b.ii.b.2. Prun. virg. 8: 7 (5um)



1.b.ii.b.3. Prun. Virg15.: 1 (<5um)



1.b.ii.b.4. Typh. lati.5: 5 (5-8um)

1.b.ii.b.4. Vibu. opal. 4: 30 (3-4um)



1.b.ii.b.5. Amer. alni.: 160 (<5um)

1.b.ii.b.5. Vibu. opal. 3: 40 (3-4um)



1.b.ii.b.6. Amer. alni. 4: 17 (<5um)



1.b.ii.b.7. Calt. palu.17: 10 (5-10um)

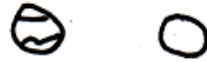
1.b.ii.b.7. Vibu. opal. 9: 10 (5um)



1.b.ii.b.8. Cory amer.1: 55 (6um)



1.b.ii.b.9. Cory amer. 2: 25 (5-10um)



1.b.ii.b.10. Cory amer. 3: 20 (5um)

1.b.ii.b.10. Vibu. opal. 7: 20 (2-3um)



1.b.ii.b.11. Cory amer. 5: 25 (5um)

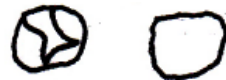


1.b.ii.b.12. Cory amer. 6: 15 (5um)



1.b.ii.b.13. Cory amer. 8: 10 (5-10um)

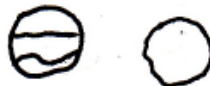
1.b.ii.b.13. Vibu. opal. 11: 3 (3-4um)



1.b.ii.b.14. Cory amer. 9: 10 (6um)



1.b.ii.b.15. Cory amer. 10: 20 (5um)



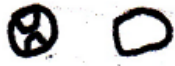
1.b.ii.b.16. Cory amer.11: 15 (5um)



1.b.ii.b.17. Cory amer. 12: 10 (6um)



1.b.ii.b.18. Cory amer.14: 40 (5um)



1.b.ii.b.19. Vibu. opal. 5: 25 (5um)



Fissure/Hilum Not Visible; Cross Touching; Rough Exterior; 90: 1.b.i.b

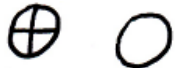
1.b.i.b.1. Ziza. aqua. 10: 10 (5µm)



1.b.i.b.2. Cory. corn.2: 70 (<5µm)



1.b.i.b.3. Cory. corn.5: 20 (<5µm)



1.b.i.b.4. Cory amer. 13: 30 (2-3µm)



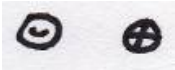
1.b.i.b.5. Cory. corn.7: 5 (1µm)



1.b.i.b.6. Cory amer. 4: 15 (5-10µm)



1.b.i.b.7. Ziza. palu. 9: 20 (3-6um)

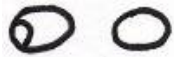


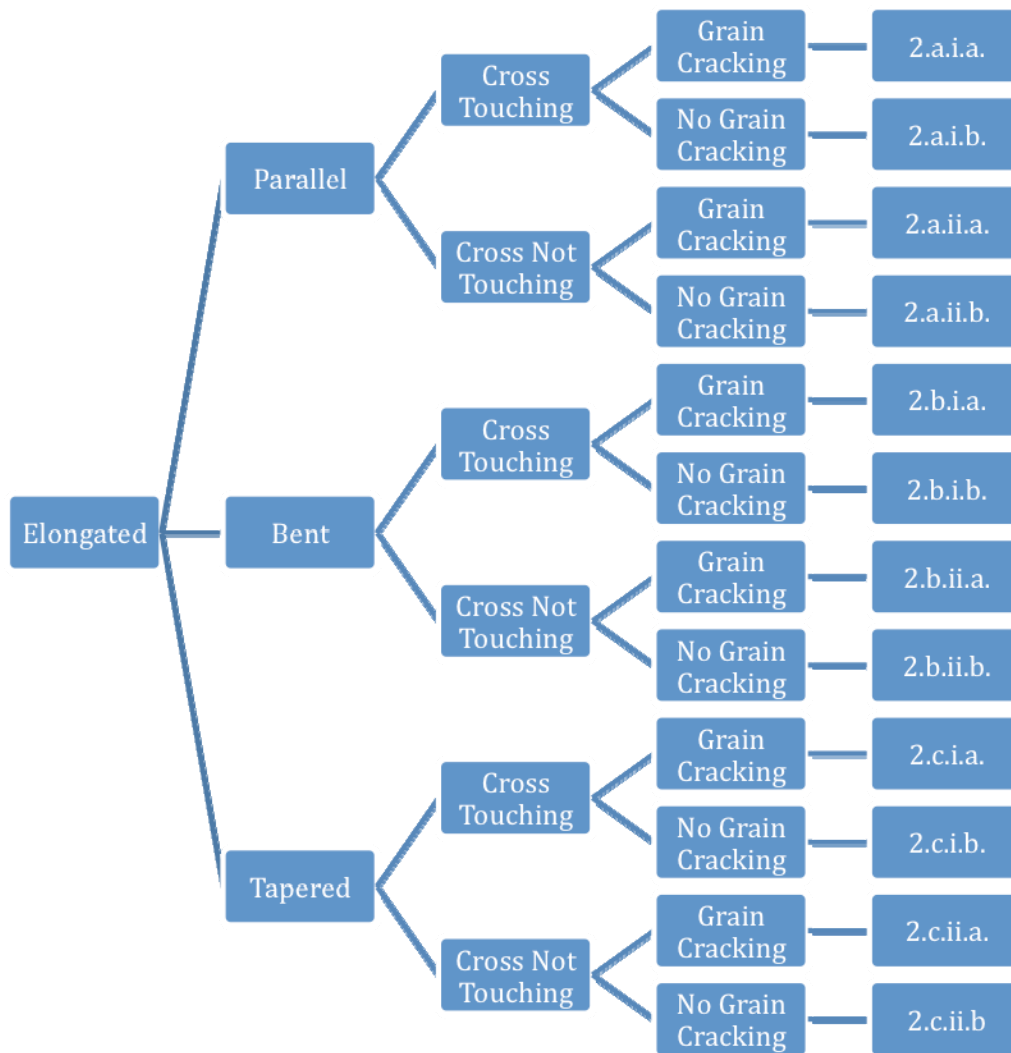
Circular Starch Grains: Fissure/Hilum
Not Visible; 1Arm:

1.b.iii.1. Vibu. opal. 2: 45 (3-4 μ m)



1.b.iii.2. Prun. pen. 9: 13 (<5 μ m)

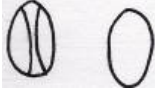




Elongated Starch Grains:

**Parallel (Straight); Cross Not Touching;
No Cracking: 2.a.ii.b**

2.a.ii.b.1. Gree. Bea.5: 45 (25-30µm)



2.a.ii.b.2. Quer. macr. 5: 65 (20µm)



2.a.ii.b.3. Peri gair 10: 20 (15µm)



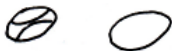
2.a.ii.b.4. Hord. juba.3: 36 (10-15µm)



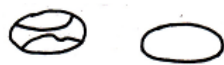
2.a.ii.b.5. Calt. palu. 10: 12 (10µm)



2.a.ii.b.6. Quer. macr. 2: 40 (10µm)



2.a.ii.b.7. Calt. palu. 6: 5 (<10µm)



2.a.ii.b.8. Calt. palu. 2: 10 (<10µm)



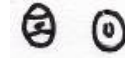
2.a.ii.b.9. Calt. palu.7: 9 (<10µm)



Hord. juba.4: 20 (5-10µm) 2.a.ii.b.10.



2.a.ii.b.11. Prun. nigr. 7: 3 (5µm)



2.a.ii.b.12. Cory. corn.4: 25 (<5µm)



2.a.ii.b.13. Prun. pen. 3: 10 (<5µm)



2.a.ii.b.14. Quer. macr. 9: 30 (20µm)



Elongated Starch Grains:

**Parallel (Straight); Cross Not Touching;
Cracking: 2.a.ii.a**

2.a.ii.a.1. WNB 2: 17 (50µm)



2.a.ii.a.2. Pinto Bean 7: 21 (40µm)

2.a.ii.a.2. WNB 7: 10 (40µm)



2.a.ii.a.3. Gree. Bea.4: 35 (25-30µm)

2.a.ii.a.3. BTB1: 60 (35µm)

2.a.ii.a.3. Pinto Bean 1: 85 (35µm)

2.a.ii.a.3. YEB1: 62 (35µm)



2.a.ii.a.4. Pinto Bean 2: 45 (35µm)



2.a.ii.a.5. Romano 3: 13 (35µm)



2.a.ii.a.6. WNB1: 30 (30-35µm)

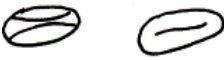
2.a.ii.a.6. BTB 3: 24 (30µm)

2.a.ii.a.6. Pinto Bean 8: 19 (35µm)



2.a.ii.a.7. Pinto Bean 10: 9 (25µm)

2.a.ii.a.7. Lima Bean 5: 52 (30µm)



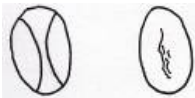
2.a.ii.a.8. Romano 5: 87 (25µm)



2.a.ii.a.9. RKB1: 102 (20µm)

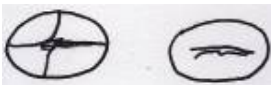
2.a.ii.a.9. WNB 6: 36 (25-30µm)

2.a.ii.a.9. YEB 2: 60 (25µm)



2.a.ii.a.10. RKB 6: 49 (<20µm)

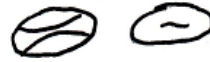
2.a.ii.a.10. YEB 3: 14 (25µm)



2.a.ii.a.11. Hord. juba.2: 47 (10-15µm)



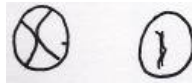
2.a.ii.a.12. BTB 5: 50 (10µm)



2.a.ii.a.13. Ziza. aqua. 4: 2 (10µm)



2.a.ii.a.14. RKB 3: 5 (15µm)



Parallel; Crosses Touching; No Cracking:

2.a.i.b

2.a.i.b.1. Plan dila 5: 17 (30µm)



2.a.i.b.2. Pelt virg 10: 10 (30µm)



2.a.i.b.3. Nymp. tube.17: 3 (30µm)



2.a.i.b.4. Plan dila 6: 53 (10-25µm)



2.a.i.b.5. Gree. Bea.10: 21 (20µm)



2.a.i.b.6. Liliu. phila. 9: 5 (20µm)



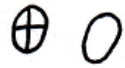
2.a.i.b.7. Quer. macr. 6: 17 (10µm)



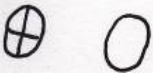
2.a.i.b.8. Calt. palu. 13: 5 (10µm)



2.a.i.b.9. Quer. macr. 3: 28 (10µm)



2.a.i.b.10. Symp foet 11: 6 (<10µm)



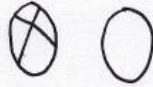
2.a.i.b.11. Calt. palu. 5: 10 (<10µm)



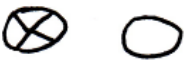
2.a.i.b.12. Quer. macr. 4: 10 (10µm)



2.a.i.b.13. Pumpkin 10: 5 (5-10µm)



2.a.i.b.14. Spar eury 8: 13 (5µm)



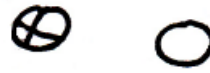
2.a.i.b.15. Zucci. Sq. 9: 4 (5µm)



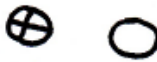
2.a.i.b.16. Calt. palu. 15: 20 (<5µm)



2.a.i.b.17. Calt. palu. 3: 18 (<5µm)



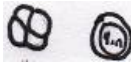
2.a.i.b.18. Quer. macr. 10: 35 (<5µm)



2.a.i.b.19. Spar eury 5: 20 (<5µm)



2.a.i.b.20. Prun. nigr. 2: 7 (<5µm)



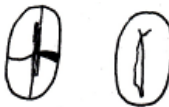
2.a.i.b.21. Pelt virg 12: 3 (5µm)

2.a.i.b.21. Peri gair 7: 45 (5µm)



**Parallel (Straight); Crosses Touching;
Cracking: 2.a.i.a**

2.a.i.a.1. Lima Bean 1: 30 (40-50µm)



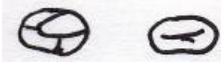
2.a.i.a.2. WNB 3: 70 (30µm)



2.a.i.a.3. BTB 8: 20 (25µm)



2.a.i.a.4. Prun. nigr. 20: 1 (5µm)



Angled; Crosses Not Touching; No Cracking: 2.b.ii.b

2.b.ii.b.1. WNB 5: 32 (30µm)

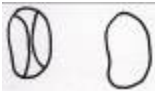
2.b.ii.b.1. Gree. Bea.9: 10 (30µm)



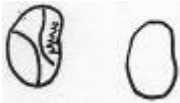
2.b.ii.b.2. Gree. Bea.11: 12 (30µm)



2.b.ii.b.3. Gree. Bea.3: 73 (25-30µm)



2.b.ii.b.4. Gree. Bea.1: 10 (20µm)



2.b.ii.b.5. Quer. macr. 7: 5 (20µm)



Angled; Crosses Not Touching; Cracking: 2.b.ii.a

2.b.ii.a.1. Romano 6: 35 (50µm)



2.b.ii.a.2. Pinto Bean 4: 10 (40µm)

2.b.ii.a.2. BTB 2: 27 (40µm)



2.b.ii.a.3. YEB 9: 15 (35µm)



2.b.ii.a.4. Pinto Bean 6: 3 (35µm)



2.b.ii.a.5. Pinto Bean 9: 9 (35µm)

2.b.ii.a.5. YEB 5: 20 (35µm)

2.b.ii.a.5. Lima Bean 12: 17 (35µm)



2.b.ii.a.6. Lima Bean 9: 17 (35µm)



2.b.ii.a.7. BTB 9: 15 (30µm)



2.b.ii.a.8. YEB 7: 16 (30µm)

2.b.ii.a.8. WNB 8: 17 (30µm)



2.b.ii.a.9. Plan dila 2: 20 (30µm)

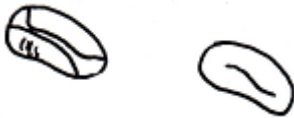


2.b.ii.a.10. BTB 6: 7 (25µm)

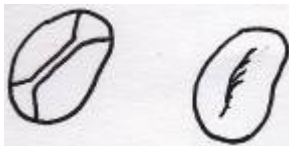
2.b.ii.a.10. Lima Bean 7: 7 (25µm)



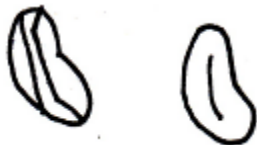
2.b.ii.a.11. Romano 4: 22 (25µm)



2.b.ii.a.12. RKB 5: 22 (<20µm)



2.b.ii.a.13. Peri gair 4: 25 (10µm)



2.b.ii.a.14. Psor. escu. 9: 21 (5-10µm)



2.b.ii.a.15. Pinto Bean 5: 5 (25µm)



2.b.ii.a.16. Romano 7: 4 (50µm)



Angled (Bent); Crosses Touching; No Cracking: 2.b.i.b.

2.b.i.b.1. Liliu. phila. 10: 5 (30µm)



2.b.i.b.2. Nymph. tube.14: 1 (30µm)



2.b.i.b.3. Plan dila 10: 25 (25µm)



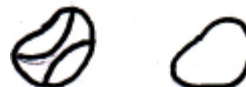
2.b.i.b.4. Pelt virg 9: 6 (20µm)



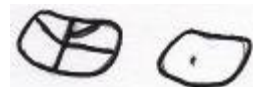
2.b.i.b.5. Hera luna. 2: 20 (10µm)



2.b.i.b.6. Hord. juba.6: 15 (5µm)



2.b.i.b.7. Kaba. Sq. 12: 3 (10µm)



Angled (Bent); Crosses Touching; Cracking: 2.b.i.a.

2.b.i.a.1. Lima Bean 8: 6 (40µm)



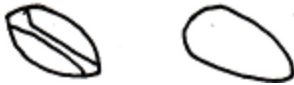
Tapering; Crosses Not Touching; No Cracking: 2.c.ii.b.

2.c.ii.b.1. Loma foen 6: 4 (15µm)

2.c.ii.b.1. Calt. palu. 16: 3 (10µm)



2.c.ii.b.2. Peri gair 11: 20 (15µm)



2.c.ii.b.3. Hera luna. 13: 28 (<10µm)



2.c.ii.b.4. Gree. Bea.8: 14 (20µm)



Hilum:

2.c.ii.b.4. Liliu. phila. 2: 8 (30µm)



2.c.ii.b.5. Plan dila 8: 10 (20µm)



Tapering; Crosses Not Touching; Cracking: 2.c.ii.a.

2.c.ii.a.1. Lima Bean 10: 11 (45µm)



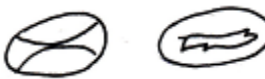
2.c.ii.a.2. Lima Bean 6: 21 (30-40µm)



2.c.ii.a.3. Liliu. phila. 8: 51 (30µm)



2.c.ii.a.4. BTB 7: 11 (30µm)



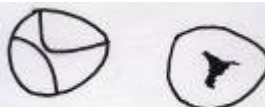
2.c.ii.a.5. Peri gair 9: 1 (20µm)



2.c.ii.a.6. RKB 8: 12 (<20µm)

2.c.ii.a.6. Lima Bean 2: 13 (25µm)

2.c.ii.a.6. YEB 8: 31 (25µm)



2.c.ii.a.7. Peri gair 2: 35 (15µm)



2.c.ii.a.8. Hord. juba.1: 124 (10-12µm)



2.c.ii.a.9. Peri gair 1: 15 (15µm)



Tapering; Crosses Touching; Cracking:

2.c.i.a.

2.c.i.a.1. Pinto Bean 11: 7 (35µm)

2.c.i.a.1. Lima Bean 11: 9 (30µm)

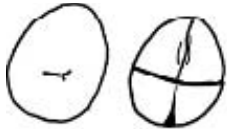


2.c.i.a.2. Lima Bean 13: 4 (25µm)



Tapering; Crosses Touching; Medial Line Cross: 2.c.i.b.

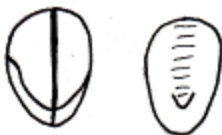
2.c.i.b.1. Nymph. tube.5: 36 (35µm)



2.c.i.b.2. Liliu. phila. 3: 57 (25-30µm)



2.c.i.b.3. Pelt virg 8: 20 (30µm)



2.c.i.b.4. Liliu. phila. 5: 17 (30µm)



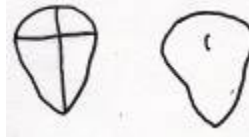
2.c.i.b.5. Nymph. tube.20: 21 (20µm)



2.c.i.b.6. Nymph. tube. 23:1 (20µm)



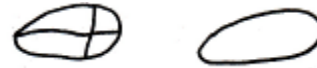
2.c.i.b.7. Peri gair 12: 1 (20 µm)



2.c.i.b.8. Butc. Sq.13: 6 (10µm)



2.c.i.b.9. Peri gair 6: 55 (10-15µm)



2.c.i.b.10. YEB 6: 31 (25µm)



2.c.i.b.11. Calt. palu. 18: 5 (10µm)



2.c.i.b.12. Nymph odor 3: 15 (15µm)



2.c.i.b.13. Peri gair 5: 35 (10µm)



**Tapering; Crosses Touching; Transecting
Medial Line Cross:**

2.c.i.b.

2.c.i.b.14. Nymp. tube.16: 2 (35µm)



2.c.i.b.15. Plan dila 1: 135 (30µm)



2.c.i.b.16. Liliu. phila. 1: 66 (30µm)



2.c.i.b.17. Nymp. tube.3: 21 (30µm)



2.c.i.b.18. Nymp. tube. 21: 1 (20µm)



2.c.i.b.19. Pelt virg 1: 66 (20µm)



2.c.i.b.20. Pelt virg 2: 1 (20µm)



2.c.i.b.21. Osma long 10: 3 (20µm)



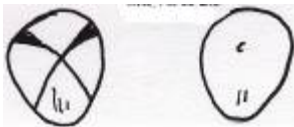
2.c.i.b.22. Pelt virg 3: 8 (15µm)



2.c.i.b.23. Calt. palu.1: 10 (15µm)



2.c.i.b.24. Nymp. tube.18: 20 (10µm)



2.c.i.b.25. Quer. macr. 1: 70 (10µm)



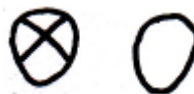
2.c.i.b.26. Calt. palu. 4: 17 (10µm)



2.c.i.b.27. Hord. juba.7:15 (10µm)



2.c.i.b.28. Comm. Gour. 18: 2 (5µm)

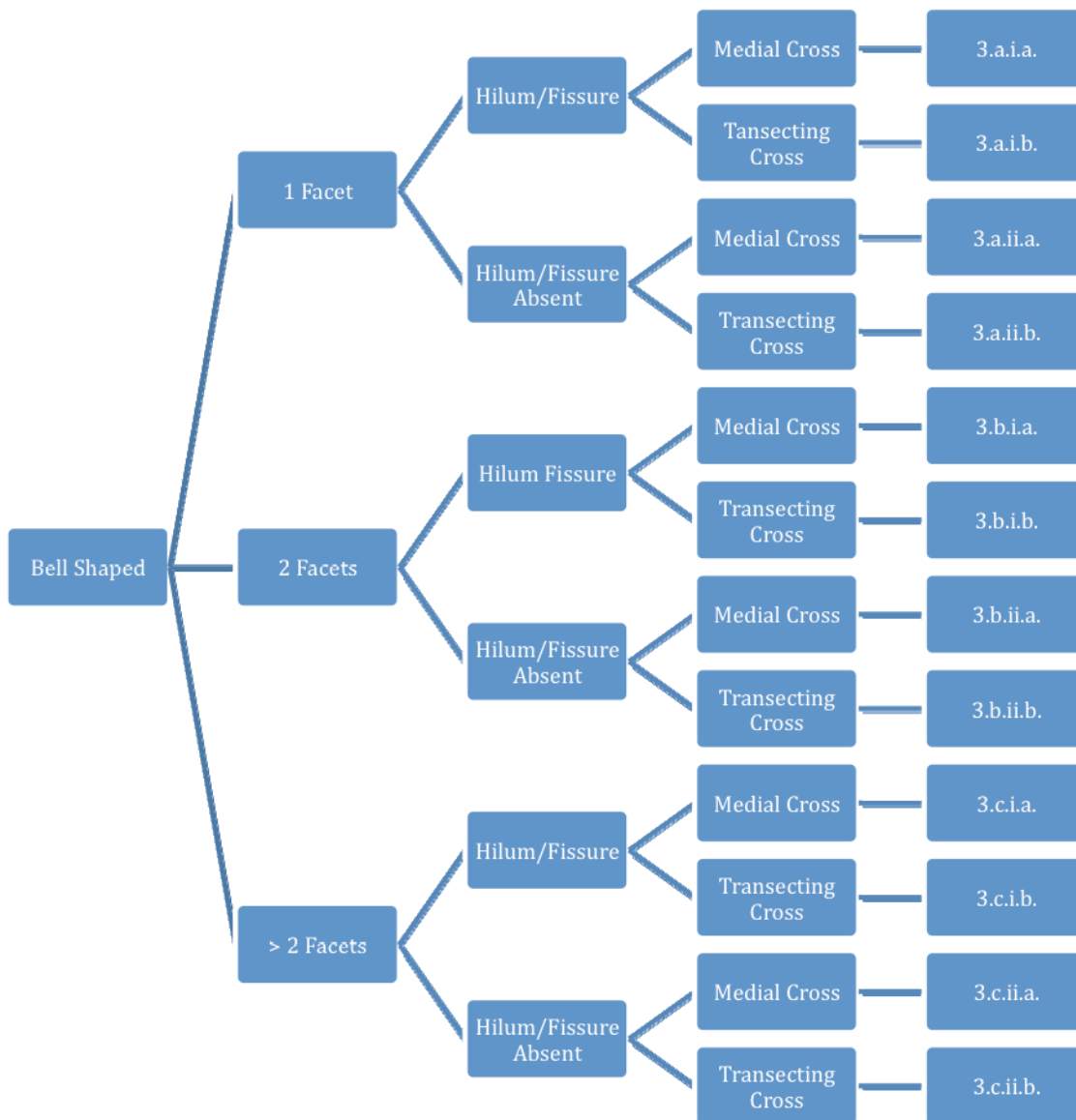


2.c.i.b.29. Pelt virg 4: 38 (15um)



2.c.i.b.30. Peri gair 8: 30 (10-20um)





Bell Shaped Starch Grains;

One Facet; Hilum/Fissure Visible; Medial Line; Darkened Area/Split Cross: 3.a.i.a.

3.a.i.a.1 Nymp. tube.6: 15 (20µm)



3.a.i.a.2.Psor. escu. 13: 5 (20µm)



3.a.i.a.3. Buttn. Sq.15:17 (15µm)



3.a.i.a.4. Hubb. Sq. 21: 1 (10-15µm)



3.a.i.a.5. Mara. arun. 3: 25 (10µm)



3.a.i.a.6. Osmo. long. 9: 3 (15µm)



3.a.i.a.7. Buttn. Sq. 24: 1 (10-15µm)



3.a.i.a.8. Buttn. Sq. 26: 1 (10-15µm)



3.a.i.a.9. Hubb. Sq.1: 4 (15µm)



3.a.i.a.10. Nymp odor 9: 5 (20µm)



3.a.i.a.11. Plan dila 12: 5 (30µm)



3.a.i.a.12. Ace. neg.2: 10 (<10um)



3.a.i.a.13. As. Sq.7: 6 (<10um)



3.a.i.a.14. As. Sq.24: 1 (15um)



3.a.i.a.15. As. Sq. 25: 1 (15um)



3.a.i.a.16. Butc. Sq. 26:1



No Darkened/Split:

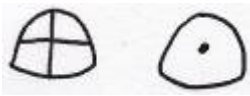
3.a.i.a.17. Buttn. Sq.11: 36 (15µm)



3.a.i.a.18. Hubb. Sq.5: 50 (5-10µm)



3.a.i.a.19. Pumpkin1: 82 (10µm)



3.a.i.a.20. Psor. escu.11: 4 (20µm)



3.a.i.a.21. Psor. escu. 20: 5 (5-10µm)



3.a.i.a.22. As. Sq.10: 8 (5µm)

3.a.i.a. 22. Peri gair 3: 25 (5-10µm)



3.a.i.a.23. Ace. neg.7: 22 (10µm)



3.a.i.a.24. As. Sq. 26: 1 (15µm)



3.a.i.a.25. As. Sq. 27:1 (15µm)



3.a.i.a.26. Butc. Sq.18: 5 (10µm)



3.a.i.a.27. Comm. Gour. 2: 12 (<20µm)



3.a.i.a.28. Comm. Gour. 4: 11 (<10µm)



3.a.i.a.29. As. Sq.18: 5 (5µm)



3.a.i.a.30. As. Sq.17: 5 (5µm)



3.a.i.a.31. As. Sq.19: 5 (5µm)



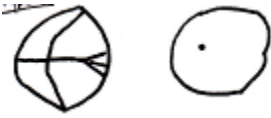
3.a.i.a.32. Psor. escu. 3: 17 (20-25µm)



3.a.i.a.33. Psor. escu. 16: 1 (20µm)



3.a.ii.a.34. Kaba. Sq. 4: 1 (15um)



3.a.ii.a.35. Aris. trip 20: 2 (20um)



**One Facet; Hilum/Fissure; Transect
Medial Line:**

3.a.i.b

Shoulders:

3.a.i.b.1. Nymph. tube.11: 19 (20um)



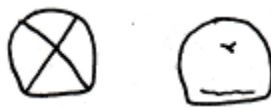
3.a.i.b.2. Nymph. tube. 22: 1 (20um)



3.a.i.b.3. Psor. escu. 21: 4 (20-25um)



3.a.i.b.4. Nymph odor 10: 15 (20um)



3.a.i.b.5. Mara. arun. 1: 38 (10um)

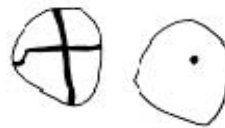


Tall:

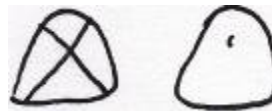
3.a.i.b.6. Buttn. Sq. 22: 1 (10-15um)



3.a.i.b.7. Buttn. Sq. 23: 1 (10-15um)



3.a.i.b.8. Comm. Gour. 1: 46 (10um)



3.a.i.b.9. Comm. Gour. 25: 1 (10um)



3.a.i.b.10. Comm. Gour. 26: 1 (10um)

3.a.i.b.10. Buttc. Sq.6: 5 (10um)



3.a.i.b.11. Hubb. Sq.4: 35 (10um)



3.a.i.b.12. Nymph. tube.1: 35 (20um)



3.a.i.b.13. Aris. trip 6: 30 (5-10µm)



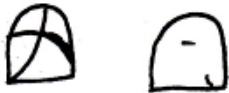
3.a.i.b.14. Aris. trip 24: 15 (20-25µm)



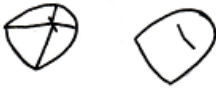
3.a.i.b.15. Clay. caro.1: 75 (20µm)



3.a.i.b.16. Clay. caro. 7: 20 (10µm)



3.a.i.b.17. Mara. arun. 13: 3 (10-15µm)



3.a.i.b.18. Buttn. Sq.1: 30 (10-20µm)



Short:

3.a.i.b.19. Comm. Gour. 22: 1 (10µm)



3.a.i.b.20. Comm. Gour. 23: 1 (10µm)



3.a.i.b.21. Hubb. Sq. 20: 1 (10-15µm)



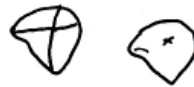
3.a.i.b.22. Kaba. Sq. 2: 10 (10-15µm)



3.a.i.b.23. Psor. escu. 5: 5 (10µm)



3.a.i.b.24. Psor. escu. 10: 75 (25µm)



3.a.i.b.25. Psor. escu. 19:17
(20-25µm)



3.a.i.b.26. Nymf. tube.4: 40 (20µm)



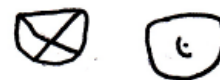
3.a.i.b.27. Clay. caro. 4: 30 (10µm)



3.a.i.b.28. Loma foen 1: 80 (15µm)



3.a.i.b.29. Nymf. odor. 5: 30 (5-10µm)



3.a.i.b.30. Nymf. odor. 6: 4 (5-10µm)

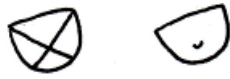


3.a.i.b.31. Nymph. odor. 7: 4 (5-10µm)

3.a.i.b.31. Hubb. Sq.2: 65 (5-10um)



3.a.i.b.32. Pelt virg 6: 15 (10µm)



3.a.i.b.33. Psor. escu. 12: 10 (20µm)



3.a.i.b.34. Mara. arun. 6: 55 (5-10µm)

3.a.i.b.34. Hera lana. 4: 9 (10um)



3.a.i.b.35. Nymph. tube.9: 47 (10-15µm)

3.a.i.b.35. Nymph. odor. 8: 10 (15um)



3.a.i.b.36. Ace. neg.8: 38 (<10um)



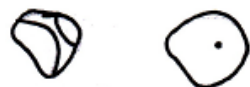
3.a.i.b.37. Ace. neg. 13: 1 (10um)



3.a.i.b.38. As. Sq.1: 15 (10um)



3.a.i.b.39. As. Sq.2: 4 (<10um)



3.a.i.b.40. As. Sq.4: 32 (<5um)



3.a.i.b.41. As. Sq.6: 10 (<10um)



3.a.i.b.42. Butt. Sq.7: 4 (15um)



3.a.i.b.43. Butt. Sq.10: 25 (5um)



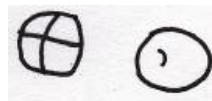
3.a.i.b.44. Comm. Gour. 11: 5 (10um)



3.a.i.b.45. Kaba. Sq. 10: 4 (10-15um)



3.a.i.b.46. Hera lana. 18: 6 (<10um)



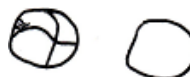
Bell Shaped Starch Grains: One Facet; Hilum/Fissure Not Visible; Medial Line;

Darkened/Split Cross: 3.a.ii.a.

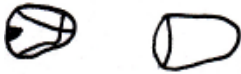
3.a.ii.a.1. Comm. Gour. 19: 1 (15µm)



3.a.ii.a.2. Buttn. Sq.10: 29 (10µm)



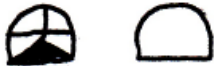
3.a.ii.a.3. Comm. Gour. 20: 1 (10µm)



3.a.ii.a.4. Hubb. Sq.11: 10 (5µm)



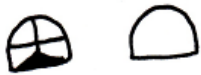
3.a.ii.a.5. Aris. trip 10: 15 (5-10µm)



3.a.ii.a.6. Clay. caro. 8: 10 (15-20µm)



3.a.ii.a.7. Spar eury 4: 45 (5µm)



3.a.ii.a.8. Symp foet 13: 25 (<10µm)



3.a.ii.a.9. Cory. corn.6: 21 (<5µm)



3.a.ii.a.10 Comm. Gour. 16: 5 (10µm)



No Darkened/Split:

3.a.ii.a.10. As. Sq.21: 6 (5µm)



3.a.ii.a.11. Buttn. Sq.13: 7 (15µm)



3.a.ii.a.12. Hubb. Sq.7: 15 (5-10µm)



3.a.ii.a.13. Pumpkin 3: 5 (5-10µm)



3.a.ii.a.14. Aris. trip 17: 19 (5-10µm)



3.a.ii.a.15. Aris. trip 18: 5 (15µm)



3.a.ii.a.16. Calt. palu. 21: 15 (<5µm)



3.a.ii.a.17. Clay. caro.10: 7 (5µm)



3.a.ii.a.18. Hera luna. 9: 1 (5-10µm)



3.a.ii.a.19. Loma foen 10: 15 (15µm)



3.a.ii.a.20. Osmo. long. 7: 35 (<5µm)



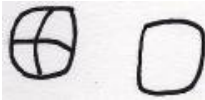
3.a.ii.a.21. Spar eury 2: 35 (<5µm)



3.a.ii.a.22. Symp foet 4: 5 (<10µm)



3.a.ii.a.23. Symp foet 12: 25 (<10µm)

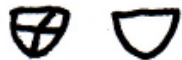


3.a.ii.a.24. Pumpkin 2: 10 (<5µm)

3.a.ii.a.24. Kaba. Sq. 17: 25 (5µm)



3.a.ii.a.25. Ziza. aqua.2: 15 (5µm)



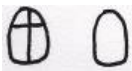
3.a.ii.a.26. Typh. lati.4: 10 (5µm)



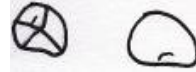
3.a.ii.a.27. Buttc. Sq.4: 17 (5µm)



3.a.ii.a. 28. Comm. Gour. 5: 7 (5µm)



3.a.ii.a.29. Comm. Gour. 13: 6 (10µm)



3.a.ii.a.30. Zucci. Sq.1: 50 (<10µm)

3.a.ii.a.30. Pelt virg 5: 47 (5-10µm)



Transecting Medial Line:

3.a.ii.b

Tall:

3.a.ii.b.1. Plan dila 3: 7 (25µm)



3.a.ii.b.2. Osmo. long. 15: 20 (20µm)

3.a.ii.b.2. Clay. caro. 2: 25 (20µm)



3.a.ii.b.3. Hubb. Sq.16: 10 (15µm)



3.a.ii.b.4. Pelt virg 7: 25 (10-15µm)



3.a.ii.b.5. Aris. trip 2: 12 (10µm)



3.a.ii.b.6. Zucc 2:



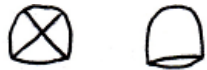
3.a.ii.b.7. Zucc 12:



3.a.ii.b.8. Calt. palu. 20: 16 (10µm)



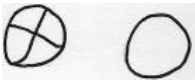
3.a.ii.b.9. Ace. neg.9: 12 (10µm)



3.a.ii.b.10. Comm. Gour. 21:1 (10µm)



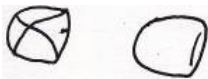
3.a.ii.b.11. Hera luna. 11: 20 (10µm)



3.a.ii.b.12. Comm. Gour. 24: 1 (10µm)



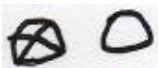
3.a.ii.b.13. Hera luna. 1: 10 (<10µm)



3.a.ii.b.14. Pumpkin 8: 30 (5-10µm)



3.a.ii.b.15. Nymp. tube.15: 20 (5µm)



3.a.ii.b.16. Pumpkin 4: 70 (5µm)



3.a.ii.b.17. Calt. palu. 12: 35 (5µm)



3.a.ii.b.18. As. Sq.12: 16 (5µm)

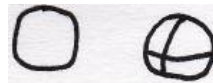


3.a.ii.b.19. Comm. Gour. 6: 27 (<5µm)

3.a.ii.b.19. Hera lana. 5: 15 (<5µm)



3.a.ii.b.20. Comm. Gour. 7: 28 (<10µm)



Short:

3.a.ii.b.21. Nymp. odor. 2: 60 (10-15µm)



3.a.ii.b.22. Osmo. long. 1: 78 (10-13µm)



3.a.ii.b.23. Osmo. long. 3: 10 (10µm)



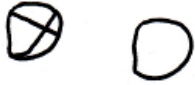
3.a.ii.b.24. Pumpkin 9: 2 (10µm)



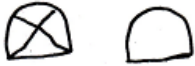
3.a.ii.b.25. Zucc 4:



3.a.ii.b.26. Zucc 8:



3.a.ii.b.27. Mara. arun. 12: 12 (10µm)



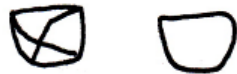
3.a.ii.b.28. Typh. lati.2: 50 (5-8µm)



3.a.ii.b.29. Butt. Sq.8: 5 (5µm)



3.a.ii.b.30. Osmo. long. 6: 26 (5µm)



3.a.ii.b.31. Osmo. long. 4: 40 (5µm)

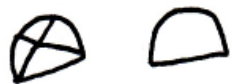
3.a.ii.b.31. Hera luna. 8: 13 (5-10µm)

3.a.ii.b.31. Hubb. Sq.15: 20 (<5µm)

3.a.ii.b.31. Symp foet 3: 37 (<10µm)

3.a.ii.b.31. Spar eury 1: 85 (5µm)

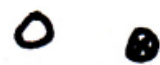
3.a.ii.b.31. Aris. trip 7: 25 (5-10µm)



3.a.ii.b.32. Spar eury 9: 25 (2-5µm)



3.a.ii.b.33. Ziza. aqua. 6: 10 (<3µm)



3.a.ii.b.34. Ace. neg.10: 2 (10um)



3.a.ii.b.35. As. Sq.15: 17 (5um)



3.a.ii.b.36. Butt. Sq.3: 20 (5um)



3.a.ii.b.37. Butt. Sq.17: 11 (10um)



3.a.ii.b.38. Comm. Gour. 14: 4 (<5um)



3.a.ii.b.39. Comm. Gour. 17: 5 (15um)



3.a.ii.b.40. Cory. corn.3: 50 (<5um)



3.a.ii.b.41. Hubb. Sq.13: 5 (15um)



3.a.ii.b.42. Zucci. Sq. 10: 8 (<10um)



**Two Facets; Hilum/Fissure Present;
Medial Line: 3.b.i.a.**

3.b.i.a.1. Psor. escu. 18: 27 (20µm)



3.b.i.a.2. Buttc. Sq. 21:1



3.b.i.a.3. Aris. trip 12: 5 (13µm)



3.b.i.a.4. Aris. trip 5: 12 (5-10µm)



3.b.i.a.5. Psor. escu. 8: 6 (5-10µm)



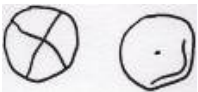
3.b.i.a.6. As. Sq.9: 4 (5µm)



3.b.i.a.7. As. Sq.22: 1 (5µm)



3.b.i.a.8. Comm. Gour. 10: 1 (15µm)



3.b.i.a.9. Nymp. tube.2: 11 (20µm)



Transect Medial Line:

3.b.i.b.

Tall:

3.b.i.b.1. Psor. escu.1: 9 (20-25µm)

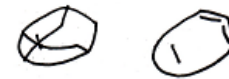


3.b.i.b.2. Aris. trip.1: 13 (20µm)



3.b.i.b.3. Clay. caro. 13: 10 (20µm)

3.b.i.b.3. Mara. arun. 15: 15 (10µm)



3.b.i.b.4. Buttn. Sq. 20: 1 (10-15µm)

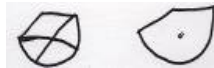


3.b.i.b.5. Hubb. Sq. 18: 1 (10-15µm)



Short:

3.b.i.b.6. Nymp. tube.19: 13 (20µm)



3.b.i.b.7. Nymp. tube.8: 3 (20µm)

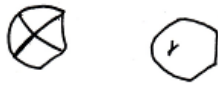


3.b.i.b.8. Aris. trip 14: 8 (20 μ m)

3.b.i.b.8. Nymp. odor. 1: 80 (15 μ m)



3.b.i.b.9. Clay. caro. 6: 11 (15-20 μ m)



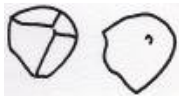
3.b.i.b.10. Mara. arun. 8: 13 (15 μ m)



3.b.i.b.11. Ace. neg.1: 23 (15 μ m)



3.b.i.b.12. Buttn. Sq.2: 95 (12 μ m)



3.b.i.b.13. Kaba. Sq. 16: 2 (10-15 μ m)



3.b.i.b.14. Mara. arun. 4: 13 (10 μ m)



3.b.i.b.15. Mara. arun. 10: 10 (10 μ m)



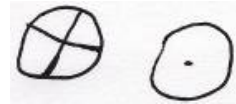
3.b.i.b.16. Pumpkin 7: 4 (10 μ m)



3.b.i.b.17. Symp foet 1: 31 (<10 μ m)



3.b.i.b.18. Ace. neg. 14: 1 (<10 μ m)



3.b.i.b.19. As. Sq. 3: 11 (<10 μ m)



3.b.i.b.20. Hubb. Sq.14: 7 (5-10 μ m)



3.b.i.b.21. Zucci. Sq. 7: 20 (5 μ m)



3.b.i.b.22. Loma foen 4: 20 (5 μ m)



3.b.i.b.23. Kaba. Sq. 5: 26 (5 μ m)



3.b.i.b.24. Kaba. Sq. 6: 65 (5 μ m)



Two Facets; No

Hilum/Fissure; Transecting Medial Line:

3.b.ii.b.

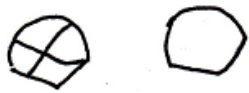
3.b.ii.b.1. Buttcc. Sq.12: 3 (10 μ m)



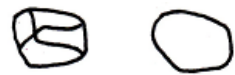
3.b.ii.b.2. Osmo. long. 11: 6 (10 μ m)

3.b.ii.b.2. Loma foen 12: 5 (15 μ m)

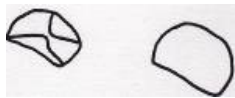
3.b.ii.b.2. Symp foet 6: 25 (<10 μ m)



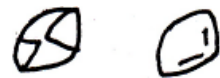
3.b.ii.b.3. Aris. trip 15: 2 (10 μ m)



3.b.ii.b.4. Hera luna. 20: 10 (10 μ m)



3.b.ii.b.5. Aris. trip 8: 7 (5-10 μ m)



3.b.ii.b.6. Hera luna. 16: 20 (<10 μ m)

3.b.ii.b.6. Symp foet 2: 1 (<10 μ m)



3.b.ii.b.7. Spar eury 7: 10 (<10 μ m)



3.b.ii.b.8. Hera luna. 19: 1 (<10 μ m)

3.b.ii.b.8. Aris. trip 8: 7 (5-10 μ m)



3.b.ii.b.9. As. Sq.8: 3 (5 μ m)

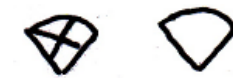
3.b.ii.b.9. Aris. trip 9: 5 (5-10 μ m)



3.b.ii.b.10. As. Sq.16: 23 (5 μ m)



3.b.ii.b.11. Ziza. aqua. 3: 16 (5 μ m)



3.b.ii.b.12. Pelt virg 14: 15 (5 μ m)

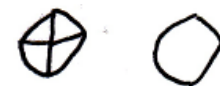
3.b.ii.b.12. Clay. caro. 9: 5 (5 μ m)

3.b.ii.b.12. Calt. palu. 8: 50 (<5 μ m)

3.b.ii.b.12. Spar eury 11: 3 (3-4 μ m)



3.b.ii.b.13. Buttcc. Sq.3: 25 (5-8 μ m)



3.b.ii.b.14. Buttn. Sq.4: 4 (10 μ m)



3.b.ii.b.15. Zucci. Sq. 3: 22 (10 μ m)



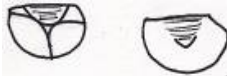
Medial Line:

3.b.ii.a.

3.b.ii.a.1. Buttc. Sq. 22:1



3.b.ii.a.2. Loma foen 11: 5 (15-20µm)



3.b.ii.a.3. Zucc 5:



3.b.ii.a.4. Clay. caro. 3: 30 (10µm)



3.b.ii.a.5. Ace. neg.11: 5 (<10µm)

3.b.ii.a.5. Symp foet 5: 50 (<10µm)

3.b.ii.a.5. Hera luna. 3: 50 (<10µm)

3.b.ii.a.5. Buttc. Sq.19: 2 (10µm)

3.b.ii.a.5. Aris. trip 11: 11 (5-10µm)

3.b.ii.a.5. Loma foen 5: 15 (10-15µm)



3.b.ii.a.6. Quer. macr. 8: 5 (10µm)



3.b.ii.a.7. Osmo. long. 12: 2 (5-10µm)



3.b.ii.a.8. Comm. Gour. 15: 6 (<10µm)



3.b.ii.a.9. Symp foet 14: 20 (<10µm)



3.b.ii.a.10. Aris. trip 22: 20 (5µm)



3.b.ii.a.11. Aris. trip 23: 20 (5µm)

3.b.ii.a.11. Spar eury 3: 35 (5µm)

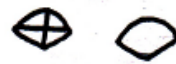
3.b.ii.a.11. Buttn. Sq.6: 42 (5µm)

3.b.ii.a.11. Nymp. odor. 11: 10 (5µm)

3.b.ii.a.11. Pelt virg 13: 8 (5µm)

3.b.ii.a.11. Mara. arun. 7: 25 (5µm)

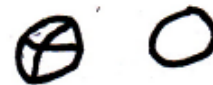
3.b.ii.a.11. Calt. palu. 22: 5 (5µm)



3.b.ii.a.12. Clay. caro. 11: 1 (5µm)



3.b.ii.a.13. Calt. palu.19: 10 (<5µm)



Multiple Facets; Hilum/Fissure

Transecting Medial Line:3.c.i.b.

3.c.i.b.1. Psor. escu. 7: 27 (20-5µm)



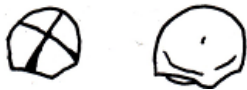
3.c.i.b.2. Psor. escu.15: 10 (20-25µm)



3.c.i.b.3. Kaba. Sq. 23: 1 (10-15µm)



3.c.i.b.4. Mara. arun. 14: 11 (10µm)

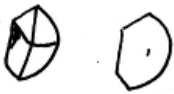


Multiple Facets; Hilum/Fissure

Medial Line:

3.c.i.a

3.c.i.a.1. Hubb. Sq.9: 11 (15µm)



3.c.i.a.2. Kaba. Sq. 3: 2 (15µm)



3.c.i.a.3. Buttn. Sq. 21: 1 (10-15µm)



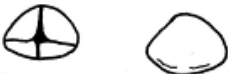
3.c.i.a.4. Buttn. Sq. 25: 1 (10-15µm)



3.c.i.a.5. As. Sq.13: 7 (<10µm)



3.c.i.a.6. Loma foen 8: 10 (15µm)



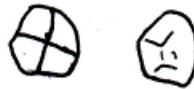
Multiple Facets; No Hilum/Fissure:

Transecting Medial Line: 3.c.ii.b.

3.c.ii.b.1. Buttn. Sq.16: 12 (20µm)



3.c.ii.b.2. Psor. escu. 6: 4 (20µm)



3.c.ii.b.3. Nymph. tube.12: 2 (15µm)



3.c.ii.b.4. Buttn. Sq.18: 7 (10-15µm)



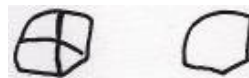
3.c.ii.b.5. Kaba. Sq. 9: 4 (10µm)



3.c.ii.b.6. Kaba. Sq. 14: 6 (10µm)



3.c.ii.b.7. Symp foet 10: 10 (<10µm)



Multiple Facets; No Hilum/Fissure;

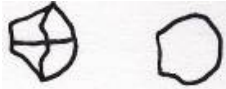
Medial Line:

3.c.ii.a.

3.c.ii.a.1. Buttc. Sq.14: 5 (5-10 μ m)

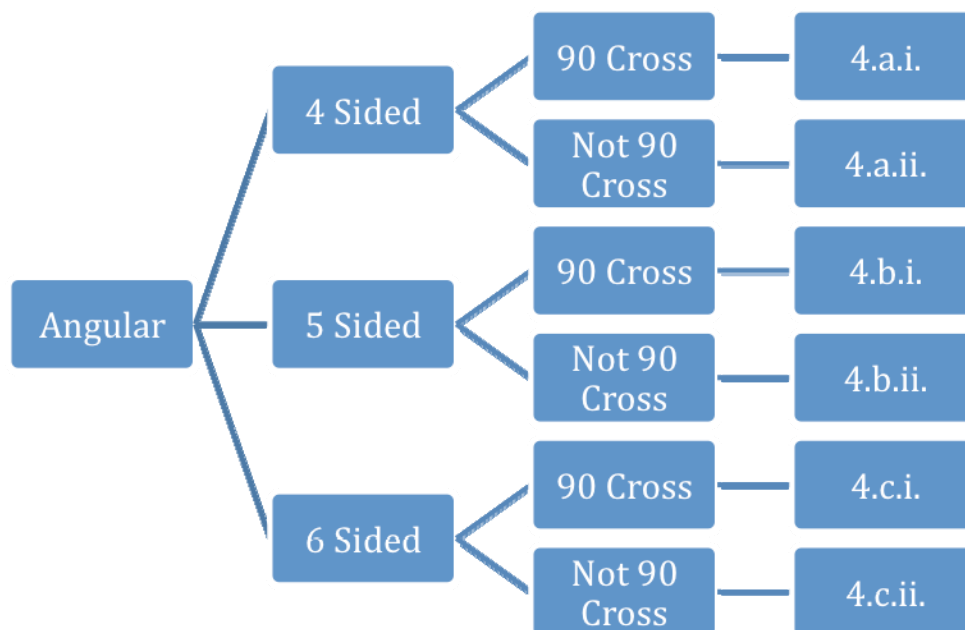


3.c.ii.a.2. Hera luna. 12: 30 (<10 μ m)



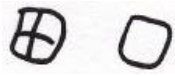
3.c.ii.a.3. Symp foet 8: 17 (<10 μ m)



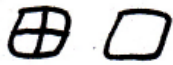


4 Sided; 90 Cross: 4.a.i.

4.a.i.1. Prun. virg. 14: 1 (<5μm)



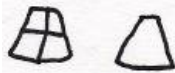
4.a.i.2. Ziza. aqua. 7: 18 (5μm)



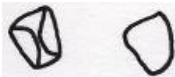
4.a.i.3. Ziza. palu. 5: 55 (5μm)



4.a.i.4. Osmo. long. 13: 12 (5μm)



4.a.i.5. Hera luna. 21: 5 (5-10μm)

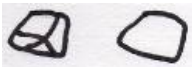


4 Sided; Not 90 Cross: 4.a.ii.

4.a.ii.1. Ziza. palu. 3: 20 (<5μm)



4.a.ii.2. Ziza. palu. 7: 10 (<5μm)



4.a.ii.3. Ziza. palu. 8: 10 (5μm)



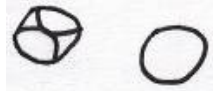
4.a.ii.4. Mara. arun. 5: 15 (5μm)



4.a.ii.5. Ziza. aqua. 8: 7 (5μm)

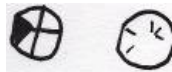


4.a.ii.6. Typh. lati. 1: 130 (5μm)



5 Sided

4.b.i.1. Kaba. Sq. 18: 13 (10μm)



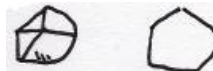
4.b.ii.1. Buttc. Sq. 2: 25 (5-10μm)



4.b.ii.2. Ziza. palu. 2: 10 (5μm)



4.b.ii.3. Ziza. palu. 1: 15 (5μm)



6 Sided:

Fissure:

4.c.i.1. Zea. May. 1: (20μm)



4.c.i.2. Zea. May. 2: (20μm)

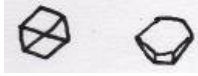


No Fissure:

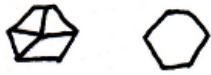
4.c.ii.1. Ziza. aqua. 9: 4 (5-10 μ m)



4.c.ii.2. Ziza. palu. 6: 133 (5-7 μ m)



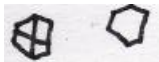
4.c.ii.3. Ziza. aqua.1: 188 (5 μ m)



4.c.ii.4. Cory. corn.1: 110 (5 μ m)



4.c.ii.5. Ziza. palu. 4: 27 (<5 μ m)



Irregular

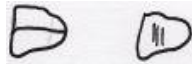
No Further Separation

Irregular Starch Grain Shapes

5.a. Ace. neg.4: 22 (<10µm)



5.b. Comm. Gour. 8: 11 (10µm)



5.c. Comm. Gour. 12: 4 (10µm)



5.d. Gree. Bea.6: 7 (10µm)



5.e. Liliu. phila. 4: 10 (30µm)



5.f. Liliu. phila. 6: 35 (30µm)



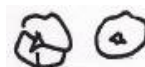
5.g. Liliu. phila. 11: 1 (30µm)



5.h. Prun. pen. 10: 2 (5µm)



5.i. Prun. pen. 11: 1 (<5µm)



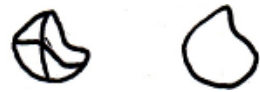
5.j. Prun. virg. 19: 1 (<5μm)

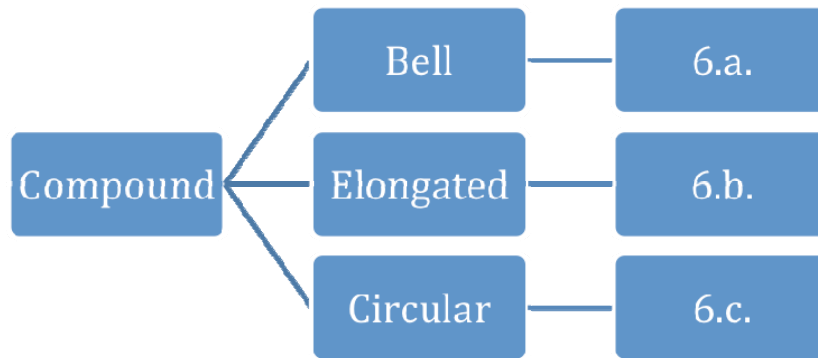


5.k. Amer. alni.10: 7 (5μm)



5.l. Calt. palu. 14: 5 (<10μm)





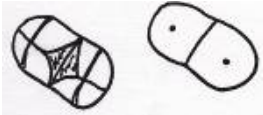
Compound/Semi-Compound Starch Grains:

Producing Bell Types: 6.a.

6.a.1. Nymp. tube.7: 3 (40µm)



6.a.2. Nymp. tube.13: 1 (40µm)



6.a.3. Nymp. tube.10: 1 (35µm)



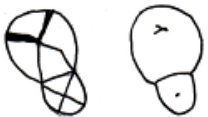
6.a.4. Plan dila 7: 2 (30µm)



6.a.5. Plan dila 9: 15 (20-30µm)



6.a.6. Nymp. odor. 12: 1 (25µm)



6.a.7. Osmo. long. 14: 10 (20µm)



6.a.8. Ace. neg. 15: 1 (15µm)



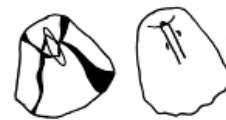
6.a.9. Kaba. Sq. 1: 1 (15µm)



6.a.10. Buttn. Sq. 27: 1 (10-15µm)



6.a.11. Buttn. Sq. 28: 1 (10-15µm)



6.a.12. Hubb. Sq. 19:1 (10-15µm)



6.a.13. Hubb. Sq.12: 1 (10µm)



6.a.14. Ace. neg.3: 65 (<10µm)



Compound/Semi-compound Starch Grains: Producing Elongated Types: 6.b

6.b.1. Romano 8: 3 (50µm) Semi-compound



6.b.2. BTB 11: 2 (40µm)



6.b.3. Romano 1: 39 (35-40 μ m)



6.b.4. Gree. Bea.7: 8 (35 μ m)



6.b.5. WNB 9: 11 (30 μ m)



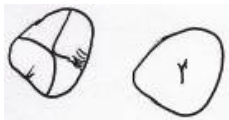
6.b.6. Plan dila 11: 6 (30 μ m)



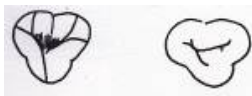
6.b.7. BTB 10: 5 (30 μ m)



6.b.8. Pinto Bean 12: 3 (30 μ m)



6.b.9. RKB 2: 21 (20 μ m)



Compound/Semi-compound Starch
Grains; Producing Circular Types: 6.c.

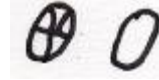
6.c.1. Prun. nigr. 18: 3 (5 μ m)



6.c.2. Prun. pen. 6: 18 (5 μ m)



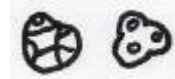
6.c.3. Amer. alni. 6: 3 (5 μ m)



6.c.4. Amer. alni.3: 11 (5 μ m)



6.c.5. Prun. virg. 4: 4 (5 μ m)

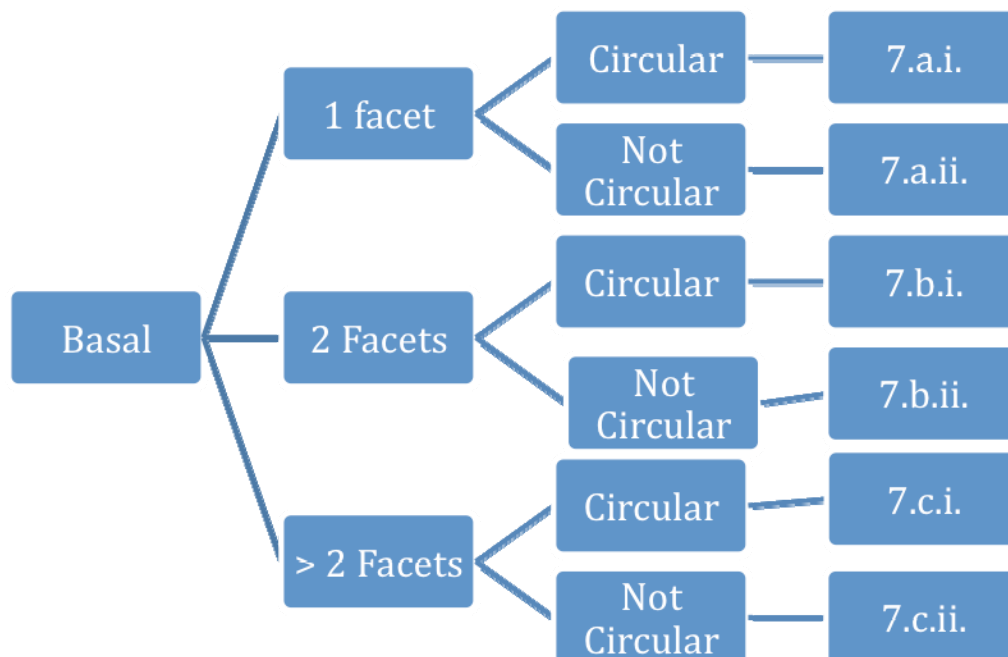


6.c.6. Prun. virg. 6: 28 (5 μ m)



6.c.7. Cory amer. 7: 10 (<5 μ m)





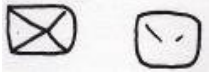
Basal Starch Grains; One Facet; Contains Angles:

7.a.ii.

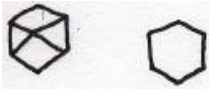
7.a.ii.1. Kaba. Sq. 19: 2 (8µm) Base



7.a.ii.2. Hera luna. 10: 5 (10µm) Base



7.a.ii.3. Symp foet 7: 30 (<10µm) Base



7.a.ii.4. Ziza. aqua. 5: 11 (5µm) Base



7.a.ii.5. Buttn. Sq. 19: 1 (10-15µm)



Basal Starch Grains; One Facet; Mostly Circular: 7.a.i.

7.a.i.1. Aris. trip 4: 11 (15µm)



7.a.i.2. Mara. arun. 2: 38 (10µm)



7.a.i.3. Ace. neg.5: 10 (10µm)



Basal Starch Grains; Two Facets; Contains Angles: 7.b.ii.

7.b.ii. 1. Hera luna. 7: 4 (<5µm) Base



7.b.ii.2 Psor. escu. 2: 17 (10µm)



Basal Starch Grains; Two Facets; Mostly Circular: 7.b.i.

7.b.i.1 Buttc. Sq.15: 13 (5-10µm)



7.b.i.2 Buttc. Sq. 20: 1



7.b.i.3. Osmo long 8: 3 (10µm)

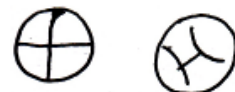


Basal Starch Grains; Multiple Facets; Mostly Circular: 7.c.i

7.c.i.1. As. Sq.14: 8 (<10µm)



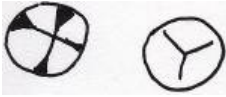
7.c.i.2. Buttc. Sq.16: 5 (10µm)



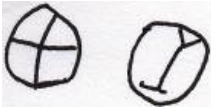
7.c.i.3. Buttc. Sq.17: 30 (10µm)



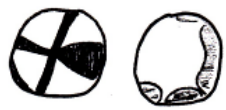
7.c.i.4. Buttn. Sq.7: 42 (10µm)



7.c.i.5. Buttn. Sq.8: 14 (10µm)



7.c.i.6. Hubb. Sq. 17: 1 (10-15µm)



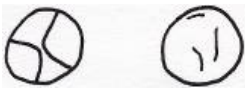
7.c.i.7. Kaba. Sq. 11: 40 (10-15µm)



7.c.i.8. Kaba. Sq. 13: 15 (10-15µm)



7.c.i.9. Kaba. Sq. 20: 4 (10µm)



7.c.i.10. Kaba. Sq. 21: 1 (10-15µm)



7.c.i.11. Kaba. Sq. 22: 1 (10-15µm)



7.c.i.12. Aris. trip 13: 2 (20µm)



7.c.i.13. Loma foen 3: 15 (10µm)



7.c.i.14. Loma foen 9: 15 (15µm)



7.c.i.14. Buttc. Sq. 23:1 (15 µm)



7.c.i.15. Kaba. Sq. 8: 1 (10µm)

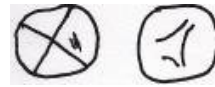


Basal Starch Grains; Multiple Facets;
Contains Angles: 7.c.ii.

7.c.ii.1. Buttc. Sq. 25:1(15-20µm)



7.c.ii.2. Buttn. Sq.9: 14 (12µm)



7.c.ii.3. Psor. escu. 4: 3 (10µm)



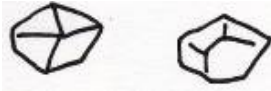
7.c.ii.4. Aris. trip 19: 5 (20µm)



7.c.ii.5. Aris. trip 25: 10 (15µm)



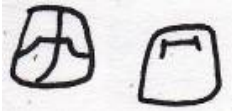
7.c.ii.6. Hera luna. 14: 40 (10 μ m)



7.c.ii.7. Hera luna. 15: 13 (5-10 μ m)



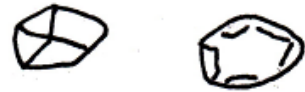
7.c.ii.8. Hera luna. 17: 2 (<10 μ m)



7.c.ii.9. Mara. arun. 9: 23 (10 μ m)



7.c.ii.10. Osmo. long. 5: 7 (5-10 μ m)



Glossary:

Angled Elongated Grain: Elongated starch grains that appear bent.

Angular Starch Grain: Starch grains where the overall shape contains angles.

Bell Shaped Starch Grain: Starch grains that contain facets and are bell shaped.

Basal Starch Grain: Starch grains where the basal portion of the starch grain is pointing upwards. These starch grains contain signs of facets on the surface of the starch grain.

Circular Starch Grain: Starch grains that are circular in shape and contain a central hilum.

Cross Not Touching: Occurs when the arms of the extinction do not touch.

Cross Touching: Occurs when the arms of the extinction cross transect each other.

Darkened Cross: Present in some starch grains where the one arm of the extinction cross thickens towards one end.

Elongated: Starch grains that at least twice as long as thick. Example: Bean Starch.

Facet: Docking location for sub-compound starch grains. Appears as a concave feature on the surface of starch grains. Depending on the starch grain, there may be one or multiple facets present.

Grain Cracking: Appearing mostly in elongated starch grains. Similar to fissures but may not be isolated to the hilum of a starch grain.

Grain Packing: Some starch grains are stored in tightly packed clusters. This packing results in angular or flattened sides.

Individual Grain: Starch grains containing no facets and are free from other organic substances.

Irregular Starch Grain: Starch grains that contain projections, angles, or other features that does not allow for categorization.

Medial Line Cross: Present in some starch grains where one arm of the extinction cross runs along the medial line of the starch grain.

Parallel Elongated Grain: Elongated starch grains where opposite sides of the starch grains are parallel and the overall thickness of the grain remains constant.

Roughened Starch Grain: A starch grain where the exterior surface appears roughened

Semi-compound Grain: Multiple starch grains adhering to each other and exhibiting a singular extinction cross.

Smooth Starch Grain: A starch grain where the exterior surface appears smooth.

Split Cross: Present in some starch grains where the one arm of the extinction cross splits near one end of the starch grain.

Tapered Elongated Grain: Elongated starch grains where thickness decreases towards one end of the starch grain.

Transecting Line Cross: Present in some starch grains where the extinction cross transects the medial line of the starch grain.

1 Arm Cross: Starch grains that when viewed under cross-polarized light only exhibits a single darkened line of the extinction cross.

90° Cross: Starch grains where the arms of the extinction cross meet at right angles.

A.3. Raw Data

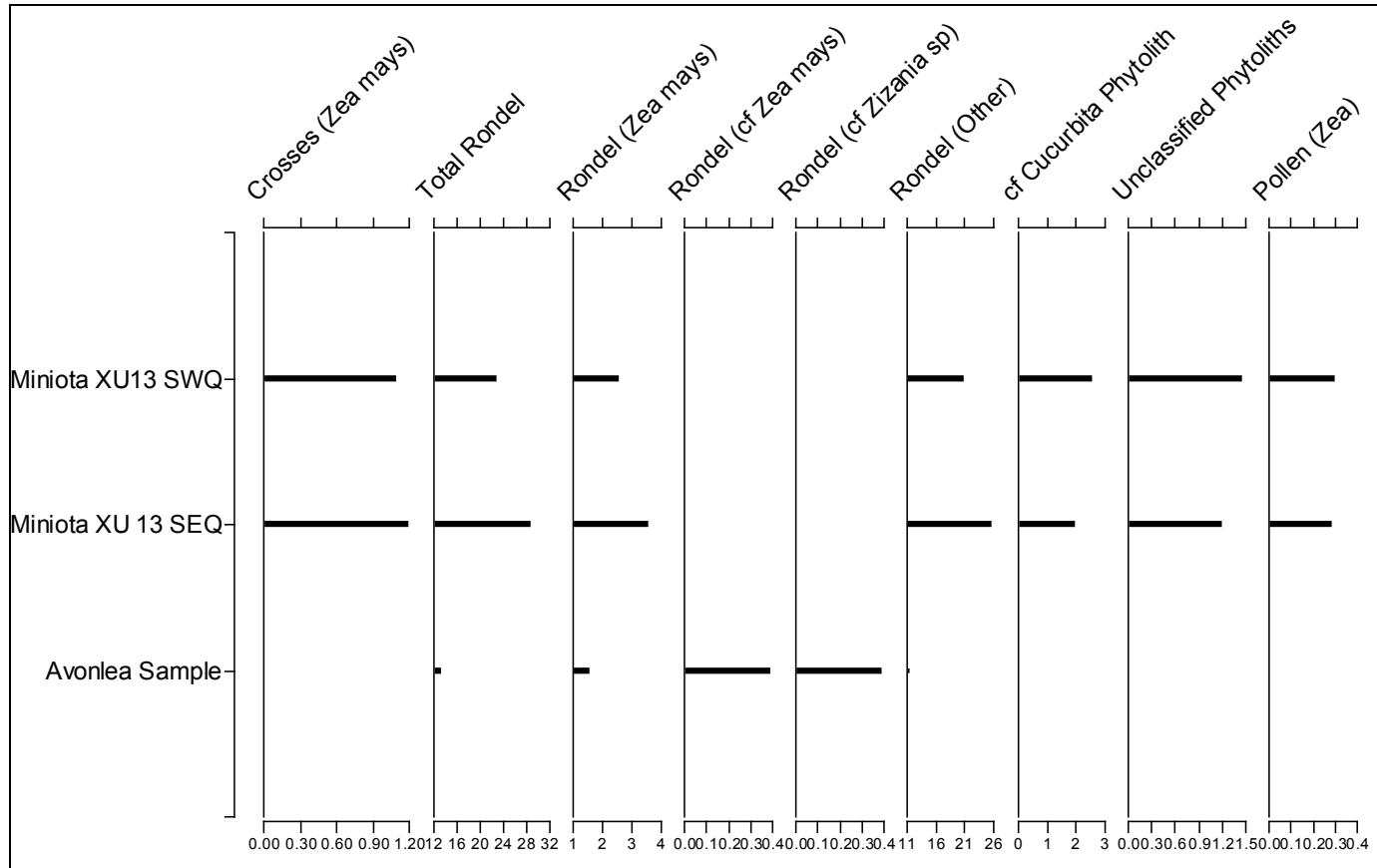


Fig. A.1. Important phytolith and pollen counts from Avonlea Soil Samples. Phytoliths presented as percentages of the total number of phytoliths counted in each sample (n= 250). Pollen presented as percentage out of the total number of microfossils counted in each sample.

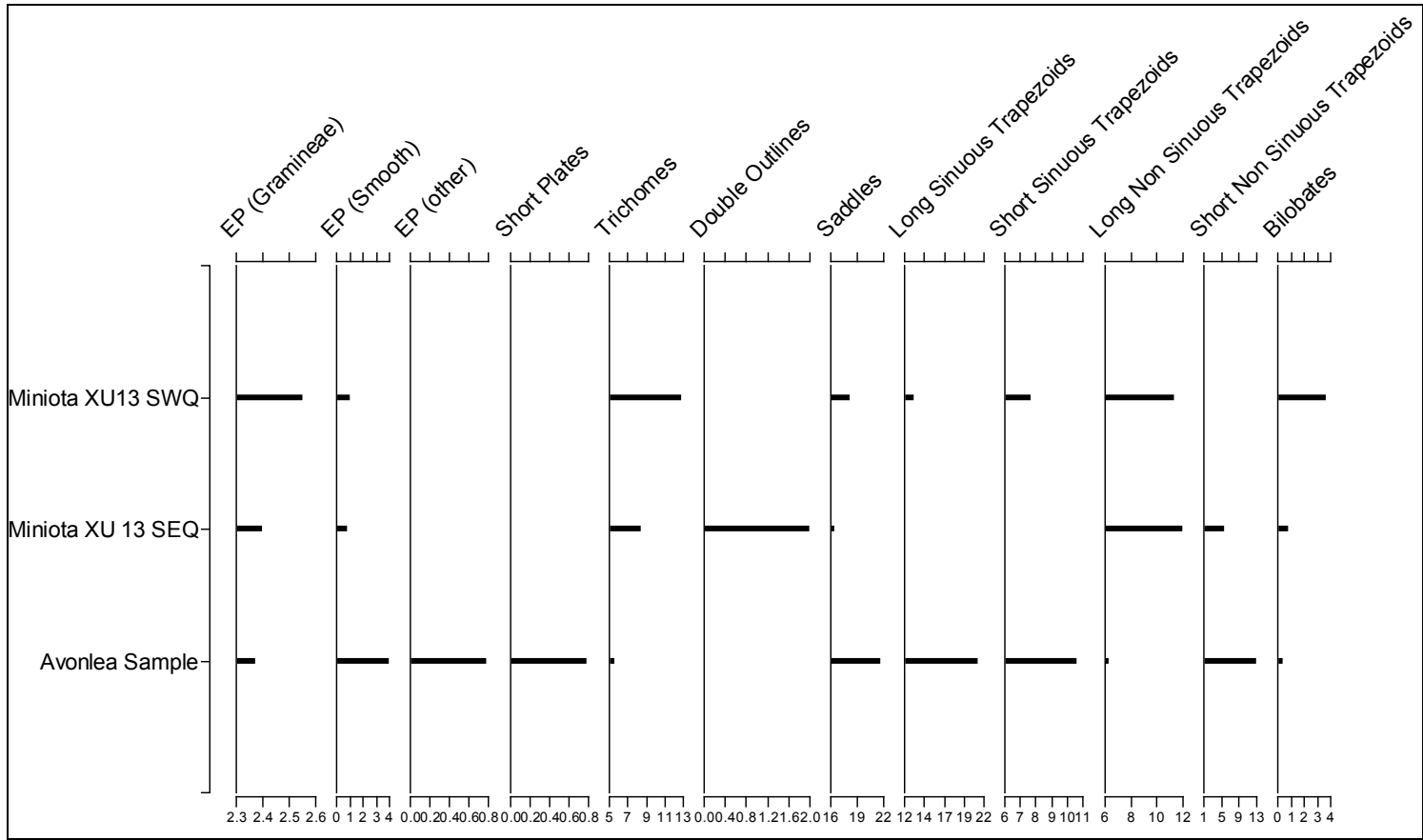


Fig. A.2. Other phytolith counts from Avonlea Soil Samples. Phytoliths presented as percentages of the total number of phytoliths counted in each sample (n= 250) (EP= Elongated Plates).

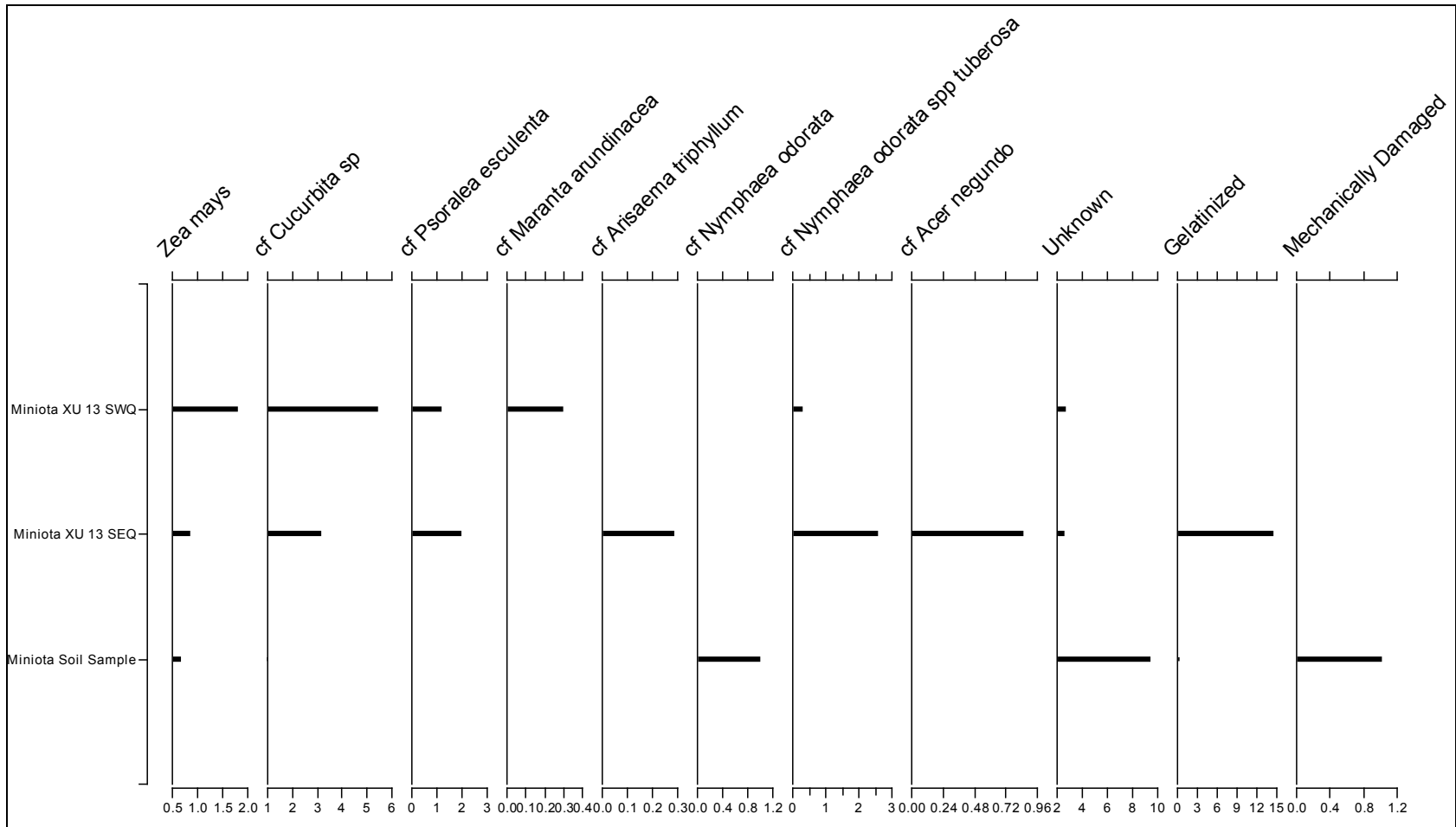


Fig. A.3. Wild and domesticated starch grains, unknown, gelatinized, and mechanically damaged starch grains from Avonlea Soil Samples. Starch grains presented as percentages out of the total microfossils counted in each sample. *Maranta arundinacea* likely represents an unknown tuber, yet to be identified.

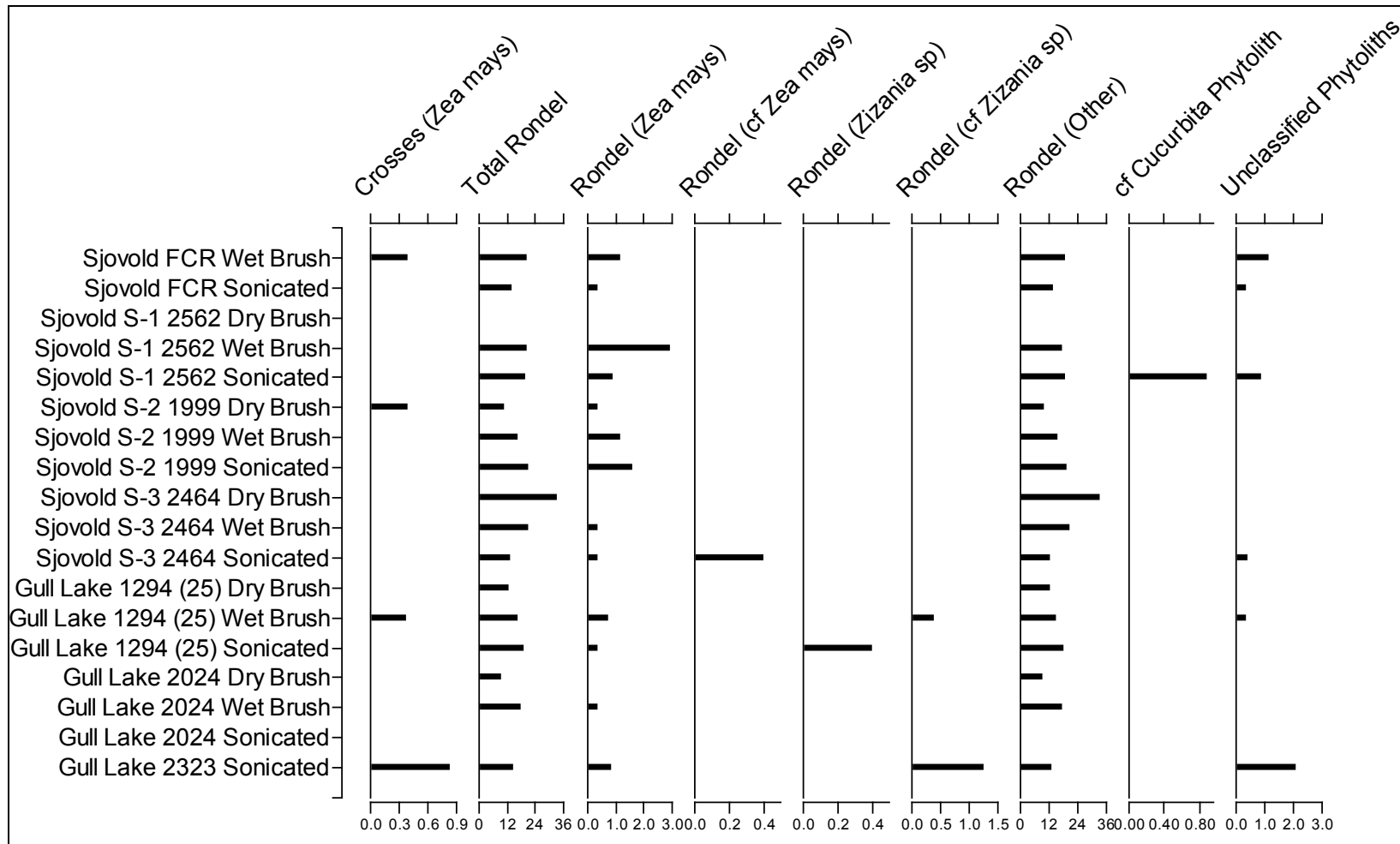


Fig. A.4. Important phytolith counts from Avonlea Stone Tool Samples. Phytoliths presented as percentages of the total number of phytoliths counted in each sample (n= 250).

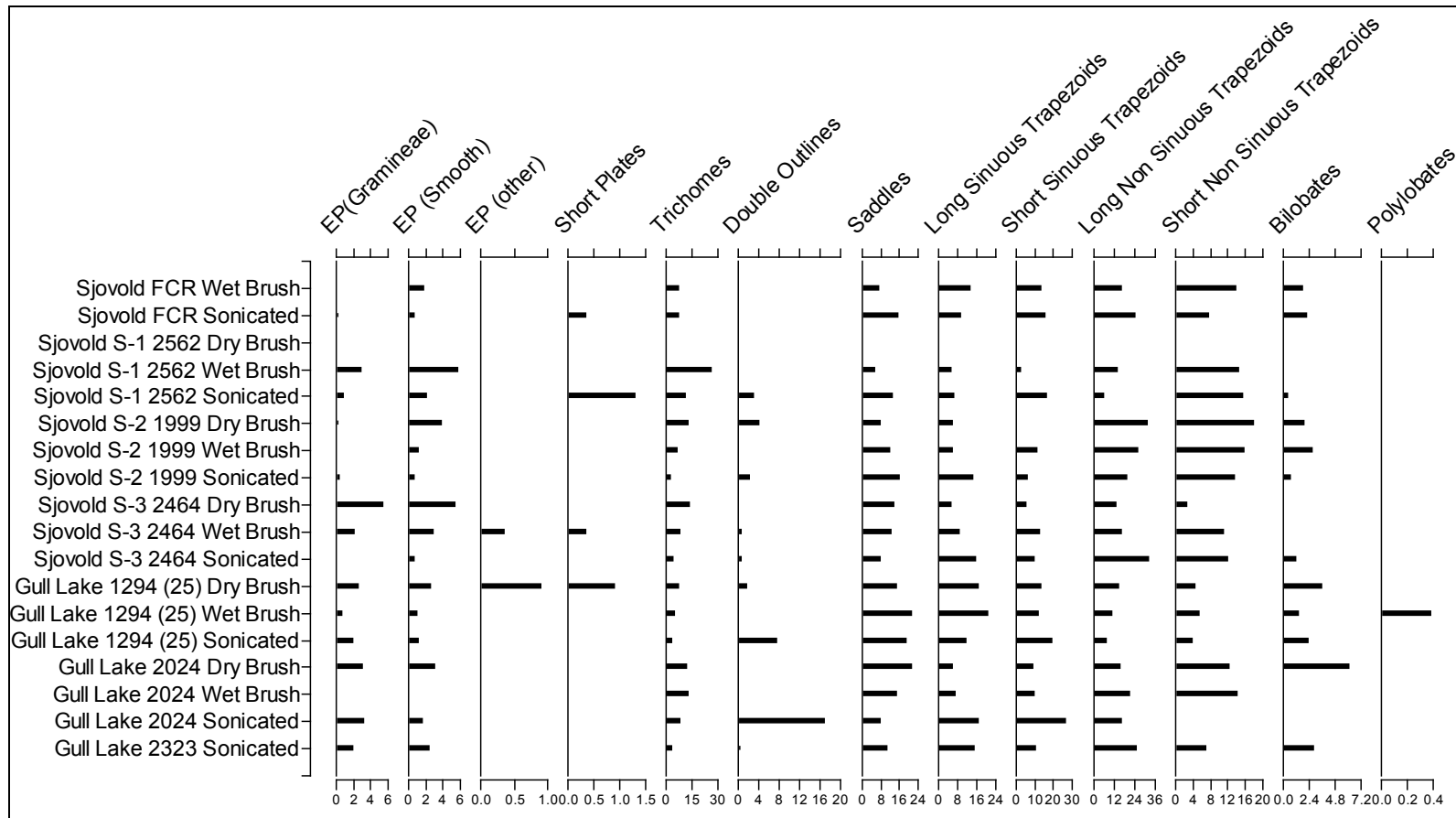


Fig. A.5. Other phytolith counts from Avonlea Stone Tool Samples. Phytoliths presented as percentages of the total number of phytoliths counted in each sample (n= 250) (EP = Elongated Plates).

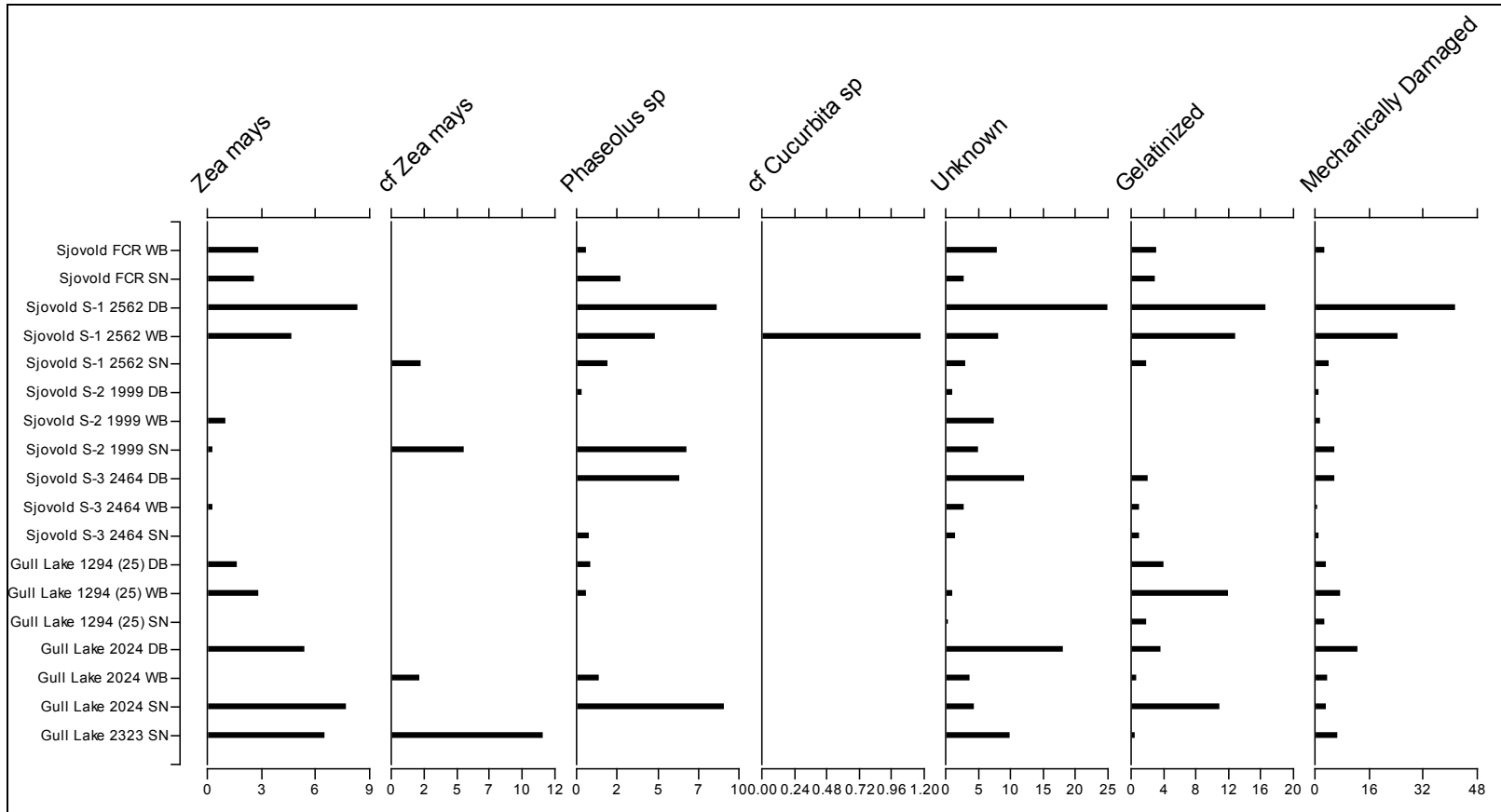


Fig. A.6. Domesticated starch, unknown, gelatinized, and mechanically damaged starches from Avonlea Stone tool Samples. Starch grains presented as percentages out of the total microfossils counted in each sample (DB = Dry Brush, WB = Wet Brush, and SN = Sonicated).

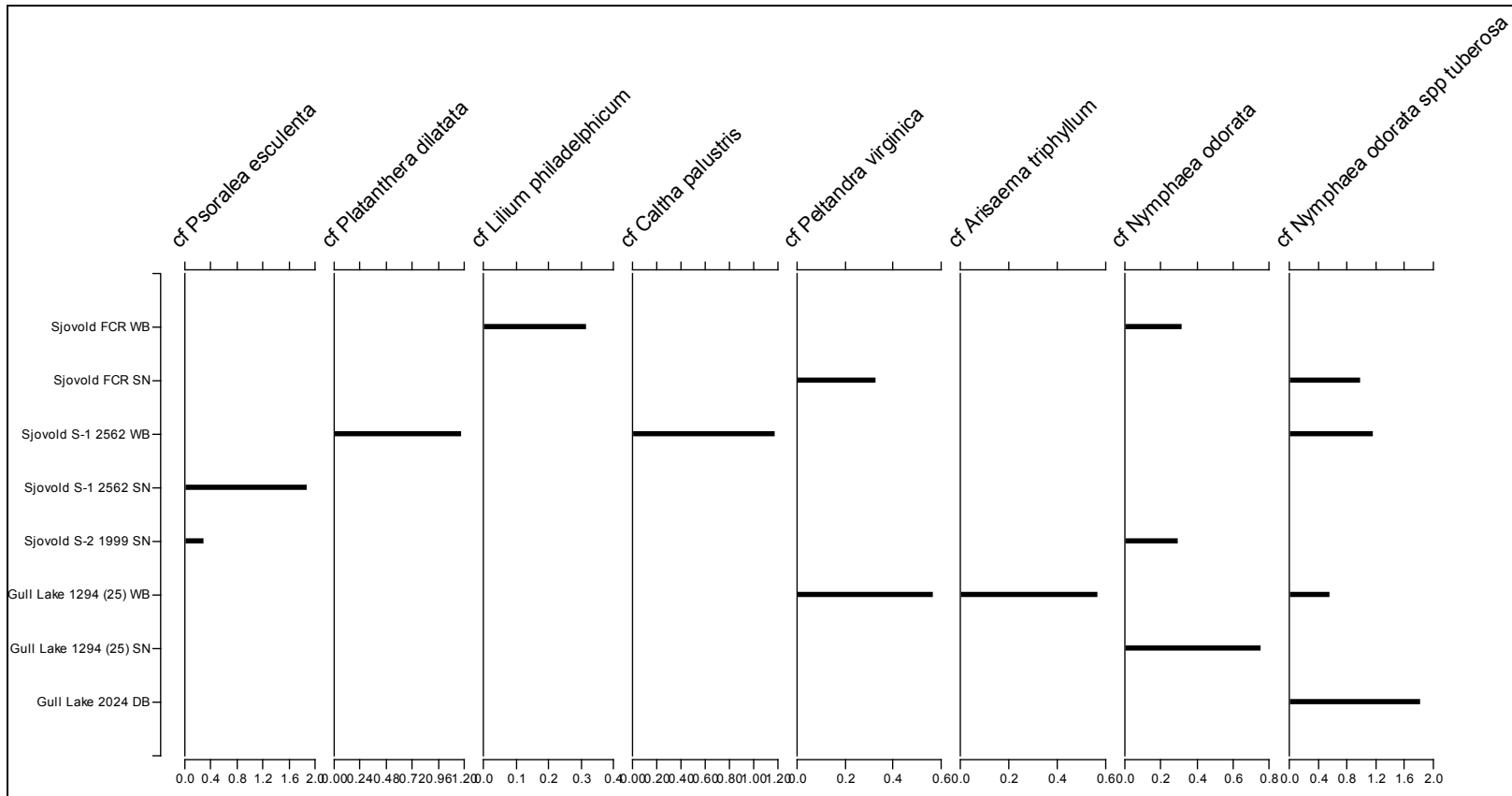


Fig. A.7. Wild starch counts from Avonlea Stone Tool Samples. Starch grains presented as percentages out of the total microfossils counted in each sample (DB = Dry Brush, WB = Wet Brush, and SN = Sonicated).

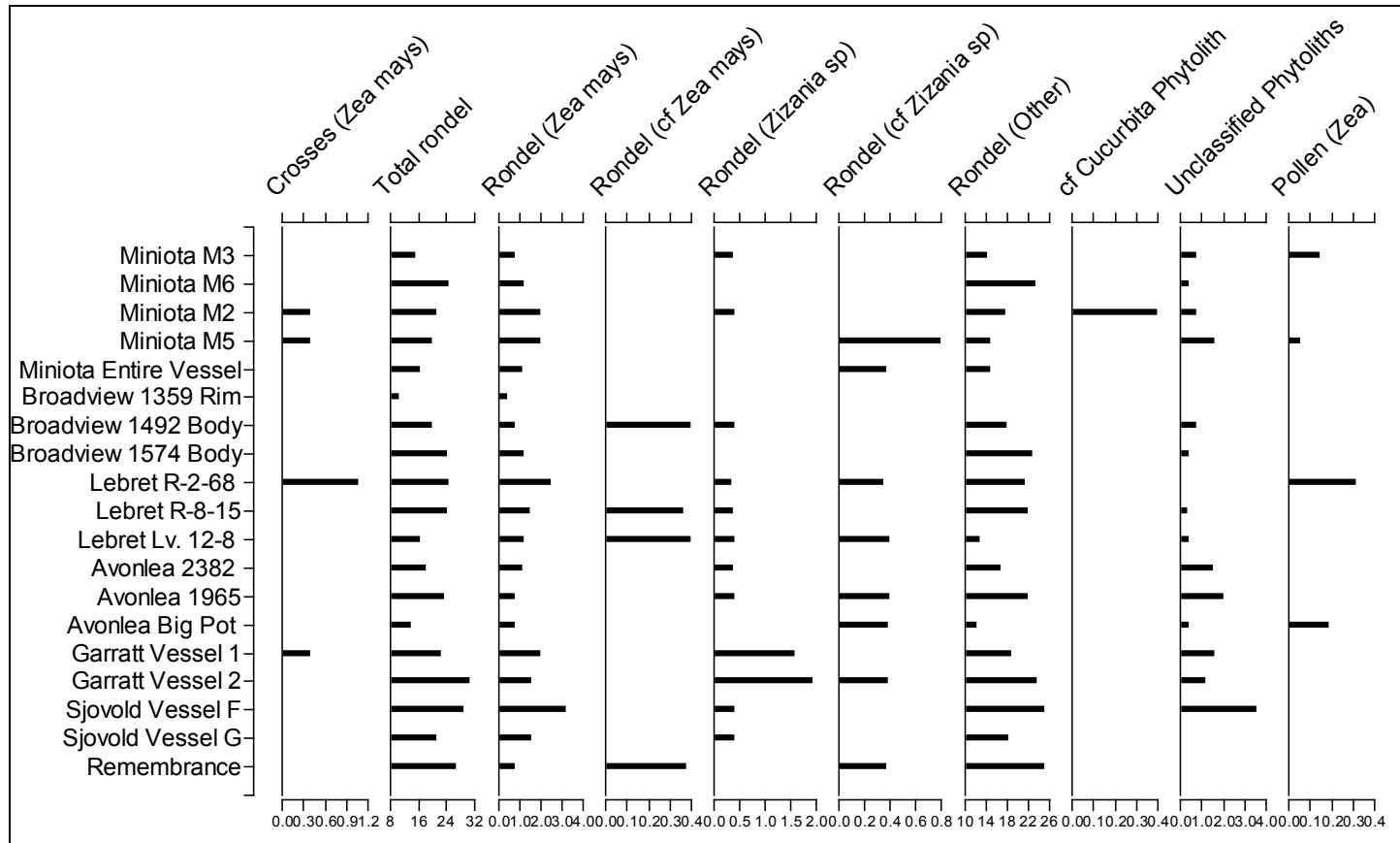


Fig. A.8. Important phytolith and pollen counts from Avonlea Food Residue Samples. Phytoliths presented as percentages of the total number of phytoliths counted in each sample (n= 250). Pollen presented as percentage out of the total number of microfossils counted in each sample.

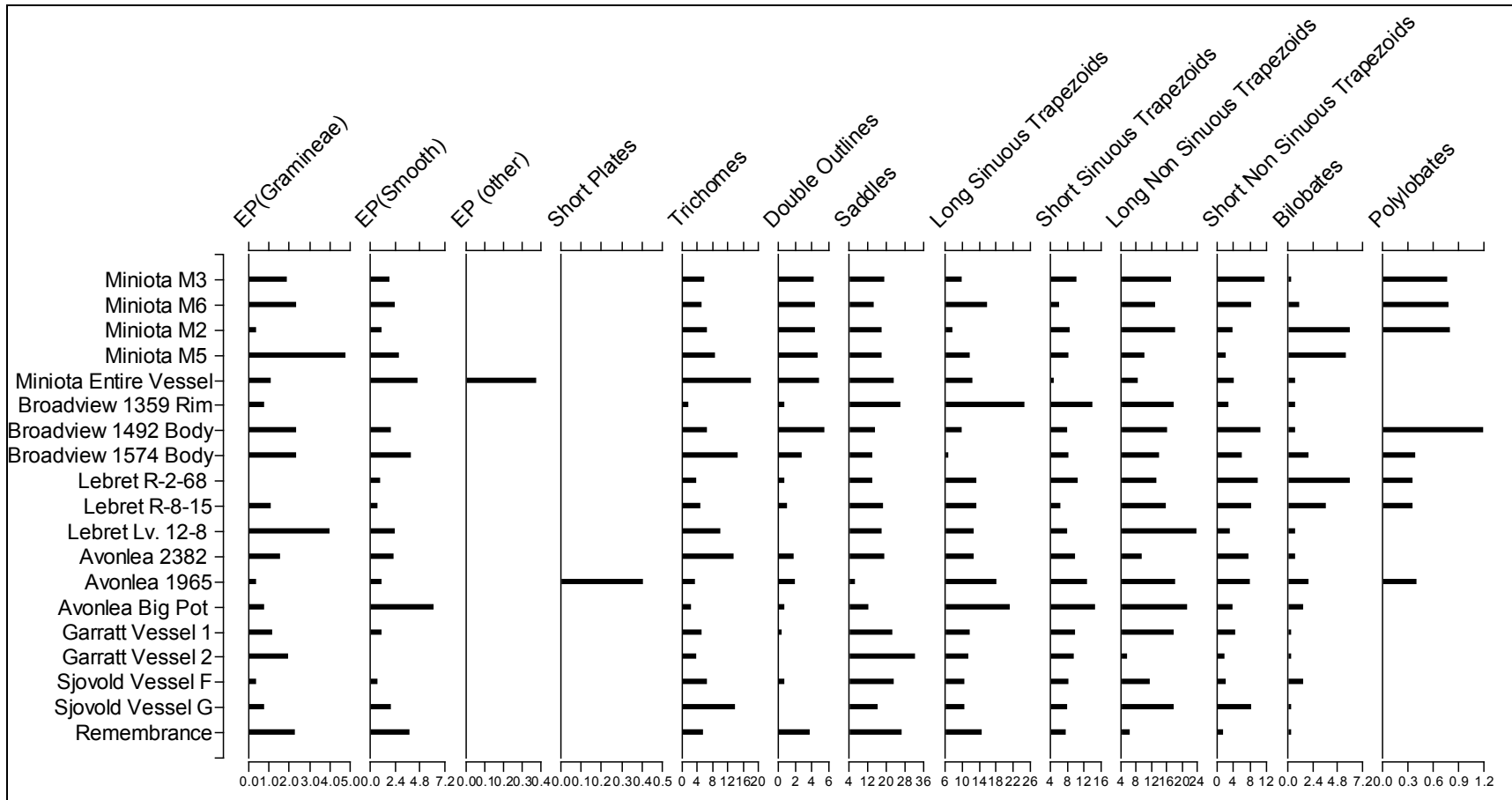


Fig. A.9. Other phytolith counts from Avonlea Food Residue Samples. Phytoliths presented as percentages of the total number of phytoliths counted in each sample (n= 250) (EP = Elongated Plates).

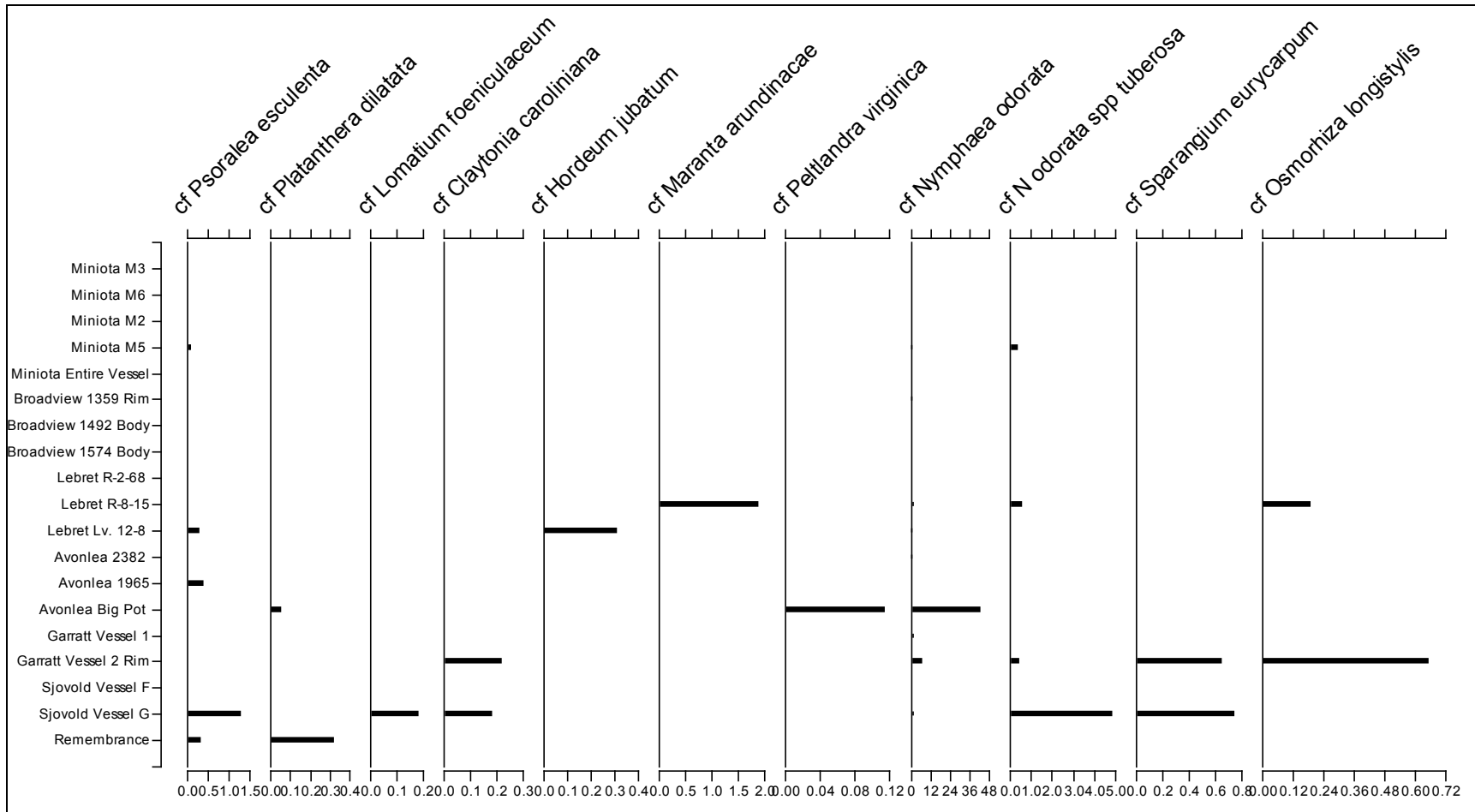


Fig. A.10. Wild starch counts from Avonlea Food Residue Samples. Starch grains presented as percentages out of the total microfossils counted in each sample. *Maranta arundinacea* likely represents an unknown tuber, yet to be identified.

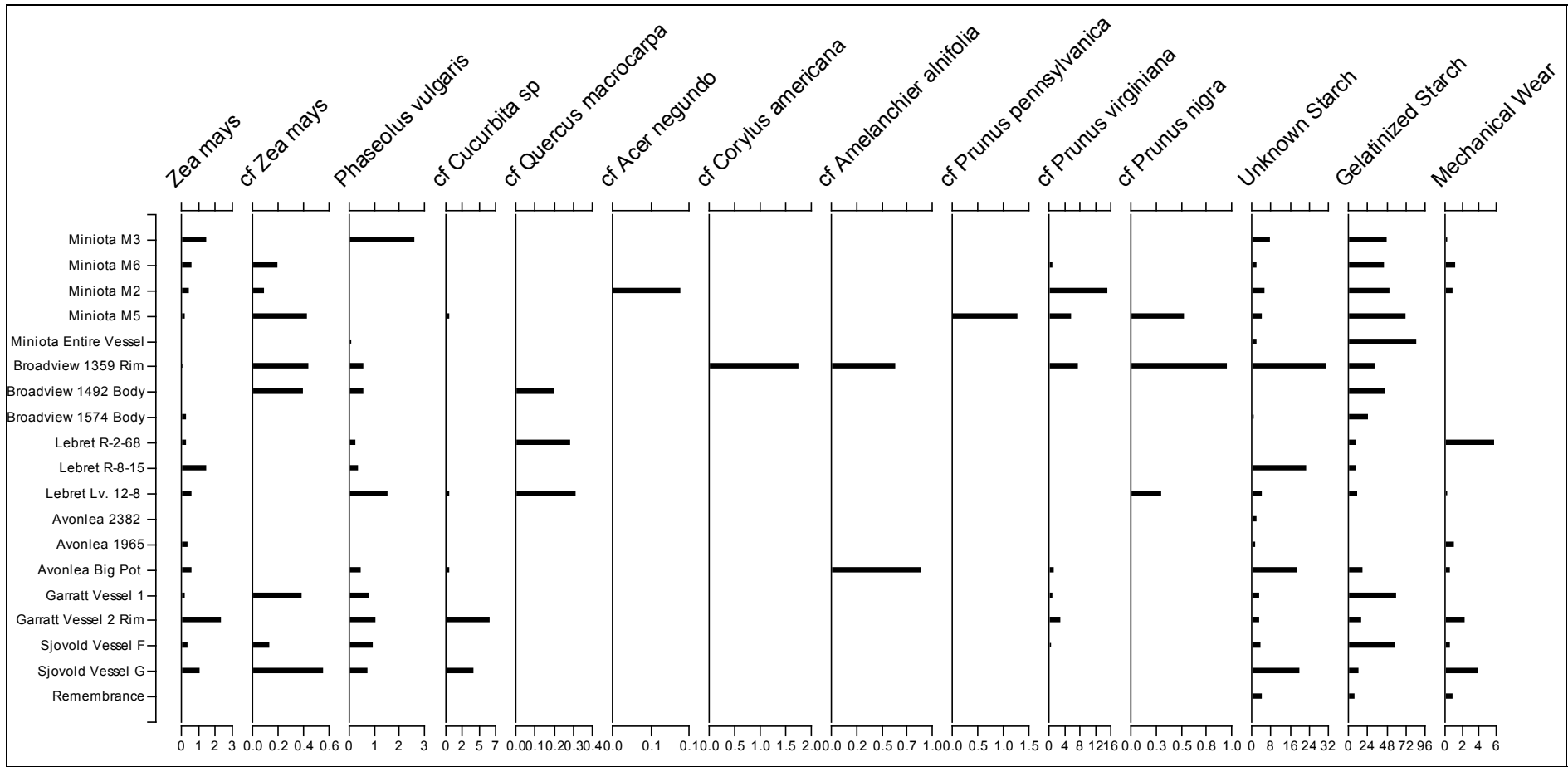


Fig. A.11. Domesticated, wild starches, unknown, gelatinized, and mechanically worn starch grains from Avonlea Food Residue Samples. Starch grains presented as percentages out of the total microfossils counted in each sample.

Table A.1. Artifact numbers, cultural affiliation, residue location, and tool type of all ceramics and stone tools. Highlighted cells indicate samples analyzed in this study. * Indicates samples used for AMS dating.

Borden	Site Name	Artifact Number	Vessel Area	Cultural Affiliation	Total Weight
EiNs-4	Sjovold	456 Vessel B	Shoulder	Moose Jaw	227.2 mg
EiNs-4	Sjovold	1000-1008 Vessel G	Rim	Avonlea	191.1 mg
EiNs-4	Sjovold	2756, 2533 Vessel F	Neck	Avonlea	26.8 mg
EaNg-1	Avonlea	Big Pot	Vessel	Avonlea	63.5 mg
EaNg-1	Avonlea	1965	Rim	Avonlea	26.8 mg
EaNg-1	Avonlea	1499	Rim	Avonlea	15.2 mg
EaNg-1	Avonlea	2382	Rim	Avonlea	24.1 mg
EaNg-1	Avonlea	2034	Body	Avonlea	20.6 mg
EaNg-1	Avonlea	2264	Rim	Avonlea	19.6 mg
EaNg-1	Avonlea	2024	Rim	Avonlea	7.0 mg
EaNg-1	Avonlea	From "Big Pot" AV-6	Body	Avonlea	0.9 mg
EaNg-1	Avonlea	From "Big Pot" AV-1	Body	Avonlea	1.7 mg
EaNg-1	Avonlea	From "Big Pot" AV-2	Body	Avonlea	14.9 mg
EaNg-1	Avonlea	From "Big Pot" AV-5	Body	Avonlea	8.0 mg
EaNg-1	Avonlea	From "Big Pot" AV-3	Body	Avonlea	5.6 mg
EaNg-1	Avonlea	From "Big Pot" AV-4	Body	Avonlea	5.7 mg
EaNg-1	Avonlea	2020	Body	Avonlea	9.1 mg
EaNg-1	Avonlea	2086	Body	Avonlea	1.0 mg
EaNg-1	Avonlea	1820	Body	Avonlea	1.1 mg
EaNg-1	Avonlea	2511	Body	Avonlea	4.5 mg
EeMw-25	Lebret	R-8 Lv. 15 SEQ	Body	Avonlea	105.3 mg

EeMw-26	Lebret	N/A	Body	Avonlea	97.5 mg
EeMw-26	Lebret	R-2-67	Body	Avonlea	13.3 mg
EeMw-25	Lebret	N/A	Body	Avonlea	3.9 mg
EeMw-26	Lebret	N/A	Shoulder	Mortlach	157.6 mg
EeMw-26	Lebret	R-8-3	Body	Plains Woodland	30.6 mg
EeMw-26	Lebret	R-2-68	Body	Avonlea	43.2 mg
EcNj-7	Garratt	Vessel 1	Rim	Avonlea	42.7 mg
EcNj-7	Garratt	Vessel 2	Rim	Avonlea	83.7 mg
EcNj-7	Garratt	Rim 1	Rim	Plains Woodland	14.4 mg
EcNj-7	Garratt	Rim 2	Rim	Plains Woodland	4.4 mg
EcNj-7	Garratt	670	Rim	Old Woman's	6.6 mg
EcNj-7	Garratt	783	Rim	Plains Woodland	6.5 mg
EbMp-6	Broadview	1359	Rim	Avonlea	9.8 mg
EbMp-6	Broadview	1492	Body	Avonlea	14.7 mg
EbMp-6	Broadview	1448	Body	Avonlea	5.9 mg
EbMp-6	Broadview	1404	Body	Avonlea	13.5 mg
EbMp-6	Broadview	1574	Body	Avonlea	14.3 mg
EbMp-6	Broadview	830	Body	Avonlea	8.8 mg
EaOd-1	Gull Lake	100	Rim	Mortlach	83.6 mg
EaOd-1	Gull Lake	143	Body	Plains Woodland	6.7 mg
EaOd-1	Gull Lake	1060	Body	Plains Woodland	230.7 mg
EaOd-1	Gull Lake	1102	Body	Plains Woodland	35.6 mg
EaOd-1	Gull Lake	919	Body	Plains Woodland	91.6 mg
EaMg 12	Miniota	M-1 (439)	Rim	Avonlea	56.1 mg
EaMg 12	Miniota	M-2 (544)	Rim	Avonlea	49.5 mg

EaMg 12	Miniota	M-3 (417-420)	Rim	Avonlea	46.4 mg
EaMg 12	Miniota	M-4 (11-13)	Neck	Avonlea	238.7 mg
EaMg 12	Miniota	M-5 (620)*	Rim	Avonlea	211.4 mg
EaMg 12	Miniota	M-6 (450,488)	Rim	Avonlea	18.6 mg
EaMg 12	Miniota	M-7 (517)	Body	Avonlea	459.4 mg
EaMg 12	Miniota	M-8 (460)	Rim	Avonlea	38.8 mg
EaMg 12	Miniota	M-9 (533)	Base	Avonlea	42.9 mg
EaMg 12	Miniota	M-10 (430)*	Body	Avonlea	913.8 mg
EaMg 12	Miniota	M-11 (29-31)	Body	Avonlea	152.9 mg
EaMg 12	Miniota	M-12 (476-480)	Neck	Avonlea	17.8 mg
EaMg 12	Miniota	M-13 (14)	Body	Avonlea	24.8 mg
EaMg 12	Miniota	M-14 (16)	Body	Avonlea	2.5 mg
EaMg 12	Miniota	M-15 (17)	Body	Avonlea	150.8 mg
EaMg 12	Miniota	M-16 (546)	Neck	Avonlea	35.7 mg
EaMg 12	Miniota	M-17 (451)	Neck	Avonlea	140.7 mg
EaMg 12	Miniota	M-18 (515)	Neck	Avonlea	23.4 mg
EaMg 12	Miniota	M-19 (637)	Neck	Avonlea	36.7 mg
EaMg 12	Miniota	M-20 (519)	Neck	Avonlea	10.8 mg
EaMg 12	Miniota	M-21 (641)	Neck	Avonlea	23.6 mg
EaMg 12	Miniota	M-22	Body	Avonlea	316.6 mg
EaMg-12	Miniota	1995/398w*	Entire	Avonlea	390.8mg
Borden	Site Name	Artifact Number	Sample Type	Stone Tool Type	Total Weight
EaOd-1	Gull Lake	2024	Dry Brush	Bell-Shaped Pestle	7.9 mg
EaOd-1	Gull Lake	2024	Wet Brush	Bell-Shaped Pestle	78.4 mg

EaOd-1	Gull Lake	2024	Sonicated	Bell-Shaped Pestle	102.3 mg
EaOd-1	Gull Lake	1294-25	Dry Brush	Bell-Shaped Pestle	7.9 mg
EaOd-1	Gull Lake	1294-25	Wet Brush	Bell-Shaped Pestle	33.6 mg
EaOd-1	Gull Lake	1294-25	Sonicated	Bell-Shaped Pestle	62.6 mg
EaOd-1	Gull Lake	2323	Sonicated	Metate	24.5 mg
EiNs-4	Sjovold	S-1 2562	Dry Brush	Hammerstone	15.4 mg
EiNs-4	Sjovold	S-1 2562	Wet Brush	Hammerstone	103.2 mg
EiNs-4	Sjovold	S-1 2562	Sonicated	Hammerstone	2.0 mg
EiNs-4	Sjovold	S-2 1999	Dry Brush	Hammerstone	2.1 mg
EiNs-4	Sjovold	S-2 1999	Wet Brush	Hammerstone	33.5 mg
EiNs-4	Sjovold	S-2 1999	Sonicated	Hammerstone	34.3 mg
EiNs-4	Sjovold	S-3 2464	Dry Brush	Chipping Anvil	5.5 mg
EiNs-4	Sjovold	S-3 2464	Wet Brush	Chipping Anvil	12.4 mg
EiNs-4	Sjovold	S-3 2464	Sonicated	Chipping Anvil	22.6 mg
EaN-4	Sjovold	FCR	Wet Brush	FCR	133 mg
EaN-4	Sjovold	FCR	Sonicated	FCR	238 mg

Table A.2 Evidence of maize from the Northeastern Woodlands and Central Plains with their uncalibrated and calibrated dates.

Site	Region	Maize Evidence	Lab Number	¹⁴ C BP	2 σ Cal.	Source
Vinette	Central New York State	Maize Phytoliths	A0500	2270 +/- 35 BP	399-208 BC	Hart <i>et al.</i> 2007
Vinette	Central New York State	Maize Phytoliths	A0455	1990 +/- 40 BP	93 BC-119 AD	Hart <i>et al.</i> 2007
Fortin 2	Central New York State	Maize Phytoliths	A0410	1995 +/- 35 BP	90 BC- 80 AD	Hart <i>et al.</i> 2007
Westheimer	Central New York State	Maize Phytoliths	A0498	1600 +/- 35 BP	AD 393-544	Hart <i>et al.</i> 2007
Felix	Central New York State	Maize Phytoliths	A0497	1575 +/- 35 BP	AD 413-565	Hart <i>et al.</i> 2007
Wickham	Central New York State	Maize Phytoliths	A0190	1425 +/- 45 BP	AD 552-667	Hart <i>et al.</i> 2007
Simmons	Central New York State	Maize Phytoliths	A0501	1390 +/- 35 BP	AD 594-683	Hart <i>et al.</i> 2007
Kipp Island	Central New York State	Maize Phytoliths	A0225	1470 +/- 43 BP	AD 443-656	Hart <i>et al.</i> 2007
Kipp Island	Central New York State	Maize Phytoliths	A0227	1428 +/- 41 BP	AD 559-663	Hart <i>et al.</i> 2007
Hunters Home	Central New York State	Maize Phytoliths	A0192	1231 +/- 44 BP	AD 678-889	Hart <i>et al.</i> 2007
Street	Central New York State	Maize Phytoliths	A0229	1043 +/- 40 BP	AD 892-1117	Hart <i>et al.</i> 2007
Klock	Central New York State	Maize Phytoliths	A0523	480 +/- 40 BP	AD 1327-1475	Hart <i>et al.</i> 2007
Garoga	Central New York State	Maize Phytoliths	A0522	425 +/- 40 BP	AD 1414-1636	Hart <i>et al.</i> 2007
Lone Pine, ON	Northeastern Woodlands	Maize Cupules	TO-4586	1040 +/- 60 BP	AD 890-1160	Crawford and Smith 2003

Grand Banks, ON	Northeastern Woodlands	Maize Kernels	TO-4584	1060 +/- 60 BP	AD 790-1150	Crawford and Smith 2003
Grand Banks, ON	Northeastern Woodlands	Maize Cupules	TO-5308	1500 +/- 150 BP	AD 650-980	Crawford and Smith 2003
Grand Banks, ON	Northeastern Woodlands	Maize Cupules	TO-5307	1570 +/- 70 BP	AD 260-610	Crawford and Smith 2003
211-1-1, NY	Northeastern Woodlands	Maize Cupules	B-53451	1090 +/- 60 BP	AD 780-1030	Crawford and Smith 2003
211-1-1, NY	Northeastern Woodlands	Maize Cupules	B-53452	1130 +/- 70 BP	AD 710-990	Crawford and Smith 2003
Trowbridge (14WY1)	Central Plains	<i>Zea mays</i>	UCR3357	200 +/- 50 BP	AD 1533-1950	Adair 2003
Trowbridge	Central Plains	<i>Zea mays</i>	Beta 75015	310 +/- 60 BP	AD 1444-1945	Adair 2003
Trowbridge	Central Plains	<i>Zea mays</i>	Beta 75016	400 +/- 60 BP	AD 1414-1642	Adair 2003
14LT304	Central Plains	<i>Zea mays</i>	AA36090	220 +/- 40 BP	AD 1637-1948	Adair 2003
14LT304	Central Plains	<i>Zea mays</i>	AA36092	295 +/- 40 BP	AD 1481-1786	Adair 2003
Quarry Creek (14LV401)	Central Plains	<i>Zea mays</i>	AA36119	930 +/- 45 BP	AD 1017-1217	Adair 2003
Quarry Creek	Central Plains	<i>Zea mays</i>	AA36120	975 +/- 40 BP	AD 993-1161	Adair 2003
McPherson (14LV57)	Central Plains	<i>Zea mays</i>	UCR3355	1880 +/- 50 BP	AD 24-311	Adair 2003
Radio Lane (14CO385)	Central Plains	<i>Zea mays</i>	AA36114	345 +/- 35 BP	AD 1449-1644	Adair 2003

Radio Lane	Central Plains	<i>Zea mays</i>	AA36115	390 +/-35 BP	AD 1437-1631	Adair 2003
Radio Lane	Central Plains	<i>Zea mays</i>	AA36116	305 +/- 35 BP	AD 1469-1786	Adair 2003
Avoca (14JN332)	Central Plains	<i>Zea mays</i>	AA36101	1165 +/- 40 BP	AD 775-981	Adair 2003
Avoca	Central Plains	<i>Zea mays</i>	AA36102	1220 +/- 40 BP	AD 687-939	Adair 2003
Andrews (25DO12)	Central Plains	<i>Zea mays</i>	AA36097	1050 +/- 40 BP	AD 895-1031	Adair 2003
Andrews	Central Plains	<i>Zea mays</i>	AA36098	1040 +/- 40 BP	AD 898-1146	Adair 2003
Two Deer (14BU55)	Central Plains	<i>Zea mays</i>	AA36113	925 +/- 60 BP	AD 998-1254	Adair 2003
14RH301	Central Plains	<i>Zea mays</i>	AA41420	598 +/- 39 BP	AD 1296-1419	Adair 2003
Patterson (25SY31)	Central Plains	<i>Zea mays</i>	AA36107	785 +/- 40 BP	AD 1188-1290	Adair 2003

Table A.3 Comparative grass specimens analyzed for phytoliths by Surette (2008).

Scientific Name	Common Name	Portion Analyzed
<i>Agrostis scabra</i>	Rough bentgrass	Inflorescence, leaf
<i>Alopecurus aequalis</i>	Shortawn foxtail	Inflorescence, leaf
<i>Alopecurus gerardii</i>	Big bluestem	Inflorescence, leaf
<i>Beckmannia syzigachne</i>	Slough grass	Inflorescence, leaf
<i>Bromus ciliatus</i>	Fringed brome	Inflorescence, leaf
<i>Calamagrostis canadensis</i>	Canada bluejoint	Inflorescence, leaf
<i>Cinna latifolia</i>	Drooping woodreed	Inflorescence, leaf
<i>Danthonia spicata</i>	Poverty grass	Inflorescence, leaf
<i>Deschampsia cespitosa</i>	Tufted hairgrass	Inflorescence, leaf
<i>Dichantherium acuminatum</i>	Hairy panicgrass	Inflorescence, leaf
<i>Distichlis spicata</i>	Salt grass, spike grass	Inflorescence, leaf
<i>Elymus canadensis</i>	Canada wild rye	Inflorescence, leaf
<i>Eragrostis hypnoides</i>	Teel lovegrass	Inflorescence, leaf
<i>Festuca rubra</i>	Red fescue	Inflorescence, leaf
<i>Glyceria grandis</i>	Tall manna grass	Inflorescence, leaf
<i>Graphephorum melicoides</i>	Melic oats	Inflorescence, leaf
<i>Hesperostina comata</i>	Speargrass	Inflorescence, leaf
<i>Hordeum jubatum</i>	Foxtail barley	Inflorescence, leaf
<i>Koeleria macrantha</i>	Junegrass	Inflorescence, leaf
<i>Leersia oryzoides</i>	Rice cutgrass	Inflorescence, leaf
<i>Milium effusum</i>	Millet grass	Inflorescence, leaf
<i>Muhlenbergia glomerata</i>	March muhly	Inflorescence, leaf
<i>Oryzopsis asperifolia</i>	Rough-leaved rice grass	Inflorescence, leaf
<i>Oryzopsis pungens</i>	Northern rice grass	Inflorescence, leaf
<i>Panicum capillare</i>	Witchgrass	Inflorescence, leaf
<i>Pascopyrum smithii</i>	Western wheatgrass	Inflorescence, leaf
<i>Phalaris arundinacea</i>	Reed canary grass	Inflorescence, leaf
<i>Phragmites australis</i>	Common reed	Inflorescence, leaf
<i>Poa palustris</i>	Fowl meadow grass	Inflorescence, leaf
<i>Schedonorus pratensis</i>	Meadow fescue	Inflorescence, leaf
<i>Schizachne purpurascens</i>	False melic	Inflorescence, leaf
<i>Sphenopholis intermedia</i>	Prairie wedgegrass	Inflorescence, leaf
<i>Sporobolus neglectus</i>	Puffsheath dropseed	Inflorescence, leaf
<i>Torreyochloa pallida</i>	Fernald's false mannagrass	Inflorescence, leaf
<i>Trisetum spicatum</i>	Spike trisetum	Inflorescence, leaf
<i>Zea mays ssp. mays</i>	Maize	Cob, leaf
<i>Zizania aquatica</i>	Annual wild rice	Inflorescence, leaf
<i>Zizania palustris</i>	Northern wild rice	Inflorescence, leaf, stem

Table A.4: Native grasses examined for phytoliths by Bozarth (1993).

Scientific Name	Common Name	Subfamily
<i>Agropyron caninum</i>	Bearded wheatgrass	Pooideae
<i>Agropyron smithii</i>	Western wheatgrass	Pooideae
<i>Andropogon gerardii</i>	Big bluestem	Panicoideae
<i>Andropogon saccharoides</i>	Longspike beardgrass	Panicoideae
<i>Andropogon scoparius</i>	Shore little bluestem	Panicoideae
<i>Aristida divaricata</i>	N/A	Chloridoideae
<i>Aristida purpurea</i>	N/A	Chloridoideae
<i>Aristida purpurea var. longiseta</i>	N/A	Chloridoideae
<i>Bouteloua curtipendula</i>	Sideoats grama	Chloridoideae
<i>Bouteloua gracilis</i>	Blue grama	Chloridoideae
<i>Bouteloua hirsutas</i>	Hairy grama	Chloridoideae
<i>Buchloe dactyloides</i>	Buffalograss	Chloridoideae
<i>Bromus pubescens</i>	Hairy woodland brome	Pooideae
<i>Calamovilfa longifolia</i>	Priarie sandreed	Chloridoideae
<i>Cenchrus longispinus</i>	Feathertop	Panicoideae
<i>Danthonia spicata</i>	Poverty oatgrass	Arundinoideae
<i>Digitaria californica</i>	Arizona cottontop	Panicoideae
<i>Distichlis spicata</i>	Saltgrass	Chloridoideae
<i>Elymus canadensis</i>	Canada wild rye	Pooideae
<i>Elymus virginicus</i>	Virginia wild rye	Pooideae
<i>Eragrostis contracta</i>	N/A	Chloridoideae
<i>Hordeum jubatum</i>	Foxtail barley	Panicoideae
<i>Leersia oryzoides</i>	Rice cutgrass	Pooideae
<i>Muhlenbergia racemosa</i>	Marsh muhley	Oryzoideae
<i>Panicum capillare</i>	Whitchgrass	Chloridoideae
<i>Panicum obtusum</i>	Vine mesquite	Panicoideae
<i>Panicum virgatum</i>	Switchgrass	Panicoideae
<i>Panicum scribnerinacea</i>	Scribner's rosette grass	Panicoideae
<i>Phalaris arundinacea</i>	Reed canarygrass	Pooideae
<i>Phragmites australis</i>	Common reed	Arundinoideae
<i>Poa arida</i>	Plains bluegrass	Pooideae
<i>Sorghastrum nutans</i>	Indian grass	Panicoideae
<i>Sporobolus asper</i>	Composite dropseed	Chloridoideae
<i>Sporobolus cryptandrus</i>	Spike dropseed	Chloridoideae
<i>Sporobolus heterolepis</i>	Priarie dropseed	Chloridoideae
<i>Sporobolus neglectus</i>	Puffsheath dropseed	Chloridoideae
<i>Stipa spartea</i>	Porcupinegrass	Pooideae
<i>Stipa viridula</i>	Green needlegrass	Pooideae
<i>Tripsacum dactyloides</i>	Eastern gamagrass	Panicoideae
<i>Vulpia octoflora</i>	Sixweeks fescue	Pooideae
<i>Zizania aquatica</i>	Annual wildrice	Oryzoideae

Table A.5: List of 154 comparative starch samples from the Lakehead University Starch Database and their contents. All check marks indicate a possible confusor with comparative samples analyzed in this thesis.

Family	Genus	Species	Common Name	Part	Abundance	Confusor	Width	Other
Aceraceae	<i>Acer</i>	<i>rubrum</i>	Red maple	S	Medium	Y	<5µm	Ontario
Acoraceae	<i>Acorus</i>	<i>americanus</i>	Sweetflag	T	Medium	N	<5µm	
Alismataceae	<i>Sagittaria</i>	<i>latifolia</i>	Broadleaf arrowhead	R	High	N	<20µm	
Alismataceae	<i>Alisma</i>	<i>triviale</i>	Water plantain	C	High	N	5µm	
Amaranthaceae	<i>Amaranthus</i>	<i>hybridus</i>	Amaranth	S	Medium	N	<5µm	
Amaranthaceae	<i>Amaranthus</i>	spp.	Amaranth	S	High	N	<1µm	
Apiaceae	<i>Daucus</i>	sp	Carrot	R	High	N	≈5µm	
Apiaceae	<i>Erigenia</i>	<i>bulbosa</i>	Harbinger of spring	T	High	N	<5µm	Ontario
Apiaceae	<i>Heracleum</i>	<i>lanatum</i>	Cow parsnip	S	Low	N	<5µm	
Apiaceae	<i>Heracleum</i>	<i>lanatum</i>	Cow parsnip	R	High	Y	10µm	
Apiaceae	<i>Lomatium</i>	<i>foeniculaceum</i>	Desert biscuitroot	R	High	Y	10µm	
Apiaceae	<i>Musineon</i>	<i>tenufolium</i>	Slender wildparsley	T	High	N	<5µm	
Apiaceae	<i>Osmorhiza</i>	<i>longistylis</i>	Sweet cicely	R	High	Y	10µm	
Apiaceae	<i>Perideridia</i>	<i>gairdneri</i>	Common yampah	T	High	Y	10µm	
Apocynaceae	<i>Apocynum</i>	<i>cannabinum</i>	Indianhemp	T	Low	N	<5µm	
Araceae	<i>Colocasia</i>	<i>esculenta</i>	Coco yam	T	High	N	<5µm	
Araceae	<i>Calla</i>	<i>palustris</i>	Water arum	T	Low	N	N/A	Raphides
Araceae	<i>Arisaema</i>	<i>triphyllum</i>	Jack-in-the-pulpit	T	High	Y	10µm	
Araceae	<i>Symplocarpus</i>	<i>feotidus</i>	Skunk cabbage	C	High	N	5µm	Raphides
Araceae	<i>Symplocarpus</i>	<i>feotidus</i>	Skunk cabbage	L	Low	N	N/A	Raphides
Araliaceae	<i>Aralia</i>	<i>nudicaulis</i>	Wild sarsaparilla	F	Low	N	N/A	
Araliaceae	<i>Panax</i>	<i>trifolius</i>	Dwarf ginseng	T	High	N	10µm	
Asteraceae	<i>Helianthus</i>	<i>annua</i>	Russian giant sunflower	S/R	Med-Low	N	≈5µm	Exotic
Asteraceae	<i>Cirsium</i>	<i>arvense</i>	Canada thistle	R	None	N	N/A	Raphides
Asteraceae	<i>Aster</i>	<i>conspicuus</i>	Western showy aster	R	Low	N	N/A	Raphides
Asteraceae	<i>Eupatorium</i>	<i>maculatum</i>	Joe-pye-weed	R	Low	N	N/A	Crystals
Asteraceae	<i>Helianthus</i>	<i>petiolaris</i>	Prairie sunflower	S	Low	N	<5µm	

Asteraceae	<i>Taraxacum</i>	spp.	Dandelion	R	Low	N	N/A	
Betulaceae	<i>Corylus</i>	<i>americana</i>	American hazelnut	S	High	Y	<5µm	
Betulaceae	<i>Betula</i>	<i>papyrifera</i>	Paper birch	S	Low	N	N/A	
Brassicaceae	<i>Brassica</i>			F/T	High	N	Small	
Brassicaceae	<i>Dentaria</i>	<i>diphylla</i>	Crinckleroot	R	High	Y	20µm	Ontario
Brassicaceae	<i>Dentaria</i>	<i>laciniata</i>	Cutleaf toothwort	T	Low	N	<5µm	E. Can.
Brassicaceae	<i>Brassica</i>	<i>napobrassica</i>	Rapeseed	T	Low	N	N/A	
Brassicaceae	<i>Brassica</i>	<i>juncea</i>	Brown mustard	S	Low	N	N/A	
Brassicaceae	<i>Armoracia</i>	<i>rusticana</i>	Horseradish	R	High	N	5-10µm	
Brassicaceae	<i>Lepidium</i>	<i>densiflorum</i>	Common pepperweed	S	Low	N	N/A	
Cabombaceae	<i>Brasenia</i>	<i>schreberi</i>	Watershield	T	Low	N	5µm	
Caprifoliaceae	<i>Lonicera</i>	spp.	Honeysuckle	F	Low	N	N/A	Crystals
Caprifoliaceae	<i>Symphoricarpos</i>	<i>occidentalis</i>	Western snowberry	F	Low	N	N/A	
Caprifoliaceae	<i>Symphoricarpos</i>	<i>occidentalis</i>	Western snowberry	R	High	Y	10µm	Raphides
Caprifoliaceae	<i>Viburnum</i>	<i>opulus</i>	High-bush cranberry	S	Medium	Y	<5µm	
Caprifoliaceae	<i>Viburnum</i>	<i>opulus</i>	High-bush cranberry	F	Low	N	N/A	
Chenopodiaceae	<i>Chenopodium</i>	<i>album</i>	Lambsquarters	S	Low	N	<5µm	
Chenopodiaceae	<i>Chenopodium</i>	<i>album</i>	Lambsquarters	R	Low	N	<5µm	
Chenopodiaceae	<i>Chenopodium</i>	<i>berlandieri</i>	Pitseed goosefoot	R	Low	N	<5µm	
Chenopodiaceae	<i>Chenopodium</i>	<i>berlandieri</i>	Pitseed goosefoot	S	Low	N	<5µm	
Chenopodiaceae	<i>Chenopodium</i>	<i>capitatum</i>	Blite goosefoot	S	Low	N	<1µm	
Chenopodiaceae	<i>Chenopodium</i>	<i>quinoa</i>	White quinoa	S	High	N	<1µm	
Chenopodiaceae	<i>Chenopodium</i>	<i>quinoa</i>	Red quinoa	S	High	N	<1µm	
Convolvulaceae	<i>Ipomoea</i>	<i>batatas</i>	Sweet potato	T	High	Y	20µm	Exotic
Cornaceae	<i>Cornus</i>	<i>canadensis</i>	Bunchberry	F	None	N	N/A	
Cornaceae	<i>Cornus</i>	<i>sericea</i>	Red-osier dogwood	S	None	N	N/A	
Cucurbitaceae	<i>Echinocystis</i>	<i>lobata</i>	Wild cucumber	S	Medium	N	N/A	
Cucurbitaceae	<i>Sicyos</i>	<i>angulatus</i>	Burr cucumber	S	Low	N	N/A	
Cupressaceae	<i>Juniperus</i>	<i>communis</i>	Common juniper	S	Low	N	N/A	
Cyperaceae	<i>Carex</i>	<i>aquatilis</i>	Water sedge	S	High	N	≈5µm	
Cyperaceae	<i>Scirpus</i>	<i>validus</i>	Softstem bulrush	R	High	N	<10µm	
Cyperaceae	<i>Scirpus</i>	<i>validus</i>	Softstem bulrush	S	High	N	<5µm	
Cyperaceae	<i>Cyperus</i>	<i>schweinitzii</i>	Schwinitz's flatsedge	T	Medium	N	<5µm	

Cyperaceae	<i>Eleocharis</i>	<i>palustris</i>	Common spikerush	St	Low	N	N/A	
Cyperaceae	<i>Eleocharis</i>	<i>palustris</i>	Common spikerush	R	High	N	N/A	
Dioscoreaceae	<i>Dioscorea</i>	<i>sp</i>	Yam	R/T	High	Y	≈15μm	Exotic
Ericaceae	<i>Arctostaphylos</i>	<i>uva-ursi</i>	Kinnikinnick	F	Low	N	N/A	Crystals
Ericaceae	<i>Ledum</i>	<i>groenlandicum</i>	Labrador tea	L	Low	N	N/A	
Ericaceae	<i>Vaccinium</i>	<i>myrtilloides</i>	Common blueberry	F	Low	N	N/A	
Ericaceae	<i>Vaccinium</i>	<i>oxycoccus</i>	Cranberry	F/S	Low	N	N/A	
Euphorbiaceae	<i>Manihot</i>	<i>esculenta</i>	Manioc	T	High	Y	20μm	Exotic
Fabaceae	<i>Vigna</i>	<i>angularis</i>	Adzuki bean	S	High	Y	20μm	Exotic
Fabaceae	<i>Cicer</i>	<i>arietinum</i>	Chick pea	S	High	Y	10μm	Exotic
Fabaceae	<i>Astragalus</i>	<i>aboriginum</i>	Indian milk-vetch	T	Low	N	5μm	Arctic
Fabaceae	<i>Apios</i>	<i>americana</i>	Groundnut	T	High	N	5μm	
Fabaceae	<i>Amphicarpaea</i>	<i>bracteata</i>	American hogpeanut	S	High	N	5μm	
Fabaceae	<i>Glycine</i>	<i>max</i>	Soybean	S	Low	N	N/A	Crystals
Fabaceae	<i>Lablab</i>	<i>purpureus</i>	Hyacinth bean	S	High	Y	20μm	Exotic
Fabaceae	<i>Lens</i>	<i>culinaris</i>	Lentils	S	High	Y	20μm	Exotic
Fabaceae	<i>Lupinus</i>	<i>arcticus</i>	Arctic lupine	S	Low	N	N/A	Raphides
Fabaceae	<i>Medicago</i>	<i>sativa</i>	Alfalfa	R	High	Y	5μm	Exotic
Fabaceae	<i>Pisum</i>	<i>sativum</i>	Pea (G)	S	High	Y	20μm	Exotic
Fabaceae	<i>Pisum</i>	<i>sativum</i>	Pea (Y)	S	High	Y	20μm	Exotic
Fabaceae	<i>Vigna</i>	<i>angularis</i>	Adzuki bean	S	High	Y	50μm	Exotic
Fabaceae	<i>Vigna</i>	<i>mungo</i>	Black gram	S	High	Y	20μm	Exotic
Fabaceae	<i>Vigna</i>	<i>radiata</i>	Mungbean	S	High	Y	30μm	Exotic
Fagaceae	<i>Castanea</i>	<i>dentata</i>	American chestnut	S	Low	N	N/A	
Fagaceae	<i>Quercus</i>	<i>rubra</i>	Red oak	S	High	Y	5-10μm	Quebec
Fumariaceae	<i>Dicentra</i>	<i>canadensis</i>	Squirrel corn	T	High	Y	50μm	Ontario
Grossulariaceae	<i>Ribes</i>	<i>hudsonianum</i>	Northern black current	F	Low	N	N/A	Crystals
Hydrophyllaceae	<i>Hydrophyllum</i>	<i>canadense</i>	Canada waterleaf	T	High	N	50μm	
Juglandaceae	<i>Juglans</i>	<i>cinerea</i>	White walnut	S	Low	N	N/A	SE. Can
Juglandaceae	<i>Juglans</i>	<i>nigra</i>	Black walnut	S	Low	N	N/A	
Lamiaceae	<i>Lycopus</i>	<i>americanus</i>	Water horehound	R	Low	N	N/A	
Lamiaceae	<i>Mentha</i>	<i>canadensis</i>	Wild mint	L/R	Medium	N	<5μm	
Liliaceae	<i>Clintonia</i>	<i>borealis</i>	Bluebead	R	High	N	<5μm	

Liliaceae	<i>Clintonia</i>	<i>borealis</i>	Bluebead	L	None	N	N/A	
Liliaceae	<i>Allium</i>	<i>textile</i>	Prairie onion	B	None	N	N/A	
Liliaceae	<i>Erythronium</i>	<i>americanum</i>	Trout lily	T	High	Y	20µm	Ontario
Liliaceae	<i>Maianthemum</i>	<i>canadense</i>	Lily-of-the-valley	F	Low	N	N/A	Raphides
Liliaceae	<i>Medeola</i>	<i>virginiana</i>	Indain cucumber	T	High	Y	20µm	Ontario
Liliaceae	<i>Streptopus</i>	<i>roseus</i>	Twisted stalk	F/R/S	High	N	10µm	Raphides
Liliaceae	<i>Trillium</i>	<i>grandiflorum</i>	White trillium	F	High	N	5µm	Raphides
Linaceae	<i>Linum</i>	<i>usitatissimum</i>	Flax	S	Low	N	N/A	
Musaceae	<i>Musa</i>	sp.	Banana	F	High	N	≈10µm	Exotic
Musaceae	<i>Musa</i>	spp.	Banana	F	High	N	20µm	Exotic
Myricaceae	<i>Myrica</i>	<i>gale</i>	Bog myrtle	L	Low	N	<5µm	Raphides
Nelumbonaceae	<i>Nelumbo</i>	<i>lutea</i>	Yellow lotus	S	High	Y	10µm	Ontario
Nymphaeaceae	<i>Nuphar</i>	<i>lutea</i>	Yellow pond-lily	S	High	N	≈1µm	
Nymphaeaceae	<i>Nuphar</i>	<i>lutea</i>	Yellow pond-lily	T	High	N	≈5µm	
Oleaceae	<i>Fraxinus</i>	<i>pennsylvanica</i>	Green ash	S	Low	N	N/A	Crystals
Onagraceae	<i>Epilobium</i>	<i>angustifolium</i>	Fireweed	St	None	N	N/A	Raphides
Onagraceae	<i>Epilobium</i>	<i>angustifolium</i>	Fireweed	R	High	N	<5µm	Raphides
Onagraceae	<i>Oenothera</i>	<i>biennis</i>	Evening primrose	L/S	Low	N	N/A	Raphides
Onocleaceae	<i>Matteuccia</i>	<i>struthiopteris</i>	Ostrich fern	H.L.	Medium	N	5µm	
Orchidaceae	<i>Platanthera</i>	<i>dilatata</i>	White bog orchid	R	High	Y	20µm	
Papaveraceae	<i>Papaver</i>	<i>somniferum</i>	Opium poppy	S	Low	N	N/A	Crystals
Pinaceae	<i>Abies</i>	<i>balsamea</i>	Balsam fir	I.B	Medium	N	5µm	
Pinaceae	<i>Larix</i>	<i>laricina</i>	Tamarack	I.B	Low	N	N/A	Crystals
Pinaceae	<i>Picea</i>	<i>glauca</i>	White spruce	S	Low	N	N/A	
Pinaceae	<i>Picea</i>	<i>glauca</i>	White spruce	I.B	High	N	5µm	
Pinaceae	<i>Pinus</i>	<i>banksiana</i>	Jake pine	I.B	Low	N	N/A	
Pinaceae	<i>Pinus</i>	<i>banksiana</i>	Jake pine	I.B	High	N	5µm	
Pinaceae	<i>Pinus</i>	<i>remota</i>	Pinyon pine	S	Medium	N	5µm	Exotic
Pinaceae	<i>Pinus</i>	<i>strobus</i>	Eastern white pine	S	Low	N	N/A	
Pinaceae	<i>Pinus</i>	<i>strobus</i>	Eastern white pine	N	High	N	N/A	
Piperaceae	<i>Piper</i>	<i>methysticum</i>	Kava	R	High	Y	10µm	Exotic
Poaceae	<i>Hordeum</i>	<i>vulgare</i>	Common Barley (pearl)	S	High	N	20µm	
Poaceae	<i>Phalaris</i>	<i>arundinacea</i>	Reed canarygrass	S	Low	N	<5µm	

Poaceae	<i>Elymus</i>	<i>canadensis</i>	Canada wild rye	S	High	N	10µm	
Poaceae	<i>Avena</i>	<i>sativa</i>	Common oat	S	High	N	5µm	
Poaceae	<i>Hordeum</i>	<i>vulgare</i>	Barley	S	High	N	20µm	
Poaceae	<i>Oryzopsis</i>	<i>asperifolia</i>	Rough-leaved ricegrass	S	Low	N	N/A	Raphides
Poaceae	<i>Oryzopsis</i>	<i>hymenoides</i>	Indian ricegrass	S	Low	N	N/A	Raphides
Poaceae	<i>Panicum</i>	<i>miliaceum</i>	Common millet	S	High	N	5µm	
Poaceae	<i>Phalaris</i>	<i>arundinacea</i>	Reed canarygrass	S	Low	N	N/A	
Poaceae	<i>Triticum</i>	<i>aestivum</i>	Common wheat	S	High	Y	20µm	Exotic
Polygonaceae	<i>Rumex</i>	<i>orbiculatus</i>	Greater water dock	S	Low	N	<5µm	
Polygonaceae	<i>Fagopyrum</i>	<i>esculentum</i>	Buckwheat	S	High	Y	20µm	
Polygonaceae	<i>Polygonum</i>	<i>lapathifolium</i>	Common knotweed	St	High	Y	30µm	
Pontederiaceae	<i>Pontederia</i>	<i>cordata</i>	Pickereelweed	T	Low	N	N/A	
Portulacaceae	<i>Claytonia</i>	<i>caroliniana</i>	Ppringbeauty	T	High	Y	5µm	
Potamogetonaceae	<i>Potamogeton</i>	sp	Pondweed	F	Low	N	<5µm	
Ranunculaceae	<i>Caltha</i>	<i>palustris</i>	Marsh marigold	R	Medium	N	<5µm	
Ranunculaceae	<i>Actaea</i>	<i>pachypoda</i>	White baneberry	F	Low	N	N/A	Ontario
Rosaceae	<i>Rubus</i>	<i>idaeus</i>	Wild red raspberry	F	Low-none	N	N/A	
Rosaceae	<i>Crataegus</i>	<i>rotundifolia</i>	Hawthorn	S	Low-none	N	N/A	
Rosaceae	<i>Crataegus</i>	<i>rotundifolia</i>	Hawthorn	F	High	N	<5µm	
Rosaceae	<i>Fragaria</i>	<i>virginiana</i>	Wild strawberry	F	Low	N	N/A	
Salicaceae	<i>Populus</i>	<i>tremuloides</i>	Trembling aspen	I.B	Low	N	N/A	
Scrophulariaceae	<i>Verbascum</i>	<i>thapsus</i>	Common mullein	S	Low	N	N/A	Exotic
Smilacaceae	<i>Smilax</i>	<i>herbacea</i>	Carrion flower	St/R	High	N	10µm	Raphides
Solanaceae	<i>Solanum</i>	<i>tuberosum</i>	Potato	T	High	Y	50µm	Exotic
Sparganiaceae	<i>Sparganium</i>	<i>eurycarpum</i>	Giant bur-reed	R	High	Y	≈10µm	
Sparganiaceae	<i>Sparganium</i>	<i>eurycarpum</i>	Giant bur-reed	St	Low	N	N/A	
Sparganiaceae	<i>Sparganium</i>	<i>eurycarpum</i>	Giant bur-reed	R	Low	N	N/A	
Taxaceae	<i>Taxus</i>	<i>canadensis</i>	Canadian yew	F	Low	N	N/A	

Legend: C=Corm, F= Fruit, IB=Inner Bark, L=Leaf, N=Needle, R=Root, S=Seed, St=Stem, and T=Tuber.