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**Plant Microfossil Analysis of Middle Woodland Food Residues,
Northern Minnesota**

**A thesis submitted in partial fulfillment of the Master of Environmental
Studies: Northern Environments and Cultures**

By: Alexandra Burchill

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ABSTRACT

Northern Minnesota lies within the southern edge of the Boreal Forest and, as a result, archaeological sites in this region typically have poor organic preservation and thin, disturbed, stratigraphy. For this reason, little is known about specific plant foods and their importance at many sites. In order to fill this gap, my research focuses on the extraction of plant microfossils (starch, phytoliths and pollen) from carbonized and non-carbonized food residues associated with Middle Woodland (100 BC – AD 500) components. My results show that wild rice was widely consumed during this time along with cultigens such as maize. No additional evidence suggested farming, so there is a possibility of trade with periphery groups to acquire the cultigens recovered from the microfossil analysis. These results demonstrate the importance of plant microfossil studies as a tool for identifying subtle evidence of wild and domesticated plants in regions characterized by poor organic preservation, small seasonally-occupied sites and other fundamental limitations. The mixed economic strategy apparent in some Northern Minnesota sites re-defines a diet of native and domesticated cultigens, which can be applied to the wider archaeobotanical literature of northeastern North America.

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DEFINITION OF TERMS

CULTIVATION: Human involvement such as the weeding, pruning, and tending to plants to affect the plant's life cycle.

DOMESTICATION: Occurs when a species is genetically altered to benefit the interests of humans.

FOOD RESIDUE ANALYSIS: Food residue analysis can be conducted on a wide variety of archaeological remains to determine the presence, and/or absence of different plant and animal species.

PHYTOLITH: A rigid structure of solid silica that forms when plants absorb groundwater. The silica is deposited in intracellular, and/or extracellular structures of the living plant.

POLLEN: Reproductive seed plants in the form of a fine to coarse powder.

STARCH: Carbohydrate produced by plants as a form of energy.

THREE SISTERS: Agricultural crops that were of great importance to Aboriginal groups in North America. The Three Sisters agricultural system consists of maize, squash, and beans and these crops were often planted together.

WOODLAND PERIOD: Chronological division used to differentiate prehistoric cultures in North America. In Eastern North America, the Woodland Period dates from 1000 BC to 1000 AD.

1.0 INTRODUCTION

1.1 Culture History

During the Paleoindian, Archaic and Woodland Periods in North America, Aboriginal groups depended on a wide variety of floral species. The reasons for this may be ideological, economical and/or environmental, but it is understood that diet always consists of plants, whether they are native to the occupied area, or traded with outside populations (Syms et al. 2013). Wild plants were widely consumed in Eastern North America (Yarnell 1993), up until the introduction and dispersal of domesticated plants such as maize (*Zea mays* ssp. *mays*), beans (*Phaseolus* sp.) and squash (*Cucurbita* sp.). The question remains of how these domesticates reached certain areas and when they were adopted into subsistence strategies.

The focus of this thesis is on the Middle Woodland period in Northern Minnesota. This period, which dates from 100 BC to 500 AD, was characterized by distinctive lithic technologies, and new ceramic forms. Associated projectiles are broadly, shallow, or corner notched, and/or have an expanding or straight stem. Middle Woodland ceramic wares had decorative differences, were thinner, and made with a finer temper; these attributes differentiated them from Early Woodland ceramics. It is generally assumed that Middle Woodland peoples occupying Northern Minnesota were semi-sedentary hunter-gatherers relying on mammals, and wild rice (*Zizania* spp.), along with starchy nuts, fruits, and seeds (Arzigian 2008; Mulholland et al. 1996; Peter and Motivans 1983; Shafer 2003). This subsistence base appears to have persisted until the arrival of the Three Sister crops (maize, beans, and squash) between 800 AD and 1200 AD, which flourished

until Precontact (Adair and Drass 2011; Hart et al. 2002; Wilson 1917). One of the research goals for this study is to readdress these currently held notions about horticultural subsistence during the Middle Woodland in Northern Minnesota.

Other research goals include reconstructing the plant component of the paleodiet and identifying whether trade or local agriculture allowed for the presence of domesticates at these sites. Cultivation, which is the weeding, pruning and tending of plants can be identified through multiple lines of evidence such as pollen and agricultural tools. Cultivation does not mean that something is fully domesticated, but that the plant's life cycle has been impacted in some way by human selection (Syms et al. 2013). Food production begins with the deliberate care towards a certain species, which may be invisible to archaeologists, but through evidence of agricultural tools, diagnostic phytoliths, starch granules and pollen, it becomes visible. Domestication occurs when humans, causing the domesticated species to become dependent for survival (Staller 2010), genetically alter plants or animals. This is visible in the archaeological record from seed sizes and diagnostic features of phytolith and starch granules.

Archaeological sites chosen for this research project are located in Northern Minnesota, within the Great Lakes- St. Lawrence Forest (Figure 1.2).

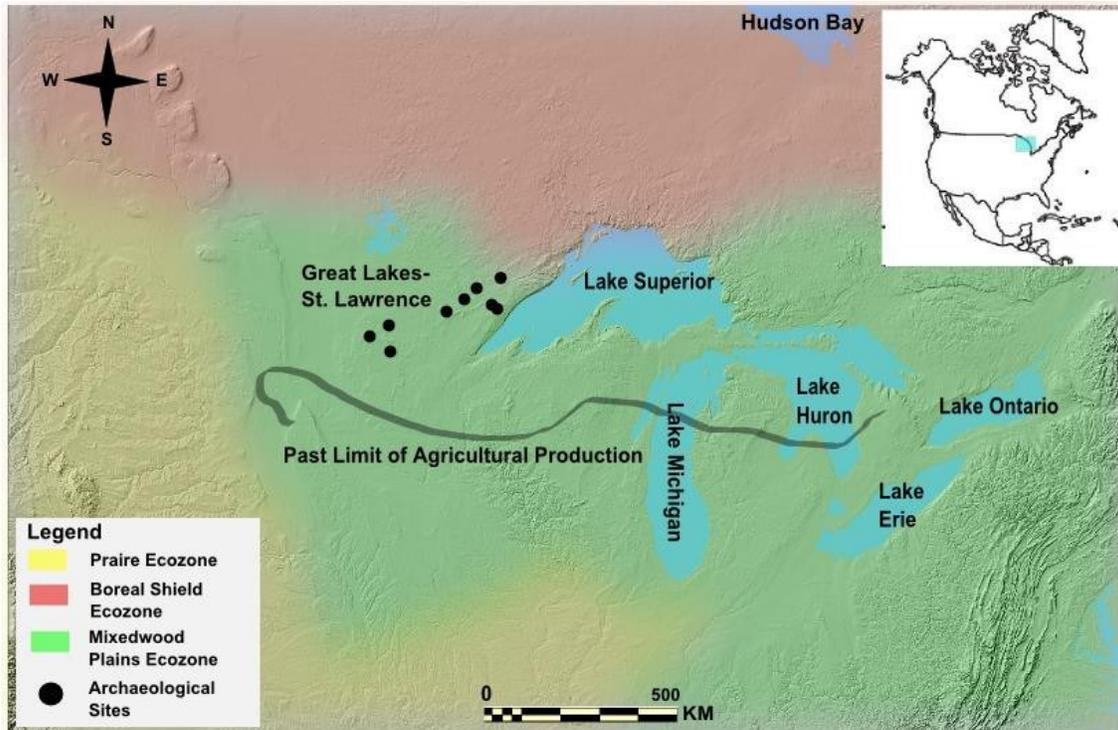


Figure 1.1: Map of study area (base map adapted from USGS 2013; Environment Canada; Minnesota Department of Natural Resources).

This area was chosen because food residue analysis has been applied to only a few sites in Northern Minnesota and recent results indicate the presence of cultivated plants in adjacent regions of Northwestern Ontario, the Canadian prairies, Southeastern Minnesota and the Dakotas (Boyd et al. 2006, 2008; Lints 2012; Mulholland 1986; Perkl 1998). For example, the Martin-Bird site from Northern Ontario yielded maize, wild rice and squash (Boyd et al. 2014). Lints' 2012 study of ten sites spanning the Northern Plains showed the widespread dispersal of beans and maize by at least AD 700. The King Coulee site in Southeastern Minnesota contained *Cucurbita pepo* seeds and the Big Hidatsa site in North Dakota showed evidence of maize cultivation (Mulholland 1993; Perkl 1998). Prehistoric sites are common along the Mississippi Headwaters and beside rivers and lakes in Central

and Northern Minnesota, making this study area a rich source of information about Woodland diet (Mulholland et al. 1996).

The sites chosen for this study are associated with Brainerd and Laurel pottery (Hohman-Caine et al. 2012); these two complexes represent the earliest pottery-producing cultures in Northern Minnesota and are the most widespread expressions of the Initial (Middle) Woodland period (Anfinson 1979; Arzigian 2008). These populations relied on a diet of bison, deer, elk and wild rice (Arzigian 2008; Lugenbeal 1976; Hohman-Caine and Goltz 1995).

Nine sites were chosen to give a comprehensive representation of paleodiet during the Middle Woodland across the region. The sites chosen include the (1) Third River Borrow Pit; (2) Big Rice; (3) Winnie Cottages; (4) No Beard; (5) Windy Bead; (6) Lost Lake; (7) Saga Island (8) Kyleleen's Bent Pine; and (9) Kyleleen's Tall Pine. From these sites, 31 ceramic sherds, two grinding stones and five soil samples were analyzed using the methods described below. The sample size was selected to allow for multiple lines of evidence to interpret patterns of trade and/or small-scale agriculture.

The counties included in the study area are Cook, Lake, St. Louis, Koochiching, Itasca, Carlton, Cass and Aitkin (Figure 1.2). Both Brainerd and Laurel ware are present in these eight counties, making this area of Northern Minnesota a suitable location for the study of Middle Woodland plant consumption.

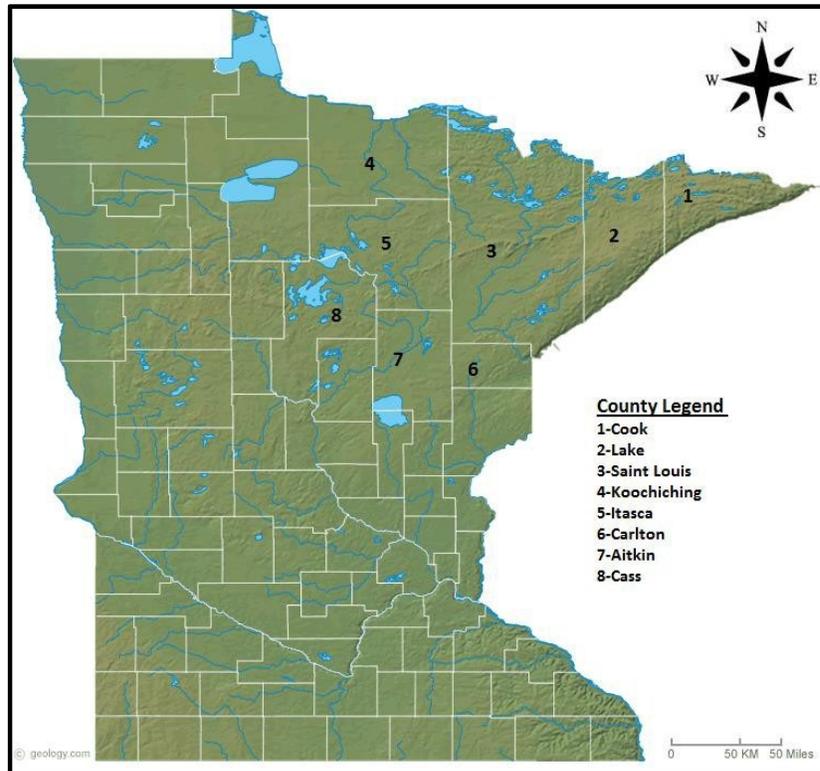


Figure 1.2: Map of Minnesota counties in the study area (source: <http://Geology.com>).

Current research from these periphery areas pushes back the timing for the introduction and dispersal of domesticated cultigens, making it likely that maize, beans and squash were present in Northern Minnesota (Boyd et al. 2006, 2008; Lints 2012; Mulholland 1993; Perkl 1998). Acidic soils prevent the preservation of organic materials such as seeds; therefore, not many macrobotanical remains have been recovered, which has hindered the discourse on prehistoric subsistence activities in Northern Minnesota. Food residue analysis from a number of different contexts has proven to be an invaluable method for inferring past diet and floral-based subsistence in cases where there is poor survival of organic material.

1.2 Methods

Food residue analysis is the microscopic identification of microfossils to determine paleodiet. The microfossils in this study include phytoliths, which are products of silica absorption from ground water; starch granules, carbohydrates in which plants store energy; and pollen grains, which are powders containing the microgametophytes of reproductive seed plants. These microfossils are especially useful in areas of poor organic preservation and they are influencing the dietary interpretations arrived at with conventional techniques (Crowther 2012; Berman and Pearsall 2008; Boyd and Surette 2010; Haslam 2004; Piperno and Dillehay 2008; Piperno et al. 2009).

Phytoliths survive in environments of good preservation because they are inorganic and very durable (Piperno 2006). Starch granules have been found in a variety of well and poorly preserved environments with some associated deposits 2 million years old (Torrence and Barton 2006). Pollen is the male gametophyte, and depending on species they can travel long distances and have been found in deposits dating to 8,050 BC (Fearn and Lui 1995; Wright 1993). Morphological characteristics led researchers to recognize key diagnostic features of phytoliths, starch and pollen, allowing for accurate species identifications (Brown 1984; Fearn and Lui 1995; Torrence 2006).

2.0 STUDY AREA

2.1 Modern Environment

Climate

Northern Minnesota has a continental climate, characterized by warm summers and cool to cold winters with an average annual rainfall of 60.96 to 63.5 centimetres. Temperatures are wide ranging, with July maximums of 21.1° to 27.8° Celsius and January minimums of -11.1° to -8.9° Celsius (Anderson et al. 1993; Mulholland et al. 1996). Three dominant air masses control the climate: southerly winds carry humid, warm air from the Gulf of Mexico, northerly winds bring dry and cool air from the Arctic and westerly winds bring dry Pacific air (Anderson et al. 1993).

Soils

Lakela (1965) describes the soils in the central part of Northeastern Minnesota as gray-brown loam, with sand and peat overlying fine sand. The western and southwestern parts of St. Louis County contain a gray loam soil over limy subsoil. The soil pH of a jack pine stand in the Superior National Forest measured 4.8 to 5.2 (Ahlgren and Ahlgren 1965). Soils unique to the Third River Borrow Pit site includes, sandy loam Typic Glossaqualfs, loamy fine sands Alfic Udipsamments, mixed typic Fluvaquents and Aquic Udipsamments. These soils reflect an environment of sand plain origin in a floodplain (Mulholland et al, 1996). Peters and Motivans' (1983) evaluation of the Big Rice site identified soils of the Baudette-Spooner-Toivola area including sands and loamy sands.

Geology

The geology of the region is an important environmental aspect for understanding resource availability. Rocky outcrops used as lithic resources date to the Early Precambrian, Middle Precambrian, Late Precambrian and Cretaceous. Geologic formations consist mostly of Precambrian bedrock; exceptions include areas of Cretaceous sediments in the Mesabi Range and Quaternary sediments (Lakela 1965). Northeastern Minnesota includes the Duluth Complex, a section of the Middle Precambrian basin with the Biwabik Iron Formation, three Lower Precambrian batholiths (Saganaga, Giant's Range and Vermillion), Lower Precambrian volcanic-sedimentary (greenstone) belt and Upper Precambrian continental lava flows (Ojakangas and Matsch 1982). Glaciofluvial deposits overlie these rock formations and from the north to the south and eastwards, geologic formations become younger. Metasediments, conglomerates, Knife Lake slates and Keewatin greenstones underlie the Northern area. Iron formations, unfolded quartzite and argillite overlie these older rock formations. To the south, intense folding acts on Huronian rocks, which are intruded by granite. The North Shore Highland is a younger rock formation within the Keweenawan system. Diabase, gabbro and other similar rocks intrude lava flows and intercalated sediments dip east to southwest towards Lake Superior (Lakela 1965).

Vegetation

Mulholland et al. (1996) and Lakela (1965) describe current vegetation in Northern Minnesota as being mostly composed of jack pine (*Pinus banksiana*), with spruce (*Picea*) thriving in lower areas of successional growth with white pine (*Pinus*

strobus), red pine (*Pinus resinosa*) and balsam fir (*Abies balsamea*). Low juniper (*Juniperus communis*) only grows in rocky forests and exposed bluffs, while creeping juniper (*Juniperus horizontalis*) can be found on the Fox Islands and Spilt Rock. Yew (*Taxus canadensis*) and white cedar (*Thuja occidentalis*) inhabit islands, rockier areas and moist lowlands. Tamarack (*Larix laricina*), black spruce (*Picea mariana*) dominant upland bogs and crevice plant life such as mosses, ferns and lichens thrive on ledges and cliffs. The mix of coniferous and deciduous forests in Northern Minnesota is typical of the mixed forest transition zone in the Great Lakes-St. Lawrence Forest. Deciduous species present includes, oak (*Quercus*), elm (*Ulmus* L.), ash (*Fraxinus*), and basswood (*Tilia americana*).

Wild rice (*Zizania* sp.) is a native plant that grows in shallow lakes and streams, and for at least the last 2,000 years, wild rice has been an important form of sustenance for Minnesotan populations (Valppu and Rapp 2000; Yost 2007; Yost et al. 2013). Yost's (2007) study on *Zizania* concluded the presence of wild rice phytoliths and pollen in modern lake deposits in Minnesota, which correlated to plant density and stand location. The presence of wild rice phytoliths and pollen is found in paleodeposits as well, and suggests a long-term reliance on wild rice by past and present populations (Yost 2007). Lake sediment cores from central Minnesota analyzed by Yost et al. (2012) yielded an abundance of *Zizania* phytolith and pollen grains. One core reached a depth of 1,400 cm, which dates to around 8,050 BC at the bottom depth. *Zizania* was identified in this core beginning at 460 cm, with an increase in pollen microfossil abundance towards the top of the sample (McAndrews 1999; Yost et al. 2013).

Ethnographic accounts by Jenks (1903) show that wild rice was important spiritually, and as a form of sustenance. The Ojibwa occupied Northern Minnesota in the last 250 years, and collected wild rice every autumn from many of the streams and lakes. The name “Mun-o-min-ik-a-sheenh-ug, or Rice-makers”, was given to the Ojibwe residing on the rice lakes of the St. Croix River (Jenks 1903). Currently, wild rice can be found in shallow, muddy lakes and streams in Northern Minnesota and is being cultivated and harvested by retailers with wild rice farms on the Mississippi shores (Mallard Club Wild Rice 2014; Thomas 1996). The archaeological significance of wild rice in Northern Minnesota will be addressed in Chapter four.

2.2 Paleoenvironment

Glacial History

Glacial history of the area has had a tremendous impact on current landforms and topography shaping, and to some extent, how Woodland peoples interacted with their environment (Wright 1993). Ojakangas and Matsch (1982) described current landforms formed by glaciation in Northeastern Minnesota as a peneplain surface of rugged terrain, where outcrops are quite common, because drift is minimal except in areas of moraines. The Black Duck and Guthrie are two till plains reflective of these glacial movements forming modern topography (Hill and Huber 1996). Wright (1993) noted that the Alexandria and Itasca moraine now cover large extents of Northeastern Minnesota (Figure 2.1).

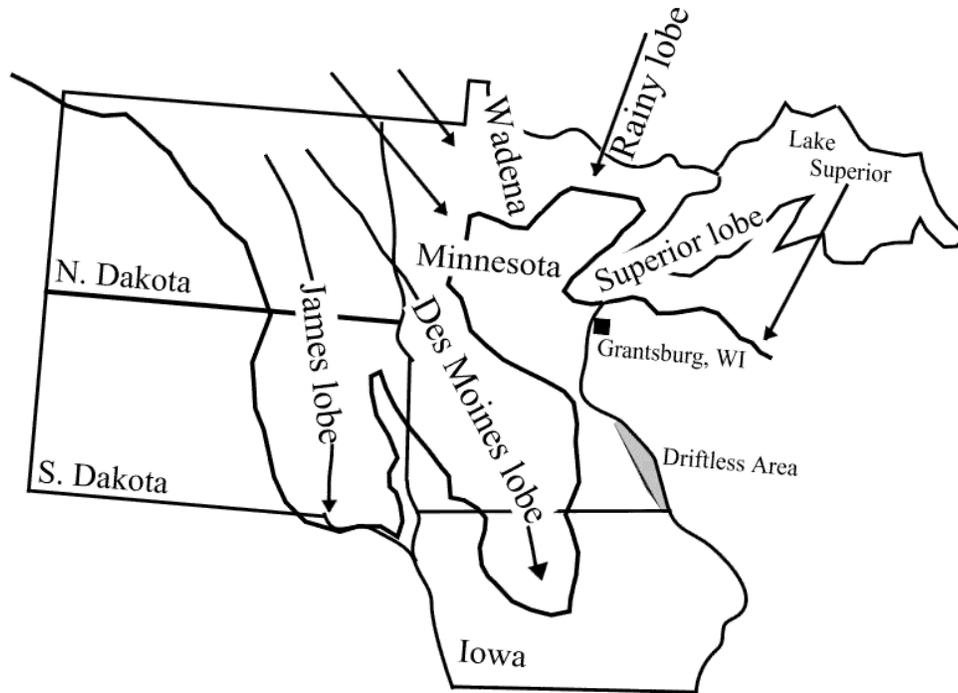


Figure 2.1: Map of glacial lobes in Minnesota (Maple Hill Park.org).

From 12,500 to 9,900 B.P glacial advances occurred in the region leaving behind three major proglacial lakes (Anderson et al. 1993; Hill and Huber 1996; Wright 1993). The three major drainage basins are the Rainy River, headward-eroding tributaries of the St. Croix and upper Mississippi, and lastly Lake Superior, in which North Shore streams flow (Ojakangas and Matsch 1982).

Wright (1993) and Ojakangas and Matsch (1982) described three lobes of glacial ice active in the area between 30,000 and 14,000 years ago and accountable for many of the Quaternary landforms visible today. They are: the Superior Lobe, Rainy Lobe and the St. Louis Sublobe (Figure 2.2).

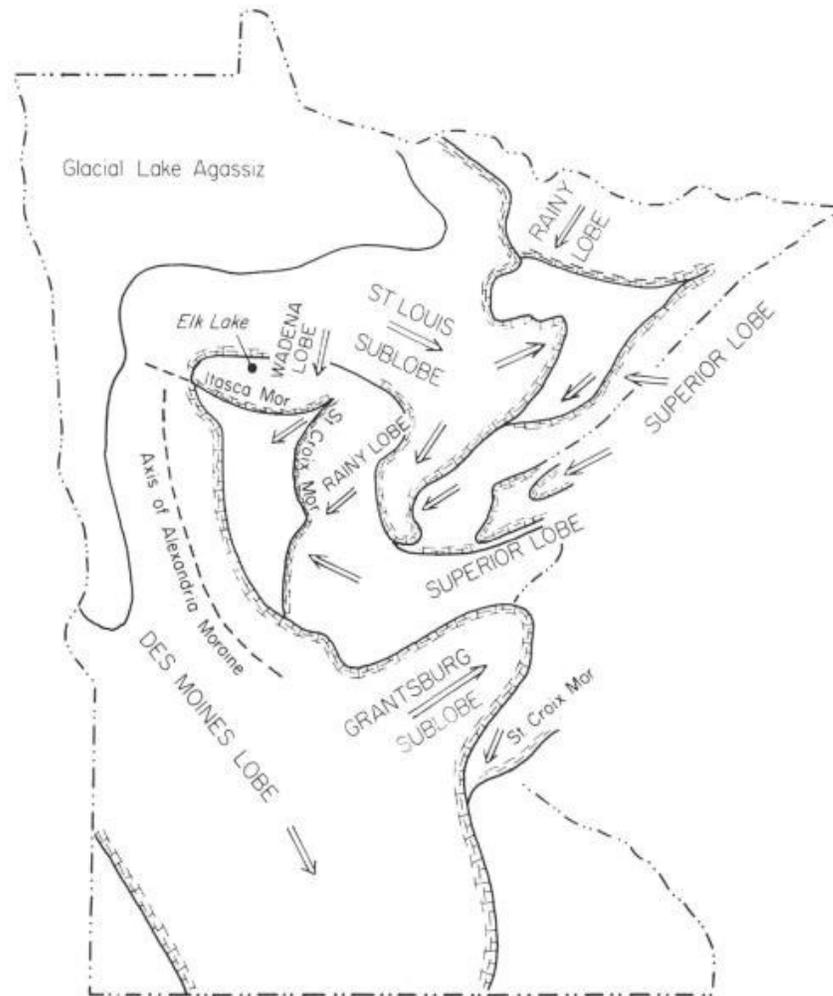


Figure 2.2: Glacial movement during the Late Wisconsin in Minnesota (Wright 1993).

The Wadena Lobe, which is thought to be contemporaneous with the Rainy Lobe moved southwards from Canada through north-central Minnesota (Wright 1993). This formed the Itasca and Alexandria Moraines about 20,000 years ago (Hill and Huber 1996; Wright 1993; Dean and Megard 1993; Ojakangas and Matsch 1982). The final glacial advance of the St. Louis Sublobe of the Des Moines Lobe, between 14,000 and 12,000 years ago, formed most of the landforms visible today (Hill and Huber 1996; Dean and Megard 1993).

The Laurentide ice sheet expanded into Minnesota from Northern regions in Canada around 30,000 years ago, and the Rainy lobe covered the upland west of the Lake Superior basin, while the lowland now occupied by the Red River channelled the Des Moines lobe (Wright 1993; Ojakangas and Matsch 1982). The Wadena Drift represents the oldest surficial drift in the area, evident from the Wadena drumlin field, marking the movement of the Wadena ice lobe. Prior to 14,000 years ago, the eastern margin of the Wadena Drift was deposited as the St. Croix moraine of the Rainy lobe and the Itasca moraine outwash buried the northern margin. The Des Moines lobe from the west covered the Alexandria moraine complex; however, the Wadena lobe may have deposited the core of the moraine. Climate fluctuations caused the Wadena lobe to retreat and re-advance south of Itasca Park, forming the Itasca moraine. The Superior and Rainy lobes terminated at the north-south St. Croix moraine. Due to subsequent climatic shifts around 14,000 years ago, the Wadena lobe at the Itasca moraine ceased, as did the Superior and Rainy river lobes at the St. Croix moraine. Only the Des Moines moraine was active after the Rainy, Superior and Wadena lobes retreated from the terminal moraines. The Des Moines lobe finally reached the terminus area 14,000 years ago and upon retreat, it left behind the Anoka sand-plain. A few proglacial lakes remained after the retreat of the St. Louis Sublobe; Glacial lake Upham, Glacial Lake Aitkin and Glacial Lake Koochiching, which drained into the developing Lake Agassiz (Wright 1993).

Around 11,700 years ago the Laurentide ice sheet retreated north, and Lake

Agassiz grew in size, spreading northwest (Wright 1993). Glacial ice began to retreat 18,000 to 14,000 years ago, and ice blocks within moraines began to melt, which is evident from basal lake sediments (Wright 1993; Dean and Megard 1993). By 11,500 BP, glacial ice had retreated from Northern Minnesota leaving Glacial Lake Koochiching and Agassiz to remain covering large extents of land (Mulholland et al. 1996). The ice eventually retreated so far to the north to enable the northward displacement of Lake Agassiz, and after about 8,000 years ago, it eventually drained eastwards towards into the St. Lawrence basin and finally northwards into Hudson and James Bay (Tyrell Sea) (Wright 1993). The Marquette re-advance of Superior lobe glacial ice took place around 10,000 BP, and this had an effect on Minnesota's northshore and areas east of Duluth, Minnesota (Phillips and Hill 2004).

Paleovegetation

Following ice retreat, different plant and animal species began to populate Northern Minnesota. Evident from Appendix 1, Woodland peoples from 50 BC to 950 AD relied on some of these species, forming various subsistence strategies. Bishop (2007), Gibbon (2012a), Hoover (1963), Mulholland et al. (1996), Peter and Motivans (1983) and Shafer (2003) determined that the main faunal elements found at some sites derive from deer and caribou, which were specifically listed in site reports. Though what is found versus what was actually consumed may be quite different because of high soil acidity levels rapidly decomposing smaller faunal elements and macrobotanicals.

Phytolith and pollen analysis have both greatly contributed to paleovegetation literature from the Great Lakes and research has shown vegetation changes

throughout the Holocene (Figures 2.3 & 2.4). Regionally, widespread vegetation shifts correspond to climate, however locally; pollen shows shifts in relation to other variables such as, fire, environmental processes and succession (Bradbury et al. 1993; Boyd et al. 2003; Wright 1993).

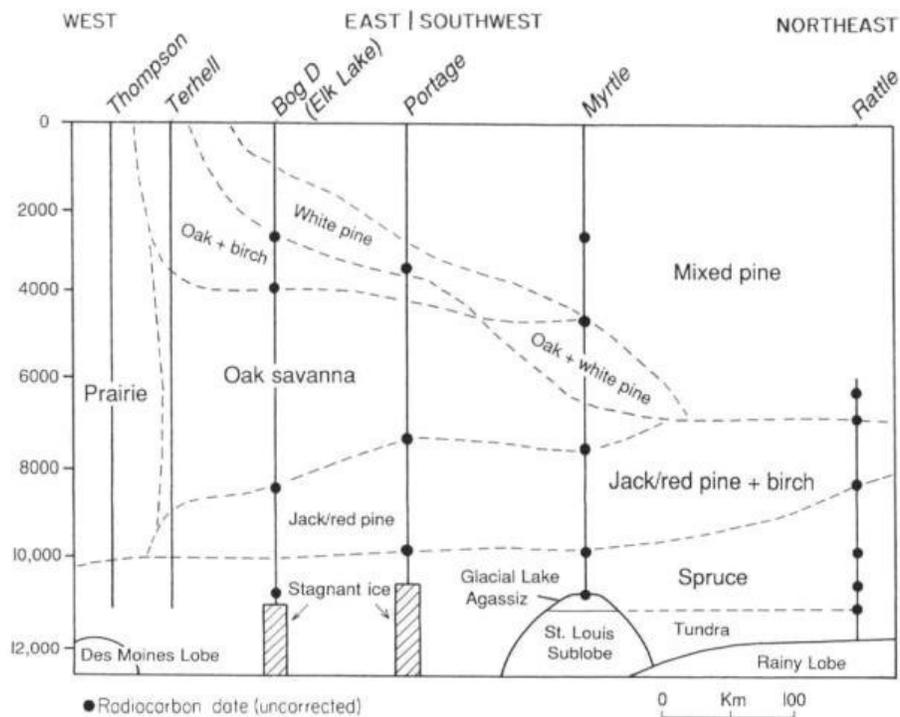


Figure 2.3: Vegetation in relation to different glacial surges versus time (Wright 1993).

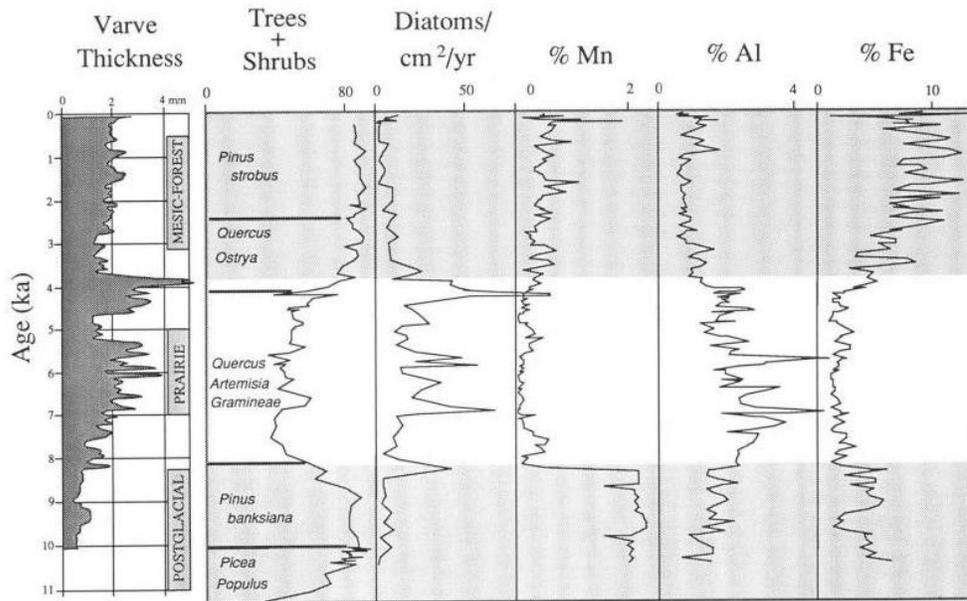


Figure 2.4: Varve thickness, pollen levels for trees and shrubs, diatom flux and elemental percentages versus time at Elk Lake (Anderson et al. 1993).

Between 20,500 to 14,700 years ago, tundra-like vegetation such as, *Arenaria rubella*, *Vaccinium uliginosum* var. *alpinum*, *Dryas integrifolia* and *Silene acaulis*, thrived in central Minnesota, and when Northern Minnesota began to deglaciate around 14,000 years ago this vegetation expanded northwards (Birks 1976; Dean and Megard 1993; Wright 1993). Shrubs such as, willows, alder, *Shepherdia canadensis* and *Empetrum* dominated regional flora between 14,700 to 13,600 along with dwarf birch. This was prior to the establishment of spruce-dominated forests 13,600 years ago. Between 13,600 and 10,000 years ago, little change occurred, except with the migration of deciduous vegetation into the region (spruce-birch, spruce-pine forests), and local changes to wetland species due to lake level fluctuations. Ten thousand years ago, *Pinus banksiana* expanded, forming the mixed coniferous-deciduous forest that can still be seen today (Birks 1976;

Mulholland et al. 1996; Wright 1993). Similar to Mulholland's et al. (1996) assessment, Wright's (1993) pollen study yielded high percentages of spruce before the introduction of pine around 10,000 B.P. Dry, warm conditions allowed for a prairie presence and moist, warm conditions developed deciduous forests creating a combination of mixed forest and boreal zones (Anderson et al. 1993; Perki 2009).

During the Middle Holocene (7800 to 4500 BP) Northern Minnesota was affected by the eastward spread of prairie vegetation, and considerable fluctuations in lake levels and stream flow (Bartlein and Watts 1993; Hohman-Caine and Goltz 1995; Wright 1993). This is evident from pollen stratigraphy showing eroded sediment caused by lower water levels at Lake Itasca (Wright 1993). In parts of North American and Europe, the Middle Holocene consisted of drier and warmer conditions than modern day, which influenced the migration of prairie-savannah vegetation into the Great Lakes-St. Lawrence Forest (Anderson et al. 1993). Prairie vegetation migrated approximately 120 km northward and eastward, and because of the drought prone sandy soils, woodland prairie transition plant species moved northeast an extra 75 to 100 km (Anderson et al. 1993; Hohman-Caine and Goltz 1995). Pollen cores record complete or partial drying of lake basins around 4,000 years ago, allowing for weed like annual vegetation to intersperse in wetter conditions. This would have caused a decreased reliance on aquatic resources that prehistoric peoples were heavily dependent on (Anderson et al. 1993; Hohman-Caine and Goltz 1995). This period of warming (4,000 ka) was caused by climatic oscillations and transitions in the three airstreams affecting Minnesota. The drier climatic conditions caused the coniferous forests to be replaced with sagebrush,

grass and oak savannah (Anderson et al. 1993; Wright 1993). Varve thickness at Elk Lake suggests a 600-year period, between 5.2 and 4.6 ka, of rapid reversal in the trend towards warm conditions (Wright 1993). This reversal was caused by a climatic variability pattern, linked to solar flux, zonal winds, and magnetic storms (Anderson et al. 1993; Bradbury et al. 1993). Between 6900 and 4000 BP the pine and oak or oak savannah intermingled with pine forest gradually moved westwards (Hohman-Caine and Goltz 1995). Elk and bison would have been successful in this environment, as evident from archaeological sites in the region (Hohman-Caine and Goltz 1995; Appendix 1).

The climate during the Early to Middle Woodland Period (1000BC to 900 AD) was cooler and defined by movements of deciduous forests replacing the prairies in Northern Minnesota (Arzigian 2008). This environment would have fostered the growth of aquatic and woodland plant resources, many of which appear in floral and faunal assemblages from Woodland archaeological sites in the region. The return of moist conditions around 4,000 ka led to the re-establishment of mixed wood tree taxa such as birch and pine (Anderson et al. 1993; Anfinson 1997; Hohman-Caine and Goltz 1995). Climatic patterns stabilized with high precipitation with resultant increased lake levels. Aquatic floral and faunal populations would have increased with lacustrine stability. Preceding the movement of white pine westward into Lake Itasca County by 2700 B.P, there is a short increase in mesic deciduous forest. Deciduous forest would have introduced species such as basswood (*Tilia americana*) and wood nettle (*Laportea canadensis*); Hohman-Caine and Goltz (1995) propose that fibres from these species may have been used for the net and

cord marks on Brainerd ceramic surfaces. The vegetation, upon early European settlement, was a combination of aspen-birch, conifer and bog swamps, pine flats, and jack pine barrens (Marschner 1974).

The climate, soils, geology, glacial history, fauna and flora of Northern Minnesota determined resource availability and the chosen subsistence strategies of Woodland peoples. The climate over time influenced environmental fluctuations and glacial movement during the Holocene and up until the Woodland period, affected the movement of people and animals. Acidic soils unique to Northern Minnesota and a Boreal ecozone determine which materials survive, and which degrade, changing site interpretations of subsistence. Glacial history of Northern Minnesota changed the landscape to shape resource distribution and access. Lastly, the fauna and flora that diffused into Northern Minnesota after ice retreat adapted to various climatic shifts during the Holocene. The paleovegetation reacting to these shifts eventually influenced what floral subsistence was available for Woodland populations.

3.0 ARCHAEOLOGICAL SITES

3.1 Introduction

Sites were selected based on age, accessibility to material, stratigraphic context and access to published reports. Age is an important factor because of recent results showing cultigens in Manitoba, Saskatchewan and Northwestern Ontario during the Late Woodland (Boyd et al. 2006; 2008; Boyd and Surette 2010; Lints 2012). Material accessibility allows for a suitable number of samples to be processed from a chosen site. A larger sample size ensures more complete interpretations and analysis, since aspects of food production can be better assessed. With a clear idea of the sample's stratigraphic context, it is easier to determine age and interpret how samples relate to each other. Site reports provide the details described above, so with records of where samples originate from within sites, and/or site background, interpretations become more reliable. Sites chosen include: Third River Borrow Pit, Big Rice, Windy Bead, Third River, Winnie Cottages, Lost Lake, Kyleleen's Tall Pine, Saga Island, and No Beard (Figure 3.1).

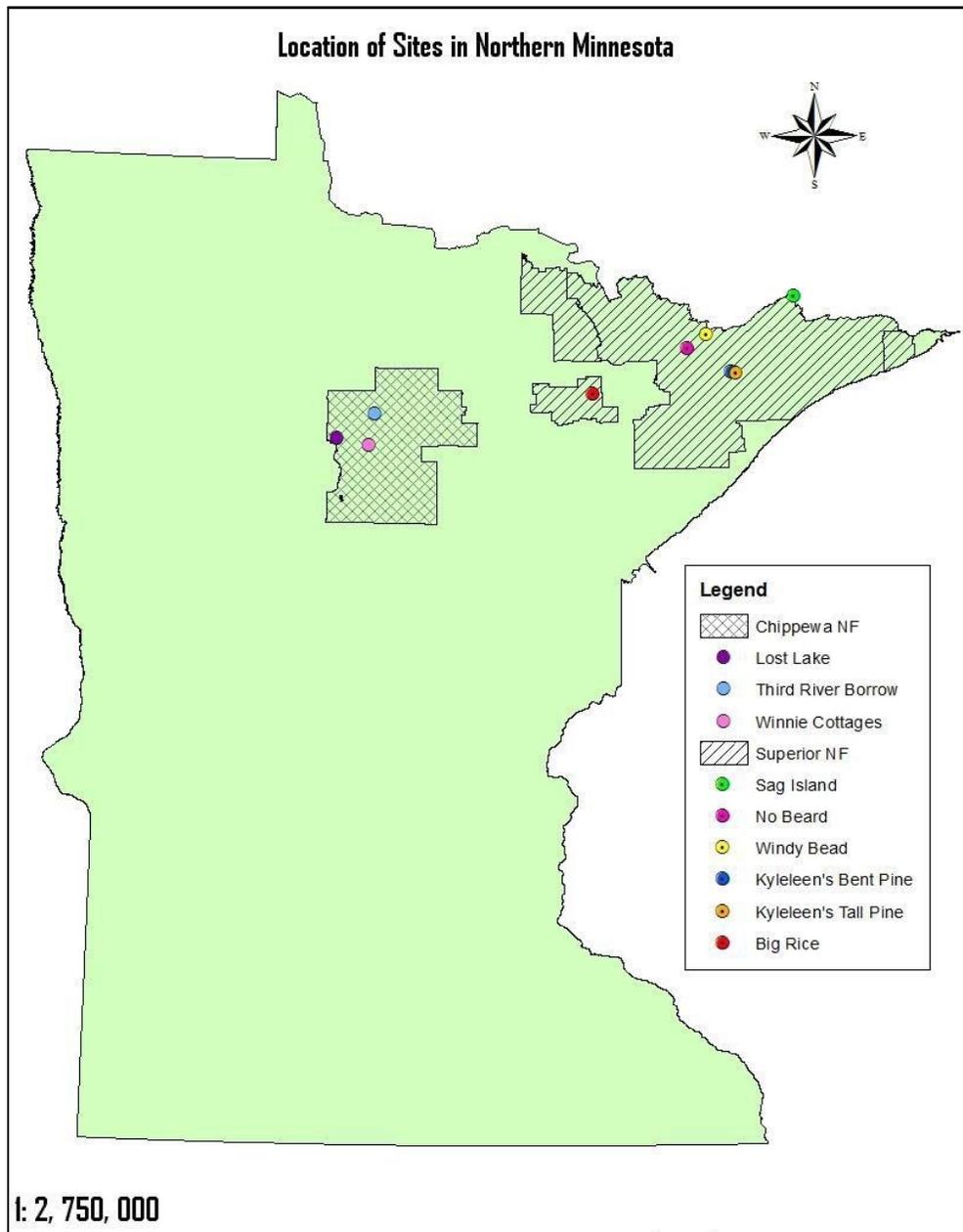


Figure 3.1: Location of the nine study sites in Northern Minnesota (Heather Hoffman 2014).

3.2 Third River Borrow Pit Site (21-176)

Located in Itasca County, Minnesota in the Blackduck District of Chippewa National Forest, the Third River Borrow Pit (TRBP site) was described by Mulholland et al. (1996) as containing abundant Brainerd pottery as well as some Laurel remains. A feature containing fish bone, charcoal and pottery had four radiocarbon dates processed from the charcoal and organic residue (Appendix 3).

The TRBP site report outlines that the site was discovered in an eroding bank where cultural material began to emerge. The site is on a terrace above a floodplain where post-glacial landforms and processes, namely the Bemidji Sand Plain glacial landform, dominate the landscape. Sediments are predominantly sandy loam Typic Glossaqualfs, while the northern area of the site contains loamy fine sands Alfic Udipsammets. A third type of soil is mixed typic Fluvaquents and Aquic Udipsammets. Site vegetation consists of spruce in low areas and jack pine with white and red pine on higher ground. Surrounding water bodies such as Dixon Lake contained wild rice in the past, suggesting wild rice cultivation by TRBP site inhabitants.

Twelve units were excavated at the TRBP in 10 cm levels, or until sediment layers could be distinguished. Unit 2S contained the largest amount of ceramics in the southern area; Unit 5S and Unit 11N also contained large quantities of ceramics. Sixty-five lithic pieces were recovered reflecting the various stages including three tools and 62 pieces of debitage; there is a 1:30 ratio for lithics to ceramics, indicating an area for ceramic production. The type of lithic material indicates a variety of local stone, including Hudson Bay Lowland chert, Swan River chert, basalt and quartz,

among others. Exotic Tongue River silicified sediment and Knife River Flint were also identified. Fire cracked rock is associated with ceramics, indicating a wide range of functions, such as ceramic firing, dispersal of hearth stones, and boil pits. In all, 2,104 ceramic body and rim sherds were recovered during all stages of survey and excavation.

Brainerd ware was the predominant type of ceramic found at the site; 50.6% was Net Impressed and 6.3% was Horizontally Corded. Laurel ware comprises 10.1% of the recoveries and these have circular punctuates, are undecorated, and/or have vertical linear impressions. In total, there are 18 Brainerd Net Impressed vessels, four Brainerd Horizontally Corded vessels, and seven Laurel vessels. Residue was found on the interior of Brainerd corded sherds from Feature 1 associated with wood charcoal. A Horizontally Corded sherd from the same feature also has carbonized residue on the inside located at an angle to the rim.

Two features of interest were excavated at TRBP site. Feature 1/1A is located in the corner of Unit 2S. The contiguous Unit 8S contains the second feature, and is labelled Feature 1 (Figure 3.2). Both features contained abundant amounts of charcoal and ceramics. Within Feature 1A, a Brainerd Horizontally Corded body sherd with adjoining rim sherd was found, as well as a second one 44 cm below the surface within Feature 1A. These sherds contained carbonized food residue, and are associated with charcoal deposits suggesting a hearth.

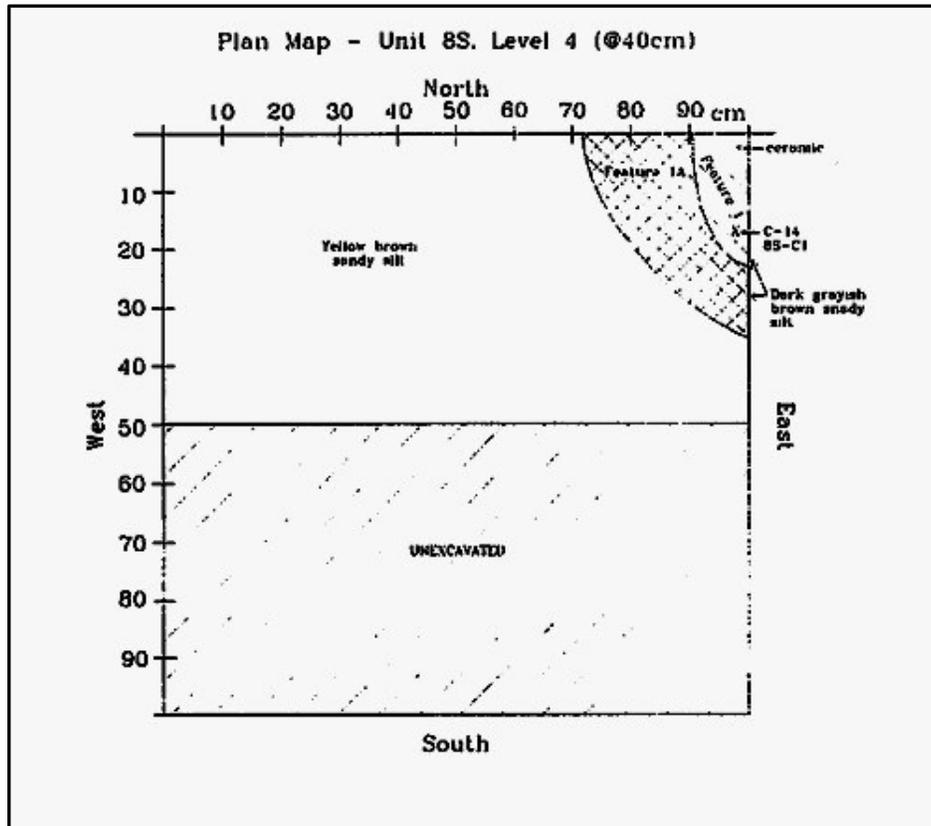


Figure 3.2: East planview of Feature 1, Unit 2S and 8S (Mulholland et al. 1996).

Flotation analysis was conducted on both Feature 1 and Feature 1/1A, and the results yielded uncharred and charred floral material. Chenopods, specifically *Chenopodium hybridum* var *gigantosperm* were identified with other weedy flora. Both in prehistoric and historic times, chenopods have been an important food source (Mulholland et al. 1996; Yarnell 1964). Other plant species that Mulholland et al. (1996) identified are elderberry (*Sambucus* sp.), smartweed (*Polygonum* sp.), blueberry (*Vaccinium* cf. *angustifolium*), wild strawberry (*Fragaria virginiana*) and raspberry (*Rubus idaeus*) macroremains.

Radiocarbon dates were taken from samples such as organic residue, and charcoal; results showed varying dates (Appendix 9). Mulholland et al. (1996) give

two reasons for differences in returned dates between samples found 0.5cm apart in the feature. One reason is that the carbonized food residue may be providing offset dates. The second reason is that the charcoal may be extraneous, or contaminated thus giving a younger date. Dating issues are common in the region, as explained more in Chapter 4, section 4.3.1. TRBP site is a predominantly Brainerd site providing an excellent opportunity to study the makers of Brainerd ware and the introduction of early cultigens into the region.

3.3 Big Rice Site (09-034)

This multicomponent site discovered in 1981 is located in Superior National Forest, St. Louis County, Minnesota in the Superior National Forest Laurentian District (Shafer 2003). As opposed to the TRBP site, the Big Rice site has predominantly Laurel ceramics. The Big Rice site is a large site where some inhabitants produced Laurel ware and relied on wild rice (Shafer 2003). Valppu and Rapp (2000) note the importance of the Big Rice site when their results showed that wild rice was first processed and consumed in relation to the production of Laurel ceramics during the Early/Middle Woodland around 50 BC (Appendix 2). The site is situated above the Big Rice Lake in the sandy sediments of the Big Rice outwash plain.

The soils at the site are composed of loamy sands and sands, and the substratum is composed of gravel and sand. Unlike the TRBP site, the Big Rice site is multicomponent, containing archaeological material from the Paleoindian, Woodland and Contact periods. Valppu and Rapp (2000) note that stratigraphic mixing is common in the upper levels from the site, evident from the mixture of Late

Woodland ceramic wares with Laurel materials. Soil samples analyzed for phytolith and starch remains in this study were extracted from the base of features surrounded by unmixed glacial deposits to prevent contamination and ensure that the sediment was collected from Middle Woodland deposits. The processing and gathering of wild rice at the site is suggested by ricing jigs and parching pits (Valppu and Rapp 2000). Parching pits are evident from black or dark brown circles with associated fire hearths (Figure 3.3, Shafer 2003).



Figure 3.3: Big Rice site feature 25, bottom of level 12, note trowel for scale (Peters and Motivans 1983).

Other ceramic wares present at the site include Selkirk, Blackduck and Sandy Lake making Big Rice one of the longest occupied sites in Northern Minnesota. A minimum of 159 different Laurel vessels were found at the Big Rice site and these

vessels are separated into different design categories such as: 15 Laurel Boss/Punctuate, 11 Laurel Plain, 27 Laurel Incised, 17 Laurel Push-pull, 67 Laurel Dentate, 11 Pseudo-Scallop shell and 11 Plain (Shafer 2003).

Other artifacts found at the site include lithics, red ochre, copper in the form of pressure flakers and historic material. Lithics are comprised of Knife River flint, jasper taconite, Lake of the Woods chert, Hudson Bay Lowland chert, Gunflint silica and Knife Lake siltstone. Types of tools include retouched and utilized flakes, projectiles and scrapers representing a low ratio of lithics to ceramics.

Different faunal material associated with the Laurel occupation suggests habitation between July and October, furthering the case for wild rice processing, which involves crop gathering during these months. Floral materials that were not associated with any cultural period in particular include *Chenopodium* sp. seeds, *Polygonum* sp. seeds, pincherry (*Prunus pensylvanica*) seeds, red-berried elder (*Sambucus pubens*), blueberry (*Vaccinium* sp.), wild rice (*Zizania aquatica* and *Z. palustris*) grains and wild red raspberry (*Rubus idaeus*) (Table 1, Valppu and Rapp 2000).

Table 1: Seeds from Area A (Valppu and Rapp 2000).

Species	Total Number	Total Percent
<i>Galium cf. aparine</i>	390	26.4
<i>Zizania aquatic</i>	305	20.6
<i>Chenopodium sp.</i>	299	20.2
<i>Polygonum sp.</i>	115	7.8
Unknowns	68	4.6
<i>Abies balsamea</i> (needles)	60	4.1
<i>Rubus ideaus</i> -type	42	2.8
Gramineae (undiff.)	42	2.8
<i>Prunus virginiana</i>	37	2.5
<i>Sambucus pubens</i>	32	2.2
<i>Diervilla lonicera</i>	31	2.1
<i>Scirpus sp.</i>	29	2.0
<i>Solanum dulcamara</i>	16	1.1
<i>Amelanchier sp.</i>	4	0.3
<i>Picea sp.</i> (needles)	4	0.3
<i>Prunus Americana</i>	3	0.2
Total	1477	100.0

3.4 Kyleleen's Tall Pine (07-505)

Kyleleen's Tall Pine is a habitation site located on a primary terrace by overlooking Isabella River and contains large quantities of various lithics and ceramics. An unspecified number of jasper taconite, Gunflint silica and Knife Lake siltstone lithic objects were recovered, in addition to one jasper taconite scraper. This is a multicomponent site with Brainerd, Blackduck and possibly Sandy Lake ceramics. It was investigated in 2012 by a University of Minnesota field school after the Pagami Creek fire swept through the area revealing cultural material. Modern vegetation recorded included grasses, shrubs, pine trees, reeds and shoreline sweet gale.

3.5 Kyleleen's Bent Pine

This is another fire affected site located close to Kyleleen's Tall Pine. The fire exposed Middle Woodland cultural material. Site forms were not available for Kyleleen's Bent Pine (personal communication, Lee Johnson).

3.6 Winnie Cottages (02-526)

The Winnie Cottages site is located in Cass County, Minnesota, near an oxbow of the Mississippi River. It was first surveyed in 1996, and from the excavation in 2007 a variety of lithics and ceramics were recovered. Winnie Cottages is situated in the Bemidji Sand Plain; therefore, soils are mostly sands and gravels carried in by meltwater from the Koochiching Lobe (11-13,000 years BP). The lithic assemblage is small in comparison to ceramics and is comprised of 756 flakes and a core. Ceramics total 3,387 sherds, and consist of mostly cordwrapped (1,950 sherds), smoothed (120 sherds), and net-impressed (32 sherds). Lithic materials are jasper silica, Gunflint silica, Knife Lake siltstone, chert, quartz, Knife River flint and quartzite. Tools recovered numbered 25 in addition to five Late Woodland projectile points. Conclusions based on the lithic assemblage are that local sources were relied on more than exotic sources, and that tool manufacture and modification was occurring on site. Local raw material that comprises most of the lithics includes, Tongue River silicified sediment, quartz and cherts. Unit 5N 10W at a depth of 25 to 30 centimeters contained Brainerd ceramics and flakes with associated charcoal. Other ceramics found elsewhere in the site include Blackduck, Psinomani, St. Croix and Onamia. Ceramics indicate mostly Late Woodland occupation with a smaller Brainerd component pre-dating the Blackduck, and Sandy Lake ceramics. One quartzite groundstone was recovered and excavators noted that there was no

evidence of battering. Faunal remains are few and poorly preserved, with some identifiable ungulate, deer and rodents.

3.7 Windy Bead (05-373)

Windy Bead is a multicomponent semi-permanent habitation site that stretches from the Paleoindian to Historic Periods. The site is located in Lake County, Minnesota, near Basswood Lake, on a westward extending peninsula. Survey and reconnaissance was conducted in 1984, 1985, and testing took place in 2001, with excavations in 2002 and 2003. Different material collected includes buttons, calcined bone, lithic debitage and tools, trade beads, musket balls, ceramics, triangular projectile points, copper beads, copper awl/punch, groundstones, and cut kettle brass/copper. Most of the ceramics are Laurel and have dentates, punctates, incised rims or Pseudo-Scalloped Shell decoration (Figures 3.4 & 3.5). Soils are organic-silt grading to sorted aeolian tossed sands and loess. Vegetation on site is predominantly birch, balsam, hazel and cedar.



Figure 3.4: Ceramic sherds from the Windy Bead site.

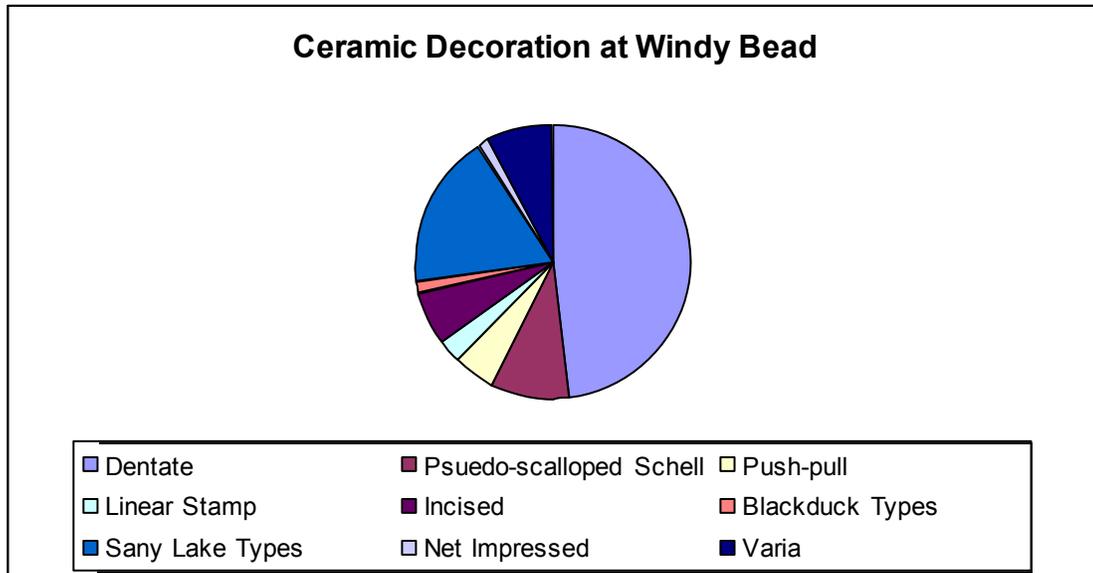


Figure 3.5: Windy Bead ceramic decorative attributes (Lee Johnson n.d).

3.8 Saga Island (02-162)

The Saga Island site is located on an island near the American-Canadian border in Cook County, Minnesota. Laurel and Historic Period material was recovered from the habitation site during survey and reconnaissance in 1982, assessment in 1984, and testing in 2000. Ceramics, trade beads, heavy gauge birdshots, calcined bone, and lithic debris make up most of the cultural material (Figure 3.6). The soil is black humus over a dark brown sandy loam interspersed with bedrock. Local vegetation includes red and white pine and the on-site vegetation is described as grass.



Figure 3.6: Laurel sherds from the Saga Island site.

3.9 Lost Lake (2-00LL)

Lost Lake material was recovered in the 1950s-1960s by an avocational archaeologist and Chippewa National Forest employee. It is described as a Prehistoric Indian village site located in Beltrami County, Minnesota. Remains include 110 lithic flakes, a small faunal assemblage, and large quantities of ceramics, which are predominantly Laurel, Blackduck, and Brainerd. Brainerd, Laurel, and Late Woodland sherds were analyzed in this study for food residue analysis.

3.10 No Beard (05-264)

The No Beard site is located in Lake County, Minnesota; 20 units were excavated in 2000 and 2002. Faunal remains derive mostly from beaver, elk, molluscs, fish, reptiles, but many of the bones are unidentifiable calcined fragments. A number of bifaces, copper tools, projectile points, scrapers, and ceramics were also recovered. The majority of lithic material is Gunflint silica, Knife Lake siltstone, jasper taconite, jasper siltstone, Hudson Bay Lowland chert, Knife River Flint, quartzite, jasper, and granite. Laurel ceramics were identified during the

excavations.

3.11 Samples

Food residue is found in a variety of contexts, including carbonized food residue found on ceramics, and non-carbonized food residue found on lithics and in soil samples (Horrocks 2005; Gott et al. 2006; Thompson et al. 1994). Food residue can also be identified from dental calculus (Hardy et al. 2009); however, obtaining dental calculus samples was beyond the scope of this study. Carbonized food remains can be found adhering to the inside and outside of ceramic vessels, which is a clear indicator of the foods consumed by the vessel producers (Boyd et al. 2006; 2008; Boyd and Surette 2010, Roper 2013; Thompson et al. 1994). Non-carbonized food remains are evidence of plant presence in soil samples, or processing methods with grinding stones (Horrocks 2005; Gott et al. 2006; Zarrillo and Kooyman 2006). Residue can vary in thickness, depending on preservation and the extent of processing or cooking. Thicker residues are more likely to yield samples of sufficient size (over 50 milligrams) to permit radiocarbon dating to help interpret aspects of when certain plant species were available to site occupants (Roper 2013).

Food residues extracted from ceramics are direct indicators of plant consumption because the recovered phytoliths, starch granules and pollen represent the plants cooked in meals (Boyd and Surette 2010). Ceramics that were used more often for cooking will have a thicker layer of residue and preserve the underlying residue (Figure 7.4). Lithics such as grinding stones or fire-cracked rock

are useful indicators of plant use because microfossils tend to become entrapped in microfissures and preserved (Barton 2007; Zarrillo and Kooyman 2006). The analysis of two groundstones analyzed from the Windy Bead and No Beard site revealed evidence of grinding (Figures 7.5 & 7.6). Soil samples are another context used to analyze non-carbonized food residue in the form of phytoliths, starch and pollen (Horrocks 2005). Over time, organic materials break down and decompose, leaving behind identifiable traces of plant material including the microfossils in the soil (Horrocks 2005). Often, soil samples will be collected from archaeological hearth features in search of micro-botanical traces of past meals.

Although samples were analyzed from nine sites in Northern Minnesota, only eight sites had accessible literature. The ninth site, Kyleleen's Bent Pine, is located in a region decimated by fire, which led to the exposure of Middle Woodland cultural material on the surface. This site was included in this study, because the Middle Woodland period ceramics contained food residue. Only the Third River Borrow Pit and Big Rice have dated material from residue and/or organic charcoal. The analyzed cultural material in the form of Brainerd and Laurel ceramics are confidently dated to Early, Middle Woodland Period in Northern Minnesota. All nine sites are located in the Superior National Forest and Chippewa National Forest, a heavily forested region well known for the many lacustrine sources dotting the landscape.

4.0 THE WOODLAND TRADITION IN THE UPPER GREAT LAKES

4.1 INTRODUCTION

The Woodland Period lasted from around 1,200 BC to 1,600 AD throughout much of the Eastern Woodlands and adjacent biomes in North America, and is chronologically situated between the Archaic and Historic Periods (Hamilton et al. 2011). Diagnostic artifacts, stratigraphic context and AMS dates differentiate these sub-periods, but are not uniformly expressed throughout the Eastern Woodlands (Thomas 1996). For example, the Early Woodland has not been identified in Northern Minnesota, leading researchers in Northern Minnesota to generally use the term “Initial Woodland” to describe the Middle Woodland, and “Terminal Woodland” to describe the Late Woodland (Hohman-Caine and Goltz 1995; Shafer 2003; Thomas 1996). This study will use the conventional tripartite division to separate the Woodland Period in Minnesota.

4.2 EARLY WOODLAND (1200 BC TO 250 AD) ARCHAEOLOGICAL COMPLEXES

Changes that took place during the Late Archaic to Early Woodland transition are reflected in transforming site settlement patterns, technological innovations and spiritual practices (Fitting 1969; Perkl 2009). The changes in settlement patterns are thought to reflect gradual response to population increases (Arzigian 2008). Ceramic production begins during the Early Woodland and projectile point morphologies change from dart to triangular points. Burial mound ceremonialism began with large burial mounds becoming a conspicuous feature of the Woodland Period in some regions (Lugenbeal 1976; Shafer 2003; Thomas 1996).

Several models have developed to explain the transition from the Late Archaic to Early Woodland in southeastern Minnesota. These include climate change and adaptation to changing conditions, population expansion causing warfare, and the replacement of Late Archaic populations by intrusive groups or immigrants with different cultural backgrounds and technology (Arzigian 2008; Perki 2009). In the 1950s generalizations were offered that Archaic populations settled in camps, while subsequent Woodland populations lived in villages as their populations increased (Fitting 1969), but this distinction might be over-stated. This over-statement reflects older ways of thinking, when the nature and subtlety of the Archaic to Woodland transition was considered much simpler.

The study of settlement patterns is important because it can reveal human-environment interactions, migrations, and economic development patterns (Silbernagel et al. 1997). To procure settlement data from the Archaic to Historic Periods, Silbernagel et al. (1997) examined a number of different sources including ethnographies, ethnohistories, resource availability, in addition to archaeological investigations and geomorphic mapping. Based on the data, Archaic lacustrine sites are located primarily in complex shoreline areas of shallow water and were probably occupied when freshwater fish were spawning. These areas also provided access to deer, wetland plants, beaver, moose and chert bedrock outcrops. Woodland sites are generally focused on interior wetland resources and are sometimes reoccupations of older, Paleoindian, sites (Silbernagel et al. 1997). Site settlement reflects resource access because certain resources become available through trade and seasonal exploitation at different times of year and in various locations.

Silbernagel et al. (1997) suggests that Early Woodland and Late Archaic sites exhibit similar seasonal occupation cycles, with population aggregation during winter months and dispersal in the summer. Thomas and Mather (1996) suggest the opposite; their data from the McKinstry site support the notion that populations concentrated in the warm months and dispersed in the winter. In the Boreal Forest to the north, broad spectrum foragers concentrated in warm months and dispersed in the winter, this was reinforced by subsistence economies utilizing wild rice gathering in the fall, fishing in the spring/summer, and land mammals in the winter (Meyer and Hamilton 1994; Reid and Rajnovich 1991). Site variation between Late Archaic and Early Woodland settlement patterns emphasizes differences in resource access throughout Minnesota.

Technological innovations during the Early Woodland include changes in projectile point morphology and the introduction of ceramics around 200 BC (Anfinson 1997). Small projectile points with expanding bases, associated with the Point Peninsula complex, appear to diffuse Northeast during the Early Woodland (Fiedel 2001; Lee 1954). Many scholars characterize the Early Woodland as beginning with the introduction and production of ceramics for efficient food processing (Fiedel 2001; Hamilton et al. 2011). The transition from bark, leather and/or wood containers to fired clay can be explained as resulting from a greater need for food storage and higher cooking temperatures. Other factors affecting the need for ceramic vessels include the introduction of new plant species that may have required higher cooking temperatures and increasing populations that warranted more food storage (Fiedel 2001; Skibo 2013). Additional possibilities for

the transition to ceramics are the ability to recycle ceramic containers, create multi-functional vessels and use them in ritual functions (Skibo 2013). Although these are possible models, why ceramic technology emerged is a complicated question and one that is still unanswered. Ceramics play an important role in the consumption, production, processing and storage of food, and may have affected changing subsistence practices (Fiedel 2001; Skibo 2013).

Ceramic types are used to differentiate between the Early, Middle and Late Woodland; these types are defined by differences in decoration, style, shape and vessel size (Figure 4.1). Different types of ceramics are present in Minnesota, and they have assisted in dating associated assemblages based on vessel characteristics (Table 2). Early Woodland ceramics have thick tempered vessel walls and are conoidal in shape with minimal decoration. The following figure illustrates ceramic development over time in different ecological areas of North America.

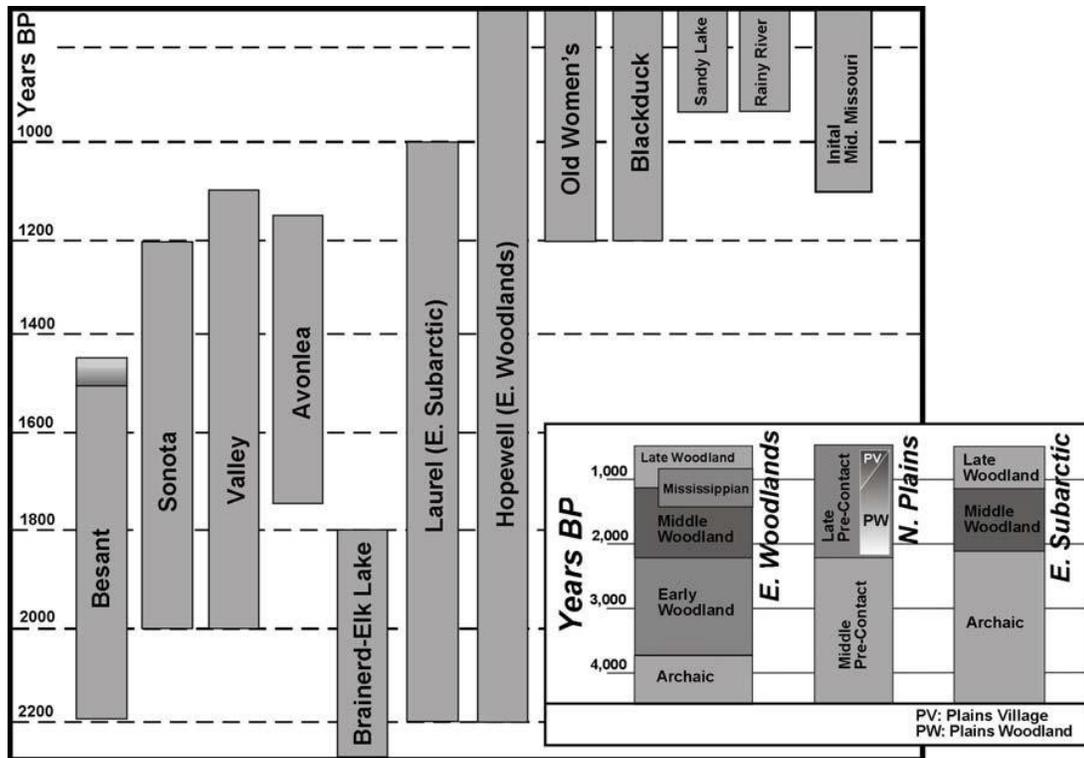


Figure 4.1: Ceramic typologies from the Sub-Arctic, Eastern Woodland and Northern Plains versus time (Hamilton et al. 2011).

Table 2: Major ceramic types dating to the Early, Middle and Late Woodland periods in Minnesota (Anfinson 1979).

Early Woodland	Middle Woodland	Late Woodland
La Moille Thick (500-350 BC)	Brainerd (1600 BC to 400 AD)	Blackduck (800-1400 AD)
Malmö/Kern Series (800 BC to 200 AD)	Laurel (100 BC- 1000 AD)	Blue Earth/Correctionville Phase (1000-1600 AD)
	Fox Lake Phase (200BC-900 AD)	Cambria Phase (1000-1300 AD)
	Howard Lake Phase (200 BC to 300 AD)	Lake Benton Phase (900 to 1500 AD)
	Pokegama Smooth (0 to 500 AD)	Onamia Series (800 to 1000 AD)
	St. Croix (500 to 800 AD)	Orr Phase (1300 to 1800 AD)
		Great Oasis Phase (900-1250 AD)
		Sandy Lake Ware (1000 to 1750 AD)

4.3 THE MIDDLE WOODLAND (100 BC TO 500 AD) ARCHAEOLOGICAL COMPLEXES

New ceramic forms, earthworks, burial mounds, and the construction of food storage pits define the Middle Woodland period in North America (Arzigian 2008; Mason 1981). In Northern Minnesota, the best indicators of the Middle Woodland are distinctive lithic technologies, new ceramic forms, and burial mound ceremonialism (Shafer 2003). Associated projectiles can be broadly, shallow, or corner notched, and/or have an expanding or straight stem. The lithics are manufactured from local and exotic materials including both Burlington chert and Knife River Flint (Arzigian 2008; Hohman-Caine and Goltz 1995; Thomas and Mather 1996; Shafer 2003). Wood working tools, small to medium sized scrapers, wedges, harpoon points, beaver incisors used as cutting tools, and copper items such as pressure flakers, beads, and awls, are also present in Middle Woodland occupations (Arzigian 2008; Donaldson and Wortner 1995; Shafer 2003).

Gibbon and Hohman-Caine (1980) recognize a shift to focal subsistence practices as opposed to more diffuse strategies, which affected settlement patterns in some areas of the Upper Great Lakes. Instead of re-settling different areas to take advantage of seasonal resources, populations settled in one area for longer periods of time and exploited the local resources. The increased density and size of crop production by some Middle Woodland populations may have resulted in larger settlement sizes (Fritz 1993; Scarry and Yarnell 2011). These crops could include a variety of plant species researched in this study such as maize (*Zea mays* ssp. *mays*) and wild rice (*Zizania* sp.). Middle Woodland settlements were occupied

more heavily in the summer and populations relied on plant cultivation and fishing. Winter settlements were smaller and more dispersed, with an increased reliance on small and large mammals for sustenance. During the winter months, most groups would have preferred wooded areas with wind protection; it is therefore not surprising that in southwestern Minnesota, there are site clusters around lakes, on islands, and on peninsulas where fuel and shelter might be concentrated and protected from periodic destruction by prairie fire (Anfinson 1997). Such locations would have also granted groups access to the denser concentrations of aquatic resources and provided protection from enemy groups (Anfinson 1997; Hohman-Caine and Goltz 1995). The transition from the Middle to Late Woodland ended by 600 AD to 800 AD in Eastern Minnesota (Gibbon and Caine 1980).

Brainerd Ceramic Assemblages

Sites with Brainerd ceramics are located in north central Minnesota (Figure 4.2), Montana and Manitoba (Anfinson 1979; Hohman-Caine and Goltz 1995; Norris 2007). Current research suggests that Brainerd ware in Northern Minnesota is the same as Rock Lake ware found in Manitoba, and extending through Saskatchewan into Alberta (Arzigian 2008; Hohman-Caine and Goltz 1995; Hohman-Caine et al. 2012; Norris 2007). The literature is somewhat divided between research in Canada and the United States, which in the past caused different labels to be applied to the same ceramics. As of 2013, there are 195 multicomponent sites and 99 single component Brainerd sites identified in Minnesota (Personal communication with LeRoy Gonsior, Minnesota Historical Society Archaeology Department, 2013).

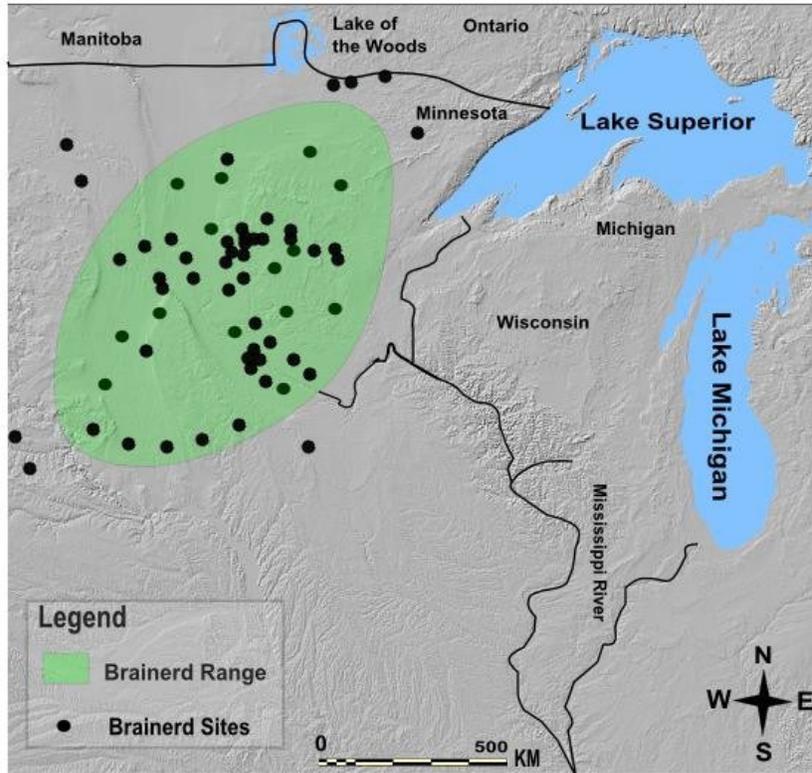


Figure 4.2: Spatial extent of Brainerd assemblages in Minnesota (Anfinson 1979; Hohman-Caine et al. 2012).

Hohman-Caine and Goltz (1995) place Brainerd ware in the artifact assemblage of a cultural manifestation called Elk Lake culture. The Elk Lake culture dates from the Late Archaic to the Early Woodland (Hohman-Caine and Goltz 1995). This varies from previous assumptions that Brainerd ware production began during the Middle Woodland. Brainerd ware dates are subject to debate, and there is a wide variety of contrary data suggesting Late Archaic/Early Woodland production. Projectile points associated with Brainerd ware range from 27 to 45 millimeters in length. Additional lithic tools associated with the Elk Lake culture include rectangular/square wedges or chisels, and scrapers of various sizes. Archaeological evidence shows that bison, deer, elk and wild rice were significant

dietary sources for Elk Lake populations in the cool, moist prairie/woodland ecotone (Arzigian 2008; Hohman-Caine and Goltz 1995). The radiometric dates collected by Hohman-Caine and Goltz (1995) begin at 1550 BC, and end around 750 BC, and this may indicate a preference for the prairie-woodland ecotone present at the time in northcentral Minnesota. The number of Brainerd sites increased in the area around 2,700 years ago coinciding with the return of white pine to the region's western edge (Wright 1968). Forests had fully returned to the region after the decline of Brainerd sites around 350 BC (Hohman-Caine and Goltz 1995; Wright 1993).

Brainerd ware was first identified at the Gull-Lake Dam site (Figure 4.3), a multicomponent habitation and mound site located in central Minnesota. There are two periods of occupation at the site; the first occupation is 800 BC to 200 AD, and the second Brainerd occupation dates from 600 AD to 900 AD (Zellie 1988). Notably the second set of dates from 600 to 900 AD varies considerably from the dates proposed by Hohman-Caine and Goltz (1995). The site consists of twelve round, elongated, and linear mounds close to the eastern side of the dam. Stratigraphic contexts from Gull Lake Dam show that producers of Brainerd ware may have used these earthen burial mounds. At this site, the Brainerd ware is also associated with scrapers, brown chalcedony debitage and side-notched projectile points (Anfinson 1979).

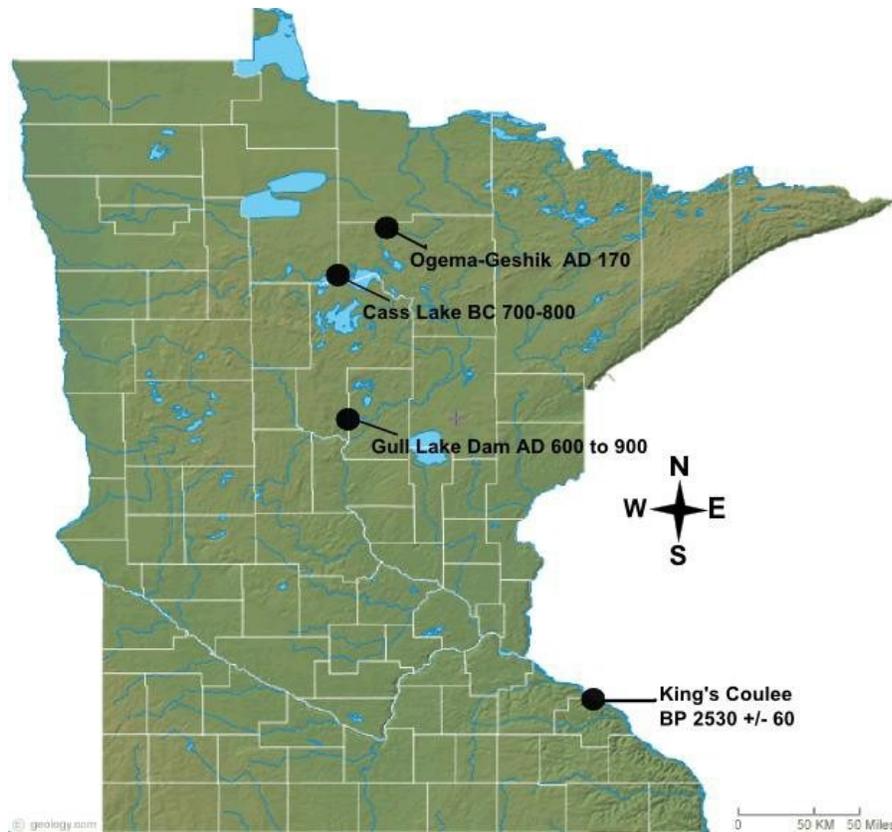


Figure 4.3: Map of Minnesota displaying the Gull Lake Dam site, King Coulee, Ogema-Geshik, and Cass Lake (Hohman-Caine and Goltz 1995; Perkl 1998; Thompson et al. 1994). Base map from <http://www.geology.com>.

In Northern Minnesota sites, the main morphological trait differentiating Brainerd from other ceramic wares is horizontally corded or net-marked surfaces (Arzigian 2008; Thompson et al. 1995). Vessel interiors are plain and only sometimes exhibit discontinuous net impressions (Hohman-Caine and Goltz 1995). Horizontally corded Brainerd ware reveals external surfaces impressed with fine cords in a z-twist pattern, applied obliquely or horizontally to the rim (Anfinson 1979; Hohman-Caine and Goltz 1995). Net-impressed Brainerd ware exhibits net dragging, causing exterior net impressions and intentional smoothing impressions to occur (Figure 4.4). Brainerd vessels, resemble Laurel and Malmo vessels, and tend

to have minimal neck constriction with conoidal body forms, and vertical rims (Arzigian 2008; Thomas 1996).



Figure 4.4: Brainerd net-impressed sherd from the Windy Bead site.

4.3.1 MIDDLE WOODLAND CHRONOLOGICAL ISSUES

There is considerable debate regarding the age of Brainerd Ware pottery in Northern Minnesota (Thompson et al. 1995). Much of this debate surrounds a set of surprisingly early dates obtained on food residue from Brainerd ceramics, charcoal and bone. These early dates suggest that while Brainerd producers existed during the Middle Woodland Period (Personal Communication with Taylor-Hollings, University of Alberta, 2014), the early dates suggest Brainerd also dates as early as the Late Archaic to Early Woodland Periods (Hohman-Caine and Goltz 1995; Hohman-Caine et al. 2012). Most of the controversial AMS dates have been collected from organic residue adhering to Brainerd ware, leading to the possibility that they are too old due to contamination from old carbon (Hohman-Caine and Goltz 1995). Table 3 provides an overview of Brainerd ware dating and the changes

that occurred from the 1950s when Brainerd ware was classified as Late Woodland to the 1990s, when Brainerd ware was reclassified as Late Archaic.

Table 3: Brainerd ware dates across Northern Minnesota (Hohman-Caine et al. 2012).

Sources	Date	Sources
Gull Lake Dam and Headwaters Reservoir	Late Woodland	Wilford (1955) and Evans (1961)
Relationship between Brainerd and Laurel ware at McKinstry and Lockport sites. Brainerd ware also underlies Blackduck and Sandy Lake pottery at several locations.	Middle Woodland	Lugenbeal (1978) and Thompson et al. (1995)
“Stratigraphic associations with late Middle Woodland St. Croix Stamped ceramics at the Gull Lake Dam site.”	AD 600 to 800	Anfinson (1979)
18 dates, 16 of which were radiocarbon dates.	1600 BC to 400 AD	Hohman-Caine and Goltz (1995)

One factor for these earlier dates may be the freshwater reservoir effect (FRE), which is defined as the introduction of old carbon into archaeological materials causing offset dates (Arzigian 2008; Hamilton et al. 2011; Roper 2013). The FRE is similar to the marine reservoir effect, which occurs when dissolved minerals or hard water affects $\delta^{14}\text{C}$ values (Fischer and Heinemeier 2003). The marine reservoir effect contributes to the offsetting of dates on marine materials, as well as on bone collagen from populations that consumed large amounts of marine resources

(Yoneda et al. 2002). Unlike the marine reservoir effect, the FRE has not conclusively proven to contribute to offset AMS dates on organic residue at inland sites (Fischer and Heinemeier 2003). Until solid evidence comes forth and unless the dates are significantly offset, it is possible that these earlier dates are correct (Hart et al. 2013; Hart and Lovis 2014).

For example, Hohman-Caine and Goltz (1995) analyzed 18 radiometric dates gathered from organic residue on Brainerd ceramics or associated contexts at nine sites. These dates expand the time range of Brainerd ware well outside of the accepted Middle Woodland range of 0 BC to 500 AD. Most of the dates Hohman-Caine and Goltz (1995) collected are from ceramics and charcoal from hearths. Direct dates deriving from cooking residue on vessels are more beneficial since they directly relate to the use of the pottery in food preparation, while the wood charcoal dates rely upon indirect associations of wood burning in hearths with pottery that may or may not be directly linked stratigraphically to the pottery production and use (Hart et al. 2013). In addition, wood charcoal is less secure than organic residue because of the risk of contamination from modern root penetration of the charcoal, or from bioturbation processes that might result in mix carbon from unrelated sources into the sample. This is a real possibility in light of the taphonomic complexity of deposition, generally poor stratigraphy and chronic forest fires in the Mississippi Headwaters region. Another consideration when indirect dating archaeological deposits using charcoal from hearths is that the fuel wood might derive from old trees that might predate the human occupation by several hundred years (Hohman-Caine and Goltz 1995). For these reasons, Hohman-Caine and

Goltz (1995) accept the dates from ceramic residue and reject the wood charcoal dates, which would mean that Brainerd ware is the earliest ceramic ware in the upper Great Lakes dating from 1600 BC to 400 AD (Arzigian 2008; Hohman-Caine and Goltz 1995; Thomas 1996).

Hohman-Caine et al. (2012) conducted a large study of Brainerd ware chronology using AMS and OSL (Optically Stimulated Luminescence) dates. Of the 81 ceramic, bone and charcoal samples, only 51 dates are deemed acceptable because of possible contamination in the thin, disturbed, sediments of Northcentral Minnesota. Additionally, perhaps caused by the FRE, the dates from some of the ceramic samples might be artificially too old for pottery production in the region. Residue dates that are significantly early for the cultural assemblage also have more negatively or less positive $^{13}\text{C}/^{12}\text{C}$ isotope ratios, suggesting a connection between offset dates and more negative isotope ratios. The issues with Brainerd ware are that the early dates may be contaminated from a number of sources (Hohman-Caine et al. 2012). As more studies are conducted on the FRE and ways to adjust for FRE contamination are developed, researchers will be able to adjust the early Brainerd dates and provide a more accurate start for Brainerd production in Minnesota (Hohman-Caine et al. 2012; Roper 2014). From the eight acceptable OSL dates, 39 acceptable ceramic residue dates, and projectile point morphology, Hohman-Caine et al. (2012) situate Brainerd ware within the Early Woodland, beginning at 2750 B.P. and ending at 1700 B.P.

A study of ^{14}C ages from ceramic residue by Roper (2013) finds age offsets between AMS dates on carbonized food residue and charcoal. This recent study

attempts to address offset AMS dates, such as the ones encountered by Hohman-Caine and Goltz (1995). Possible causes for these offset dates could include the FRE, contamination from shell-tempered sherds, nixtamalizing of corn, organic matter in vessel fabric, fish consumption, vessel temper, and the use of hardwater for cooking (Roper 2013). Results from Roper's study show that the introduction of old carbon into residue may be a large factor in offset dates and a major cause of dates that are too early for the cultural assemblage (2013), and could explain the erroneously old dates collected from Brainerd ceramics by Hohman-Caine et al. (2012).

In contrast, while Hart and Lovis (2014) do not dispute the presence of a FRE, or the apparent inaccuracies of AMS residue dates, they do recognize the low validity applied to statistical tests on offset AMS dates from organic residue. Low statistical validity is a result of researchers not considering sample size and conducting tests on low quantities of data. To exemplify studies with low statistical validity, Hart and Lovis (2014) bring into question Roper's (2013) study on offset dates from organic residue and her possible causes, including shell temper in vessels and nixtamalizing corn. Hart and Lovis (2014) contend that shell temper in vessels causing offset AMS dates is an unlikely scenario because CaCO_3 is only 12 percent carbon and the shell quantities exposed to leaching are small, making the ancient carbon concentrations in shell unable to constitute the resulting offset carbon 14 ages of 115 to 442 years. Since Brainerd ware is not shell tempered, any contribution shell temper may have to providing offset dates is nullified.

Hart and Lovis (2014) also reject nixtamalizing of corn to explain anomalously

old dates on residue because of low statistical validity. Nixtamalizing describes the alkaline processing used to produce hominy with lime from shell lime, limestone or wood ash. This is done by heating calcium carbonate (in the form of shell, or limestone) between 600 to 900 degrees Celsius. In order to account for age offsets, there has to be 80 percent carbon from at least a 50-year-old wood, or 40 percent carbon from a 100-year-old wood. Only 0.1 percent to 5 percent lime by maize weight is used in traditional nixtamalization, and only 5 percent to 30 percent carbon is present in wood ash; therefore, the proportions of wood needed to result in significant age offsets are unlikely.

As discussed by Hart and Lovis (2014), evidence of fish consumption as a source of ancient carbon causing offset AMS dates on organic residue has also been rejected because it is considered statistically weak. The carbon content in fish varies by species type and fat content, so in statistically valid offsets there must be large quantities of fish cooked in relation to other foods and/or a high percentage of old carbon in the aquatic system (Hart and Lovis 2014). In effect, simply recovering fish or mollusc remains at archaeological sites does not confirm the presence of the FRE (Hart et al. 2013).

Carbonates from marl deposits, bedrock and calcareous materials are likely the main sources of radiometrically dead carbon resulting in questionably early dates (Arzigian 2008; Hohman-Caine et al. 2012; Hart et al. 2013). Ancient carbon is sequestered in streams and lakes and can enter freshwater systems through groundwater, contributing to the geologic substrate of an area. When calcareous bedrock, soils with calcareous substrata or glacial till begin to weather, the

groundwater becomes contaminated with ancient carbon (Hart et al. 2013). Hohman-Caine et al. (2012) analyzed the nature and extent of geologic formations near Brainerd sites in order to identify if the carbonate content in geologic deposits was causing offset dates. Although surficial glacial drift does cover the study area, the later (i.e. more acceptable) Brainerd dates apply in areas where there are significant surficial carbonate deposits. If carbonate deposits were the cause of offset Brainerd dates, marl deposits, bedrock and calcareous material would have been found near areas of older dates, not younger ones (Hohman-Caine et al. 2012). Although, it is possible that ceramic vessels were not produced near clay sources and the material used to make vessels was located near areas of carbonate deposits and carried into areas of ceramic production.

The paste used to make vessels, as well as boiling hard water in the finished vessel are two additional factors that may introduce old carbon into samples causing offset OSL and AMS dates (Hohman-Caine et al. 2012). Clay sources used to make Brainerd vessels were generally collected near surface deposits that were depleted in carbonates; therefore, the ceramic paste could not include old carbon. Full alkali/acid/alkali pretreatments on Brainerd sherds prior to AMS dating would potentially remove any possibility of old carbon contamination from boiling hard water in the finished vessel. The paste used to make Brainerd ware and boiling water in the finished vessel are unlikely sources of offset OSL and AMS dates (Hohman-Caine et al. 2012).

Hohman-Caine et al. (2012) and Fisher and Heinenmeier (2003) identify that significant indicators of offset dates are found in carbon and nitrogen stable isotope

values present in chemical analysis. Put simply, the isotopic composition of key elements (notably the relative abundance of ^{13}C relative to ^{12}C ($\delta^{13}\text{C}$) or ^{15}N to ^{14}N ($\delta^{15}\text{N}$) reflect different photosynthetic pathways, the difference between terrestrial versus marine foodwebs, or the relative importance of some cultigens. This has implications for radiocarbon dating since elevated values of $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ may indicate food sources that could contribute to offset dates. In contrast, when Hart et al. (2013) reviewed $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ values from the Finger Lakes region in New York and from sites in Greenland, they found that increased consumption of maize at sites in the Finger Lakes region directly correlates to an increase in isotropic ratio or elevated $^{13}\text{C}/^{12}\text{C}$ values (maize is a C4 plant that is more likely to integrate ^{13}C into its structure). Enriched $\delta^{15}\text{N}$ values from modern plants have been found in some Greenland archaeological middens containing marine organisms (^{15}N is found in enriched abundances in marine contexts, and decomposition of marine food wastes allows a higher abundance in terrestrial plants growing on such middens that would normally be expected of terrestrial plants). Elevated N isotopic ratios have also been linked to the enrichment of N15 in soils from organic fertilizers (Hart et al. 2013). As a result, $^{13}\text{C}/^{12}\text{C}$ and $^{15}\text{N}/^{14}\text{N}$ values may be poor indicators of offset dates in some regions because external factors cause increased or decreased values.

Despite numerous studies, no conclusions about the exact cause of offset AMS dates could be made; furthermore, old carbon does not seem to have implicated Brainerd ware dates in Northern Minnesota (Hart and Lovis 2007a and 2007b; Hart et al. 2013; Hohman-Caine et al. 2012; Roper 2013). It is likely that

sample contamination is the result of a number of factors, or that some of the early dates are correct (Hart and Lovis 2014; Roper 2013). Archaeological chronologies tend to be rigid and “law-like,” making it difficult for researchers to challenge established chronologies. There is no dispute that the FRE may be the cause of offset dates, but at issue is how dramatic that offset might be. Until solid evidence comes forth, researchers should entertain the thought of some early dates being correct (Hart et al. 2013; Hart and Lovis 2014).

Laurel Phase (100 BC – AD 1000)

The Laurel phase is associated with some of the earliest and most widespread pottery in the region (Mason 1981; Thomas 1996). Notably, given assumptions about aquatic diets in the Boreal Forest, residue dates on Laurel material should be older than expected, due to the FRE. Wilford was the first scholar to place Laurel material within the broader scope of Minnesota archaeological material (Brandzin-Low 1997). Laurel assemblages extend all the way from Northern Minnesota, to east-central Saskatchewan, Northern Ontario and the southern half of Manitoba (Anfinson 1979; Brandzin-Low 1997; Thomas 1996; Figure 4.5).

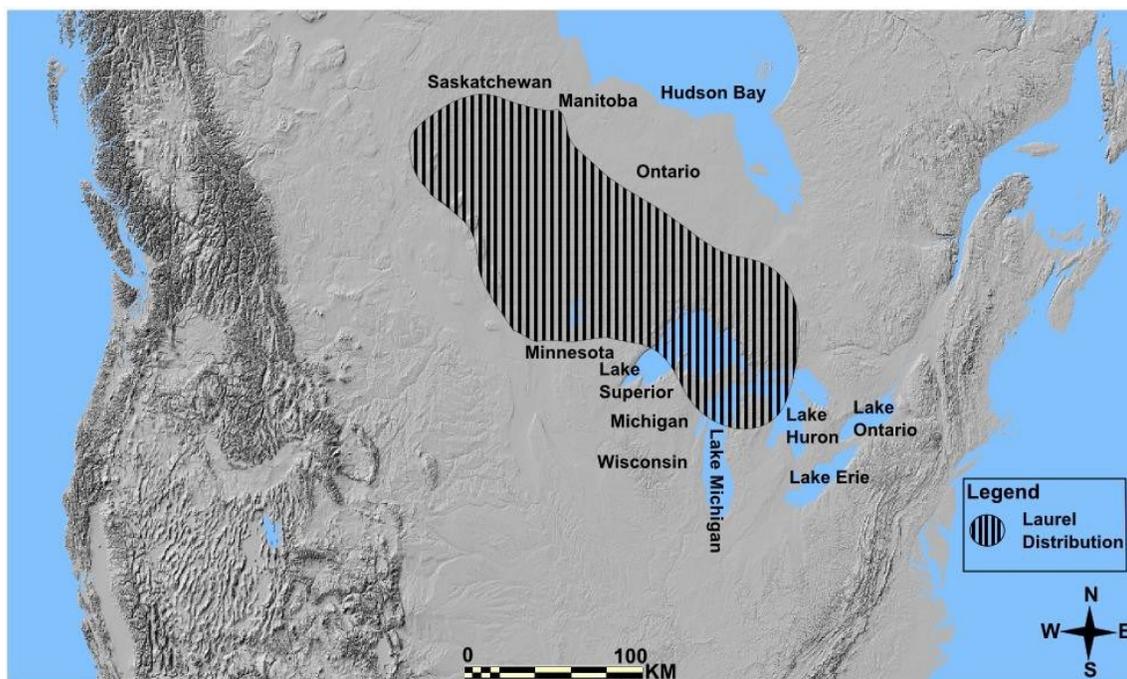


Figure 4.5: Distribution of Laurel assemblages across Eastern North America (Meyer and Hamilton 1994).

Morphological similarities between ceramics and stratigraphic associations show that Laurel ware may have been influenced by Howard Lake, and/or Malmo producing cultures (Anfinson 1979). Laurel ceramics have a similar distribution to Blackduck assemblages, which has some researchers speculating the replacement of Laurel ware with Blackduck ware at the end of the Middle Woodland (Thomas and Mather 1996).

Dr. Andrew C. Lawson and George Bryce first recorded Laurel ware in 1884 at the Minnesota Mounds. The McKinstry Mound 1 was crudely excavated in 1896 by L.H. Kempton and G.G. Hulber (Brandzin-Low 1997; Thomas and Mather 1996). This site was possibly a fishing station, in addition to a locus for mortuary ceremonialism, based on the location of the site and the presence of burial mounds. Lithic production does not seem to have been a major activity at this site, and the

large amount of ceramics suggests a firing area (Thomas and Mather 1996).

Laurel sites are commonly found near water, in the vicinity of rivers, lakes and rapids (Dawson 1981; Janzen 1968). At many of these sites, there is aquatic resource exploitation of wild rice, fish and other wetland plant species (Meyer and Hamilton 1994). Laurel populations utilized seasonal resources, such as fish in the summer and land mammals in the winter (Meyer and Hamilton 1994).

Laurel ware is composed of many different traits and/or decoration styles (Anfinson 1979; Meyer and Hamilton 1994). Vessels are typically coiled when there is an absence of decoration. The rim is straight, everted or inverted slightly, while the lip is flattened and unthickened. There is a slight neck constriction, the shoulders are gently rounded, the base is conoidal and the body is elongate globular (Anfinson 1979; Thomas and Mather 1996). Decoration is usually on the upper lip and neck, and consists of mostly punctates, incising, dentate stamping, bosses, push-pull bands, cordwrapped stick impressions and pseudo-scallop shell stamps (Figure 4.6, Meyer and Hamilton 1994).



Figure 4.6: Laurel rim sherd from the Saga Island site.

The Laurel culture is connected with Hopewellian groups from Ohio and Illinois, as suggested by the presence of burial mound ceremonialism sometimes with exotic grave inclusions in some contexts, most notably northern Minnesota and the boundary waters (Hamilton et al. 2011; Mason 1981; Thomas and Mather 1996). Interactions between Avonlea groups on the Canadian Plains and Laurel groups from the Boreal Forest are also evident from chronological and archaeological evidence (Meyer and Hamilton 1994). Avonlea groundstone celts that are similar to ones found in Laurel sites were recovered at the Miniota site in Manitoba (Landals 1995). The Gravel Pit site in Northern Saskatchewan contained Avonlea and Laurel material in close stratigraphic association, signifying trade and cultural contact (Klimko 1985; Meyer and Walde 2009). The appearance of Avonlea ceramics and artifacts in Laurel components, and vice-versa, supports cultural interactions between these groups, particularly along the forest and plains ecological boundaries

(Meyer and Hamilton 1994; Morgan 1979).

Associated with Laurel ceramics are various lithics made from Yellowstone obsidian, and Knife River Flint and a preponderance of local materials suggesting extra-regional exchange networks (Lugenbeal 1976; Thomas and Mather 1996). The rest of the Laurel artifact assemblage includes: a high ratio of scrapers, antler harpoons, copper tools, ornamental artifacts, notched and stemmed projectile points, and hafted beaver incisors (Stoltman 1973). Burial mounds accompanied by red-ochre and secondary burials are found at some Laurel sites (Brandzin-Low 1997; Janzen 1968; Thomas and Mather 1996).

Evidence of wild rice has been recovered from a number of Laurel sites in Northern Minnesota and Northwestern Ontario, and this local wetland plant was an important component of Laurel diet (Boyd and Surette 2010; Surette 2008; Valppu and Rapp 2000). Charcoal from the Big Rice site in Northern Minnesota was AMS dated to 50 BC and the charcoal was stratigraphically associated with wild rice kernels (*Zizania aquatica*). In the upper levels of the Big Rice site, many ricing features containing mixed ceramics were also recovered (Valppu and Rapp 2000). Surette (2008) identified wild rice phytoliths from organic residue in several Laurel vessels from Northwestern Ontario. Hamilton and Nicholson (2006) suggests that organic remains recovered at Laurel sites indicate a broad hunting and gathering subsistence strategy that relied on seasonal rounds. These seasonal rounds included wild rice gathering in the fall and sturgeon fishing during the spring spawning runs (Thomas and Mather 1996).

Laurel settlement patterns reflect the seasonal rounds made to obtain a wide

array of faunal and floral resources. Bands of 50 to 100 individuals joined larger groups during the spring, and in the fall, families split off and made for winter camps (Hamilton and Meyer 1994; Reid and Rajnovich 1991). Populations were more sedentary than their Archaic ancestors, suggested by the identification of fishing villages, an increase in artifact density at Laurel sites, the appearance of ceramics, and the nature of domestic architecture (Thomas and Mather 1996). At the Ballynacree site north of Lake of the Woods in Northwestern Ontario, there are five Laurel house structures with dates around 1240 AD, although this is rather late for Laurel and the context and association of these dates may be off. One oval lodge measuring three to six meters in width was excavated and this structure would have been able to support 10 to 13 people (Reid and Rajnovich 1985).

The type-site for the Laurel phase is the Smith Mound or Grand Mound. The Smith Mound is a multicomponent habitation and mound site located on the southern bank of the Rainy River (Anfinson 1979). The Smith site contains remains from both Laurel and Blackduck habitation, which are separated into four phases of occupation by Lugenbeal (1976). The Smith site is only one mound site among many in the Rainy River area. A habitation area located close to mound contains faunal remains, lithic tools, and other remains indicating daily site use (Lugenbeal 1976). There is a high degree of seasonality at the site and the faunal assemblage supports fishing during warmer times of the year. Additional artifacts that were found include antler harpoons, cold hammered copper, and cut beaver incisors (Anfinson 1979).

4.4 LATE WOODLAND (500-1750 AD) ARCHAEOLOGICAL COMPLEXES

The period from AD 500 to AD 800 represents the transformation to increased settlements and burial mound ceremonialism. During this transitional shift, ceramics also change shape reflecting Late Woodland varieties, and small triangular projectile points (arrow tips) replace stemmed and notched dart forms (Gibbon 2012b). Starting around AD 700, the Upper Mississippian Oneota tradition expanded and Mississippian groups migrated into the Upper Great Lakes region (Egan-Bruhy 2013). Between AD 600 and AD 800, characteristics of the Late Woodland were widespread across central and northern Minnesota and the Blackduck, Kathio, and Clam River complexes swept across the region (Gibbon 2012b). Around AD 1050, Middle Mississippian impacts were felt in predominantly eastern Minnesota, these impacts included a dependence on maize agriculture (Egan-Bruhy 2013). From AD 1250 to AD 1750 Oneota and Plains village traits dispersed throughout Minnesota and with these traits, the Psinomani Complex moved outwards from central Minnesota, and the Blackduck Complex shifted northwards (Gibbon 2012b).

During the Late Woodland Period, house structures increase in number and size and there appears to be an intensive trading network in the Eastern Woodlands, as supported by exotic cherts (Ferris 1999; Fitting 1969). Some cultural groups inhabiting the Upper Great Lakes relied on subsistence agriculture, which had an impact on population sizes and settlement patterns (Gibbon 2012b; Hamilton et al. 2011). The majority of Late Woodland sites are sedentary villages, local hunting and gathering areas, and fishing stations (Gibbon 2012b). In addition to the cultivation of domesticates, wild plants and various mammal species formed the

subsistence base of Late Woodland populations (Hamilton et al. 2011). Wild rice harvesting became more intensive in Northern Minnesota during this time and towards the end of the Late Woodland, some sites began to represent semi-sedentary lifestyles supported by wild rice harvesting (Gibbon 2012b). Most of the Late Woodland sites are predominantly habitation and mound sites (Arzigian 2008). The number of burial mounds increase, which reflects the Arvilla burial complex expanding across central Minnesota (Gibbon 2012b). The Arvilla burial complex includes circular, or linear mounds, the use of yellow and red ochre, Broad Side Notched and Prairie Side Notched projectiles, small mortuary vessels, disarticulated and flexed secondary burials, and bone and shell ornamental grave goods in deep pits (Gibbon 2012b). Late Woodland burials are generally intrusive into older burial mounds and they are partially flexed in sitting or semi-sitting positions (Arzigian 2008; Hamilton et al. 2011).

A number of bone tools were recovered from Late Woodland sites, including bear canine ornaments, spatulas, awls, fleshers, cut beaver incisors, and unilaterally barbed harpoons. Typical lithic artifacts include side-notched points, triangular points, side scrapers, trapezoidal end scrapers, tubular-shaped drills, thumbnail scrapers, oval and lunate knives (Arzigian 2008; Gibbon 2012a). Notched triangular points correspond to the introduction of the bow and arrow around 600 AD (Blitz 1988). These triangular points probably appeared earlier; however, after 50 BC the bow and arrow was the primary hunting technology (Hamilton et al. 2011). Copper artifacts such as fishhooks, beads and gorges are also unique to the Late Woodland. Ceramics appear to transition away from thick, conoidal shaped vessels

in the Middle Woodland to thin-walled globular and shouldered vessels with constricted necks and outflaring rims at the start of the Late Woodland (Gibbon 2012b; Hamilton et al. 2011; Thomas 1996).

4.5 PALEODIET OF WOODLAND PEOPLES

Woodland subsistence practices changed during the Early, Middle and Late Woodland, reflecting the adoption and cultivation of various floral species. The Three Sisters or maize, beans (*Phaseolus* sp.) and squash (*Cucurbita* sp.) formed an agricultural system that was adopted at various times during the Woodland Period (Fiedel 2001; Lovis et al. 2001; Mt. Pleasant 2006; Staller 2010). The introduction of the Three Sisters restructured the subsistence economies of various groups with an increased reliance on agricultural practices. Native plants were still utilized in addition to the Three Sisters; however, over time their significance dwindled (Fritz 2011; Scarry and Scarry 2005; Syms et al. 2013). Answering when and why certain domesticated crops became important to past cultural groups is complex, because populations had differential access to a variety of plant species through trade and seasonal exploitation over time (Boyd et al. 2014). Traditional subsistence strategies added to the complexity because indigenous flora may have been more important culturally and/or economically than non-native plant resources. Plant selection may be culturally determined when certain plant resources are chosen over others due to taste preferences and/or their importance as traditional food sources. Economic factors also influence food selection since plants have different nutritional values and harvest rates; therefore, the choices are based on resource stability and security. For example, although resources such as

chenopods were present during the Middle and early Late Woodland, populations preferred to rely on wetland fauna and flora (Lovis et al. 2001). They may have used traditional food sources and native plants because they were more accessible and better tasting than weedy annuals. Another example is maize, which was present throughout the Woodland in some areas; however, it was not consumed significantly until the Late Woodland, suggesting food selection and a continued reliance on native species (Lovis et al. 2001).

Domesticated plant species have been adapted genetically from wild progenitors and can become more beneficial over time with larger harvests (Staller 2010; Syms et al. 2013). Evidence of domesticate use at Middle Woodland sites shows a shift from hunting and gathering economies to more horticulture-based strategies, focused on supporting population increases (Arzigian 2008). During the Late Woodland, agricultural practices intensified and some populations in the Eastern Woodlands were fully sedentary (Arzigian 2008).

Lovis et al. (2001) conducted research at the Schultz site in Michigan to try to understand more about the subsistence practices of Woodland peoples. This site was occupied between 600 and 1100 AD, which Lovis et al. (2001) consider a critical point in the transformation to agricultural subsistence. Data from the site show intense harvesting of select plant foods, and a limited use of domesticates. Mirroring the movement to more intensive agricultural practices is a population increase during the Middle Woodland. Once population growth began, groups collected resources with larger harvests, leading to a greater reliance on domesticated species (Lovis et al. 2001).

Agricultural techniques for the procurement of maize, beans, and squash are the product of tradition and/or efficiency. Maize has been grown in the Americas at different times and in various ways (Boyd et al. 2010; Scarry and Scarry 2005). For example, Scarry and Scarry (2005) describe maize cultivation in Late Prehistoric societies of the Southwest United States as varying in complexity because of cultural differences. In some areas, farming was communal and gender specific (Mt. Pleasant 2006). Men would assist the women with clearing the fields, planting and harvesting. In the early spring or late winter, men burned stumps and underbrush to clear fields. Women typically prepared fields, weeded, and did most of the planting and harvesting. Hoes and digging sticks were used to create hills forming ranks, and these ranks were spaced out in meter intervals. With maize, 4 to 10 grains were placed in each hill, while beans and squash were planted between the maize so that the vines could grow on the maize stalks (Fritz 2011; Mt. Pleasant 2006; Scarry and Yarnell 2011; Staller 2010). Maize requires warm soil temperatures and well-drained soils, but since northeastern soils are often wet and cold in May, mound agriculture was used to improve soil drainage and create air flow (Mt. Pleasant 2006). When the crops sprouted, the plants could be thinned, weeded and hoed to promote root development, and when plants ripened, they were harvested primarily by women and prepared for storage. Plants given by each household were stored in community granaries after a harvest. The Cherokee populations followed this general practice, as did the Tunica, Powhatan, Iroquois and Chickasaw, but with slight variations (Mt. Pleasant 2006; Scarry and Scarry 2005).

Maize

Prior to 1492, while maize was unknown in Europe, it was cultivated extensively in the western hemisphere for sustenance, religious, and artistic purposes (Buckler and Stevens 2005; Staller 2010). The earliest evidence of maize is from the Oaxaca Valley in Mexico at the Guila Naquitz Cave dating back 6250 years (Buckler and Stevens 2005; Piperno and Flannery 2001). Maize is a C4 grass and the photosynthetic pathway used by C4 plants creates molecules with four carbon atoms. This higher demand for Carbon results in them being less discriminating against the heavier (and rarer) ^{13}C , therefore proportionately more ^{13}C end up in C4 plants than in C3 plants that are more common in temperate and northern temperate climate zones. Maize is also a member of Gramineae, or the grass family Poaceae (Buckler and Stevens 2005; Staller 2010; Vogel and Van der Merwe 1977).

Varieties of maize can be associated with a specific culture and this is evident when a group would consciously select phylogenetic varieties of maize (Staller 2010). The phylogenetic varieties of maize are a cause of dispute among researchers tracking domestication events in the genus *Zea* (Kato 1984). Teosinte, the wild progenitor of maize, produces 6 to 12 kernels in two rows, while modern maize produces 20 rows of kernels (Buckler and Stevens 2005). Currently, five species of *Zea* are recognized: *Zea nicaraguensis*, *Zea luxurians*, *Zea perennis*, *Zea mays* L., *Zea diploperennis*. Four subspecies divide *Zea mays* L.: *Zea mays* L. ssp. *mays*, *Zea mays* L. ssp. *mexicana*, *Zea mays* L. ssp. *huehuetenangensis*, *Zea mays* L. ssp. *parviglumis* (Buckler and Stevens 2005). *Zea mays* L. ssp. *parviglumis* is the

likely ancestor of maize based on simple sequence repeat markers and isozyme data (Buckler and Stevens 2005; Doebley 1984; Matsuoka et al 2001). Current archaeological discourse supports a single domestication event from *teosinte* (*Z. Mays* ssp. *parviglumis*) with later diversification (Benz 2006; Buckler and Stevens 2005; Piperno et al. 2009; Matsuoka 2001; Staller et al. 2006). This diversification may have occurred in North America as maize adapted quickly to the new environment, allowing for greater productivity and climate tolerance (Figure 4.7, Staller 2010).

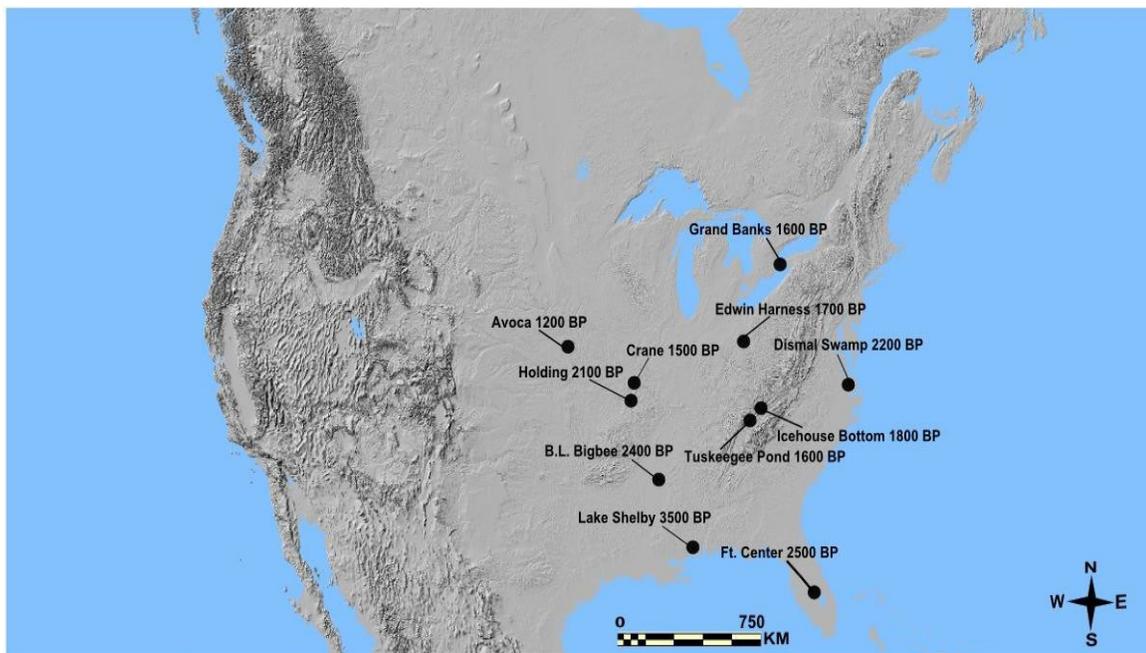


Figure 4.7: Map of Late Archaic and Early Woodland sites with evidence of maize (Fern and Lui 1995).

The single domestication event may have occurred in southern Mexico around 9,000 years ago (Staller et al. 2006; Staller 2010). A phylogenetic approach was taken by Matsuoka (2001) to reconfirm microsatellite data, and results support a single monophyletic lineage in the highlands of Mexico, originating from *Zea mays*

ssp. parviglumis. Afterwards, two discrete expansion events may have led to the spread of maize in some regions of the Southwest United States and South America (Matsuoka 2001). Alternatively, phytolith and starch data from the Central Balsas River Valley in southwestern Mexico place the origins of domesticated maize in the tropical rainforest 8,700 years ago, rather than in the Mexican highlands (Piperno et al. 2009). Although evidence strongly points to a single domestication event, some researchers still support the idea of multiple domestication occurrences (Kato Y 1984; Staller 2010). Until future research can fully interpret the origins of domesticated maize, it will be considered a Mexican cultigen dating to the early 7050 BC (Piperno 2009).

Several studies push back the dates of maize cultivation and consumption in North America (Figures 4.7 & 4.8). Most researchers select either a set of sites, or an individual site to identify patterns of early domesticated plant consumption; the results are confined to the particular study area and do not extend throughout the entire region. Hart et al. (2003) conducted a study on the introduction of certain crops to the northeastern United States, with a focus on *Zea mays*. Three sites from the northern Finger Lakes region (New York State) had archaeological contexts analyzed with phytoliths, carbon isotope, along with AMS radiocarbon dating. The results of Hart et al. (2003) from one site push back the entry of maize and squash in the Finger Lakes region to 100 BC, in contrast to dates from the Middle Woodland Period.

Maize cultivation began sooner than the Late Woodland Period in northwestern Ontario, which is contrary to what the literature suggests about the timing and

emergence of maize in the Boreal Forest. An example is the Martin-Bird site, which is located on Whitefish Lake in north-western Ontario, 100 kilometers southwest of Thunder Bay. A Terminal (or Late) Woodland occupation (600-1400 AD) yielded a copper tool-making cache and a Blackduck burial mound (Dawson 1987). In Boyd et al. (2014), 68 carbonized food residue samples were analyzed from archaeological sites around Whitefish Lake. Eighty-six percent of these samples were obtained from the Martin-Bird site, including a mortuary vessel recovered from the centre of a burial mound. Carbonized food residue adhering to this vessel revealed a wide range of microfossils: the site contained not only maize starch granules and phytoliths, but also starch from domesticated bean and wild rice phytoliths. Starch granules with the characteristics of squash were identified, although these can also be found in a variety of wild plant species. The mortuary vessel and other residues analyzed at Martin-Bird reveal a broader history of maize cultivation in the Boreal Forest than previously thought (Boyd et al. 2014).

Residues containing evidence of maize and beans have also been found in Saskatchewan and Manitoba (Figure 4.8).

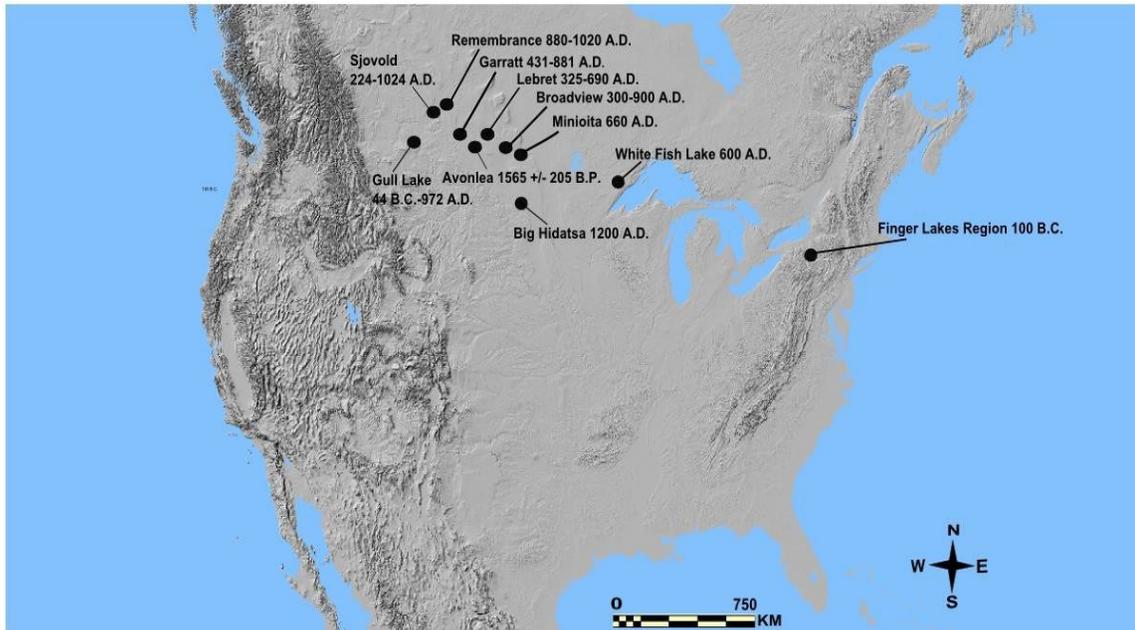


Figure 4.8: Location of sites with early evidence of maize. Maize was utilized sometime within the available dates, and may not date to the beginning of site occupation (Boyd et al 2014; Hart et al. 2003; Lints 2012; Mulholland 1993)

Lints' (2012) study examined eight sites in these two provinces and found that maize and beans were dispersed among Plains inhabitants by 660-710 AD. Various native plant taxa, including wild rice, were also found indicating a wide-ranging plant diet (Lints 2012). In North Dakota, at the Plains Village Big Hidatsa site, Mulholland (1993) identified maize phytoliths from sediment collected in test pits. Big Hidatsa was occupied from the mid-1700's to 1845, and both explorers and ethnographers record corn as a staple food for site occupants (Wilson 1917). The distribution of phytoliths from different parts of maize plants at the Hidatsa site may be the result of husking the cobs in the fields and carrying the ears into the habitation area for drying, threshing and winnowing. Cross-shaped phytoliths are only found in maize husks and the leaves, which is why only small quantities were recovered from

village contexts. The husk and leaves of corn would not have been brought into the village area in large amounts (Mulholland 1993).

Vogel and Van der Merwe (1977) investigated human skeletal evidence from New York State dating to the 11th century AD. These remains revealed a period of change in North America, in which maize was diffusing from Central American sources (Vogel and Van der Merwe 1977). C4 plants, such as maize have more positive C^{13}/C^{12} ratios than other terrestrial plants. Isotopic studies involve measuring the carbon isotope ratios, which determine whether C3 or C4 plants make up most of the diet (Katzenberg et al. 1995). Four sites are analyzed in Vogel and Van der Merwe's (1977) study; two are pre-horticultural and two are horticultural. Results show a noticeable difference in the isotopic ratios between the two groups of sites, confirming the presence and diffusion of maize into North America. Katzenberg et al. (1995) conducted a similar study, looking at the stable nitrogen and carbon isotope content of human skeletons in Southern Ontario from 400 to 1500 AD. Their results revealed a steady increase in $\delta^{13}C$ values from 400 to 1500 AD and a slight decrease in $\delta^{15}N$ values during the early Historic Period. The decrease in $\delta^{15}N$ could also indicate a decline in aquatic foods, perhaps with plant protein from beans. From 600 to 1250 AD, maize consumption gradually increased in Southern Ontario and during this time, the importance of meat protein decreased slightly in the early Historic Period (Katzenberg et al. 1995).

Squash

Domesticated squash is one of the Three Sister crops associated with early agriculture in North America (Staller 2010). Pepo squash (*Cucurbita pepo* ssp.

ovifera) was present in Eastern North America 2490 BC, and is the oldest plant manipulated for human consumption in the Eastern Woodlands (Simon 2009; Smith 2011). *Cucurbita pepo*, along with other squash species, may have been used for protein rich seeds, shamanistic tools, fishing net floats, and/or as containers (Scarry and Yarnell 2011; Simon 2009; Smith 2011). One non-edible type, *Lagenaria* (bottle gourd squash) was used as a container because it is lightweight and strong. *Lagenaria* was either brought to North America around 10,000 B.P by Paleoindian peoples, or it was carried by ocean currents from Asia to America (Smith 2011). *Lagenaria* did not reach Eastern North America until roughly 7,300 B.P (Scarry and Yarnell 2011; Smith 2011). Of the edible varieties, wild *Cucurbita* are bitter and small with protein rich seeds that can be cut and dried, eaten green, roasted, and boiled (Perkl 1998). Domestication processes led to the development of larger, thick-fleshed fruits and sweeter squashes (Perkl 1998). Three different varieties of *Cucurbita* were cultivated and domesticated in various regions of North America. The first variety, *Cucurbita pepo* ssp. *pepo*, includes marrow, zucchini and pumpkin. The next variety is *Cucurbita argyrosperma*, known as cushaw squash. *Cucurbita moschata* includes butternut squash and Kentucky field pumpkin. Pumpkin and cushaw were later additions to the Eastern Woodlands, arriving shortly after 1000 AD (Scarry and Yarnell 2011). Most commonly recovered from archaeological sites in North America, *Cucurbita pepo* var. *ovifera* includes crookneck and acorn squash, and scallop and ornamental gourds (Smith 2011).

Cucurbita pepo cultivation began in Eastern North America throughout the Mississippi corridor and subsequently moved to the north and west (Perkl 1998;

Simon 2009). It was previously thought that squash in the Upper Midwest was the result of trade from Mesoamerican sources; however, current research shows that the eastern United States was a center of independent domestication (Perkl 1998; Simon 2009). Protein allozyme analysis yielded results showing that native squash is most similar to *Cucurbita pepo* subspecies *ovifera*, either *texana*, or *ozarkana*. These two species originate from central Texas and the Ozark Mountains; therefore, trade must have occurred as *Cucurbita pepo* is outside the given range of the wild ancestor, which raises the question of how widely distributed wild squash was and the impact trade had on extending the range (Simon 2009).

The manipulation of squashes and gourds is more apparent during the Late Archaic than the Woodland Period, with *Cucurbita pepo* rinds and seeds recovered at sites across the Eastern Woodlands (Yarnell 1993). Wild cucurbits were present in Maine at 5700 B.P and Central Pennsylvania at 5400 B.P (Fiedel 2001; Simon 2009; 2011). Phylogenetic characteristics are visible from the archaeological record, suggesting plant domestication and selection for favoured traits. In particular, rinds become thickened, seeds are enlarged, rind surfaces are lobed and there is a 2 mm baseline thickness in comparison to the wild progenitors (Yarnell 1993).

Domesticated squash (*Cucurbita pepo*) was found in the form of 21 fragmented and whole uncharred seeds at a multicomponent habitation site in King Coulee, Southeastern Minnesota (Figure 4.3). Accelerator mass spectrometry radiocarbon dates indicate that *Cucurbita pepo* was present during the Late Archaic, 580 BC, and during the Late Woodland (780 AD). This established the earliest evidence of domesticated plants in the Upper Midwest, and pushed Cucurbit cultivation north of

the known Midcontinental range (Perkl 1998). It is likely that the *Cucurbita pepo* found at the King Coulee site in southeastern Minnesota was traded along the Mississippi corridor because evidence for cultivation at the site has not been found as of yet (Perkl 1998).

Domesticated Bean

There were five species of domesticated bean grown by North American Indigenous populations: jack bean (*Canavalia ensiformis*), tepary bean (*Phaseolus acutifolius* var. *latifolius*), common bean (*P. vulgaris*), small lima, or sieva (*P. lunatus*), and scarlet runner bean (*P. coccineus*) (Fritz 2011). Four of the five species originated in Mexico; the fifth species (tepary bean) originated from Mesoamerica or the Sonoran Desert of the Southwest United States (Fritz 2011). *Phaseolus spp.* (a wild species of bean) was dated between 10,600 and 8,500 B.P at Guilá Naquitz Cave in the highlands of Mexico (Piperno 2011). Beans are typically boiled without parching, so they are not charred as much as other cultigens; this makes them difficult to identify at sites because they do not preserve as well (Fritz 2011), a characteristic that affects our understanding of the antiquity of domesticated beans (Boyd et al. 2014).

Of the Three Sister crops in Eastern North America, common beans appear to be the latest arrival, with dates ranging between 1250 and 1300 AD in the central Mississippi Valley. In the Northeastern Woodlands, beans were dated no earlier than 1200 AD (Fritz 2011; Hart et al. 2002). Beans are complimentary to maize, because they are an excellent source of protein and contain amino acids missing in maize (Bernal et al. 2004; Boyd et al. 2014; Hart et al. 2002). Beans also fix

nitrogen in the soil, which increases agricultural soil fertility (Bernal et al. 2004; Fritz 2011; Smith 1992).

Archaeological evidence also suggests that beans were the last of the Three Sister crops to arrive in the Boreal Forest, while maize and squash agriculture took place much earlier. One reason for this may be that traditional trade networks and cultural subsistence practices caused the exclusion of domesticated beans until the Late Woodland (Boyd et al. 2014; Hart and Scarry 1999; Fritz 2011). Additionally, beans are susceptible to spring frost and difficult to cultivate in shorter growing seasons (Boyd et al. 2014; Mt. Pleasant 2006).

Common bean (*P. vulgaris*) remains were AMS dated to 1070 +/- 60 AD in the Northeastern Woodlands, and eight other sites contained pre-1300 AD dates. The date of 1070 +/- 60 AD came from wood charcoal in a feature nearby a storage pit full of charred maize, beans, and squash at the Roundtop site in New York (Hart and Scarry 1999). The eight sites containing pre-AD 1300 dated beans are located in the Susquehanna River Valley, New York, with the exception of one site in Pennsylvania. Hart and Scarry (1999) suggest that the early date at the Roundtop site of 1070 +/-60 AD pushes back the date for intense cultivation of the Three Sister crops in Northeastern North America (Figure 4.9).

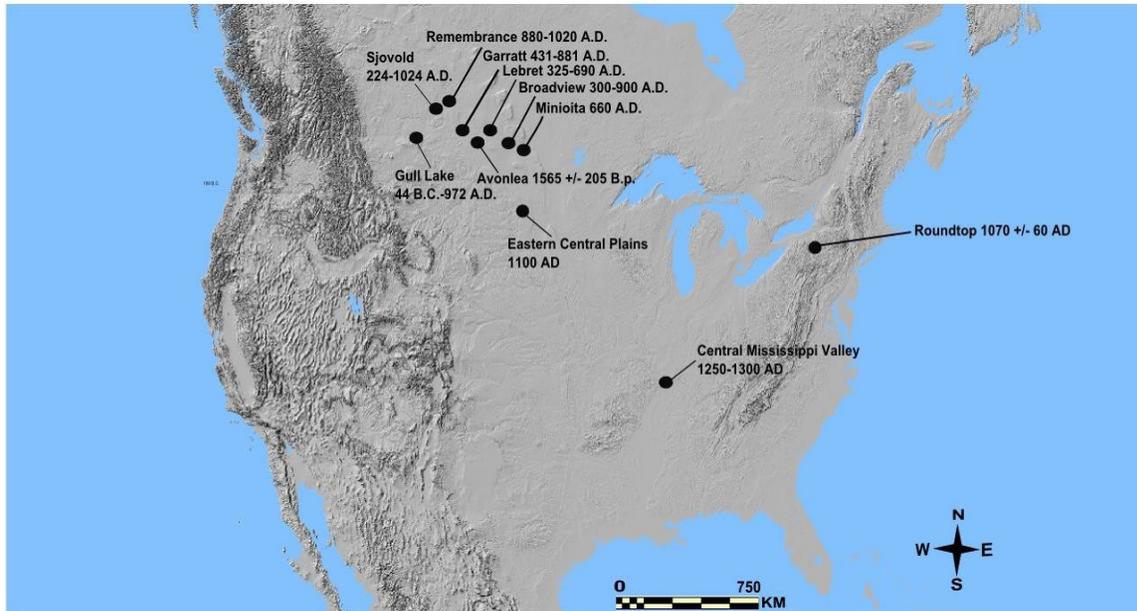


Figure 4.9: Location of sites with domesticated bean (Hart and Scarry 1999; Lints 2012).

Wild Rice

Wild rice (*Zizania sp.*) belongs to the family *Poaceae*, and the tribe *Oryzoidae* and is an aquatic semi-annual grass. There are four different species of wild rice: *Z. aquatica* L., *Z. palustris* L. (Northern USA and Canada), *Z. latifolia* Turcz. (Asia), and *Z. texana* A. S. Hitchc. (Texas) (Archibold et al. 1985; Bunzel et al. 2002). Wild rice is gynaeandrous, meaning that the anthers mature later than the female flowers, ensuring cross-fertilization. Germination begins with temperatures between 4° and 6° degrees Celsius, and growth begins in the spring with a life-cycle of 110 days (Archibold et al. 1985). *Z. aquatica* was originally thought to be the only wild rice consumed by Northern populations; however, *Z. palustris* is also a northerly species so both species may have been utilized at some northerly sites. The chaff portion of wild rice plants produce phytoliths and after the rice is processed, enough chaff may remain with the seeds to account for wild rice phytoliths in pottery residue

(Mulholland 1993).

Paleovegetation changes throughout the Holocene include the introduction and dispersal of wild rice (*Z. sp.*) into Northern Minnesota. Pollen cores from this area suggest that wild rice populations were increasing around 1000 BC in some lakes (Yost et al. 2013). Human populations for over 9,000 years have occupied the lakes and surrounding area of Mille Lacs State Park, North-central Minnesota. Yost et al. (2013) identified the past presence of wild rice (*Zizania* spp L.) in this area by analyzing phytolith content of lacustrine sediment samples. Birks (1976) confirmed the presence of wild rice in central Minnesota with *Zizania* seeds found in detrital copropel. Birks' (1976) study showed that *Z.aquatica* spread in Rice Lake because the lake became more shallow through sediment accumulation, resulting in the replacement of *Najas flexilis* by wild rice. This trend may be seen across other central Minnesota lakes around 10,500 years ago (Birks 1976).

Wild rice (*Z. palustris* L.) phytolith evidence was also found on Brainerd ceramics at the Call Lake I site, dating between 700 and 800 BC, and at the Ogema-Geshik site, dating to 170 AD (Hohman-Caine and Goltz 1995; Thompson et al. 1994). Only the rondel bases were used to determine the presence of wild rice phytoliths in Thompson et al. (1994), so the residues should be re-analyzed for diagnostic indicators of wild rice. Charred wild rice grains were also found in St. Louis County, Minnesota, associated with Laurel pottery (Thompson et al. 1994).

Archaeological data from Middle and Late Woodland material supports the interpretation that wild rice was processed and consumed throughout central Canada (Boyd et al. 2014). Whitefish Lake in Northwestern Ontario was cored by

Boyd et al. (2013), yielding evidence of wild rice (*Zizania* sp.) phytoliths. Wild rice colonized Whitefish Lake by 6,100 cal BP, likely in response to rising lake levels (Boyd et al. 2014). The analysis of 176 sites across the Boreal Forest and north-eastern Plains revealed that some Middle to Late Woodland populations consumed a diet consisting of wild rice, maize, beans, and squash in addition to native plants. Microfossils recovered from sites on the Canadian Plains contained more bean evidence than wild rice, while microfossils extracted from the Boreal Forest samples had less evidence of bean. In the Boreal Forest, wild rice is known to have played an extensive dietary role in the subsistence economies of prehistoric and historic populations. The wild rice microfossils recovered from the Canadian Plains suggests trade with Boreal populations, and/or a wider distribution of the plant (Boyd et al. 2014; Lints 2012). The lower quantities of bean recovered from sites in the Boreal Forest (north-east of the Plains) can be explained by a complementary reliance on maize and wild rice. In the north-eastern Plains, wild rice may have been of lesser importance than bean because wild rice is not easily available, and beans and wild rice contain similar nutrients (Boyd et al 2014). Wild rice becomes less complementary to maize, as opposed to bean, after it is cooked because the protein degrades; therefore, there may have been a greater emphasis on bean throughout time (Boyd et al. 2014; Hart et al. 2007)

Lake Ogechie in Central Minnesota was important to Ojibwe peoples who harvested wild rice from the shallow lake before European contact (Yost et al. 2013). Wild rice is typically harvested with two people per canoe, traversing shallow wild rice stands in lakes (Yost et al. 2013). One individual stands at the stern while the

other stands amidship and, using a cedar knocking stick to bend the wild rice stalks over the canoe bow, with a second stick to thrash the rip kernels from the stalk and into the canoe. The rice is later dried over fires and trampled in a thrashing pit to remove the husks (Wilcox 2007).

Native Plant Species

Prior to the arrival of domesticates in the Great Lakes, many different native plant species were used for medicinal, technological, ritual and subsistence purposes (Marles et al. 2000; Simon 2009; Crawford 2011). Marles et al. (2000) interviewed elders with ethnobotanical knowledge from around the Boreal Forest in Northwestern Ontario. Each elder supplied different accounts of plant use, suggesting that there are local variations in how individuals and bands select, prepare and process plants (Crawford 2011; Marles et al. 2000).

A wide variety of native plants would have been available to Archaic and Woodland Period populations in Northern Minnesota, and approximately 2,000 native plant species were available across the Northeast United States (Crawford 2011). Some of the different plant species available would have included wild fruits and vegetables. Different types of common wild fruit species include various cranberries *Viburnum trilobum* (high-bush cranberries), *Vaccinium vitis-idaea* (mountain cranberries) and *Vaccinium oxycoccos* (bog cranberries). Additional types of berries were consumed: *Fragaria * ananassa* (strawberry), *Prunus pennsylvanica* (pin cherry), *Amelanchier alnifolia* (saskatoons), *Rubus chamaemorus* (cloudberry), *Ribes uva-crispa* (goose-berry), *Shepherdia canadensis* (buffalo berry), *Empetrum nigrum* (crowberry), and *Cyanococcus* (blueberry). Other

varieties of wild fruit species are *Ribes* (currant), *Corylus* (hazelnut), *Rosa rugosa* (rosehip). Some traditional vegetables include tree species such as the inner bark of Pinaceae (Pine), *Betula* (Birch) and *Populus* (Aspen). Additional traditional vegetables include *Typha latifolia* (cattail), Poales (reeds), *Chamerion angustifolium* (fireweed) and *Allium* (wild onion) (Crawford 2011; Smith 2011).

The wide variety of plant foods added nutrients, vitamins, carbohydrates and phytochemicals to traditional diets (Scarry 2003; Marles et al. 2000; Smith 2011), but throughout the Archaic and Woodland Periods, different wild plant species became available through trade and/or access to new resources. The following describes the wide variety of native plants recovered from Early, Middle and Late Archaic contexts. Recovering evidence of plant use at Archaic sites is difficult in Northern Minnesota because of site age and poor preservation. Often, Archaic plant assemblages yield only a few wood fragments or pieces of nutshell. Early Archaic sites from the Eastern Woodlands had better preservation and contained walnut shell, grape seed, hickory shell, chenopod testa, acorn shell, and oak, maple, elm and pine wood assemblage (Johannessen 1993; Simon 2009). Middle Archaic sites in the Eastern Woodlands contained macrobotanical remains similar to those found in the Early Archaic sites, including nutshell, hickory, and acorn (Scarry 2003). A wide variety of fleshy-fruit seeds were recovered, such as blackberry, raspberry, sumac, grape, and persimmon. Tubers, bulbs and roots were also important, although less evident in the archaeological record. Wild bean (*Strophostyles*) and giant ragweed (*Ambrosia trifida*) are commonly found in Middle Archaic sites from more southerly areas of the Eastern Woodlands (Simon 2009). Late Archaic Period

sites in the Northeast United States have better preservation, yielding more macrobotanical remains and information on Archaic plant use (Crawford 2011). Seeds became more common, along with weedy plant species and thick-shelled hickory, although nutshell (black walnut and acorn) and wood still dominate plant assemblages (Crawford 2011). Hogpeanut tubers, American lotus, wetland sedge, rushes and wetland plants such as wild rice were also consumed (Simon 2009). Weedy annuals were exploited, and human movement dispersed the range of plants (Yarnell 1993).

Squash (*Cucurbita pepo*), sunflower (*Helianthus annuus*), chenopodium (*Chenopodium berlandieri*), giant ragweed (*Ambrosia trifida*), knotweed (*Polygonum*), maygrass (*Phalaris caroliniana*), little barley (*Hordeum pusillum*) and sumpweed (*Iva annua*) are weedy annual species included in the Eastern Agricultural Complex, which was spread from the southeastern United States to the Eastern Woodlands (Scarry and Yarnell 2011; Simon 2009; Syms et al. 2013). These native plants made up a large part of Archaic and Woodland diets up until the introduction of the Three Sister crops, when they became incorporated into subsistence economies over the span of the Woodland Period (Scarry and Yarnell 2011). The native chenopod, sunflower, sumpweed or marshelder and maygrass were the most widely consumed weedy annuals (Scarry and Yarnell 2011; Yarnell 1993).

Two other members of the Eastern Agricultural Complex, which arrived later than previously mentioned plant species, are little barley (*Hordeum pusillum*) and erect knotweed (*Polygonum erectum*) (Crawford 2011; Scarry and Yarnell 2011;

Simon 2009). Giant ragweed (*Ambrosia trifida*) and barnyard grass (*Echinochloa muricata*) are also common weedy annuals, although the ranges of these plants were restricted. *Chenopodium* has the largest range out of the weedy annuals and is commonly found along major rivers. Chenopod seeds have convex margins and thick coats. Sumpweed is the second most common weedy annual, and a fully domesticated subspecies. Sunflower seeds have a larger range than sumpweed and, based on AMS dates from the Hayes site in Texas, were domesticated by 2200 BC (Simon 2009). Macrobotanicals found in Brainerd occupation levels at the Roosevelt Lake site yielded possible chenopod seeds, seeds from strawberry, raspberry, and nut shells including hazelnut and acorn (Arzigian 2008). Thompson et al. (1994) also detected chenopod and amaranth starch granules.

Bone, shell and stone hoes have been recovered at a number of sites across the Eastern Woodlands and Canadian Plains (Boyd et al. 2006; Scarry and Yarnell 2011). Hoes would have been used to harvest agricultural crops efficiently, and although chert sickle blades can be used to cut larger bundles of stems, there is not much archaeological evidence to support the use of sickle blades in North America. Squash was most likely handpicked and plants with small heads may have been either beaten or hand stripped allowing the seeds to fall onto cloth or in a basket. Attached pericarps or glumes on oily seeds or smaller grains were removed by parching, threshing and winnowing the plants (Scarry and Yarnell 2011).

The Woodland Period in Northern Minnesota is characterized by changes in settlement patterns, technology and subsistence practices. Settlements tend to become larger towards to the Late Woodland and reflect growing population sizes.

Ceramic technology emerges during the Early Woodland and over the course of the Woodland Period there are a number of stylistic shifts, including the transition from conoidal to globular vessels. Lithic technology changes to reflect hunting strategies and triangular points appear around 600 AD corresponding with the use of the bow and arrow. Subsistence practices changed over the Woodland Period, when populations incorporated non-native cultigens such as the Three Sisters, into diets dependent on wild plants and various mammals. During the Early to Middle Woodland Period, populations maintained a broad-based subsistence strategy that focused on wild rice gathering in the fall and the fishing during the spawning run in the spring. Wild plants and mammals supplied additional nutrients and carbohydrates to Woodland groups inhabiting Northern Minnesota. The introduction of the Three Sisters at different times during the Woodland Period marked an increased reliance on subsistence agriculture, which would have resulted in a localized subsistence strategy. Although native plants and mammals were still important dietary components, the significance of these species dwindled with an increased reliance on the Three Sisters agricultural system.

The timing and extent of the Three Sisters during the Woodland Period leave difficult questions to answer in Northern Minnesota because of poor site preservation and thin, disturbed, stratigraphy. Macrobotanical remains such as plant seeds do not survive well in the acidic soils; therefore, alternative methods are needed for inquiry into the floral subsistence of the Woodland Period. Food residue analysis and the identification of phytoliths, starch granules, and pollen grains can guide interpretations and answer questions about when and where specific plant

species may have been utilized.

5.0 PHYTOLITH AND STARCH ANALYSIS IN ARCHAEOLOGY

5.1 INTRODUCTION

Food residue analysis is a collection of methods that can be used to interpret the paleodiet and subsistence practices of ancient peoples. Plant microfossil analysis is one such method that involves the extraction and microscopic analysis of phytoliths, starch granules, and other remains, from archaeological samples. For the past 30 years, food residue analysis has taken archaeologists from general assumptions about food consumption to facts based on evidence found on microscopic slides (Boyd et al. 2014; Pearsall 1982; Powers 1992). This chapter describes the structure of phytoliths and starch granules, corresponding literature, and reviews current archaeological analyses and applications.

5.2 PHYTOLITHS

Phytoliths develop when plants deposit solid silica within an extracellular or intracellular location after silica is absorbed from groundwater in a soluble state (Piperno 1988; 2006). When the plant dies, the silica microfossils produced by this process are incorporated into sediments and/or soils. A number of factors such as soil composition, water content, taxonomic affinity of the plant, and climatic environment of growth determine how phytoliths develop in plants. Soluble silica (H^4SiO^4) is absorbed by plant roots, and is carried upwards to aerial organs by water-conducting tissue in the transpiration stream. Some silica is manifested in the growing plant as silicon dioxide (SiO^2), filling in the cell walls, lumina, and intercellular spaces (Piperno 2006). Phytoliths are composed of mostly amorphous

(noncrystalline) silicon dioxide (SiO_2) with 4 to 9% water composition. They contain tiny amounts of impurities such as Fe, Mn, P, Cu, organic C, Al, N and Mg. These elements minerals reside within the cytoplasm of living cells and when the cell fills with silica, they remain enclosed within the phytolith. Biogenic silica from plants has a specific gravity of 1.5 to 2.3 and is optically isotropic, ranging in refractive index from 1.41 to 1.47. Colours range from light brown to opaque to colourless under transmitted light. Carbon is sometimes visible inside phytoliths from trapped cellular contents and dark spherical cavities, and when no carbon is visible, phytoliths may contain cellular cytoplasmic matter. Organic and burnt phytoliths have a lower specific gravity than other phytoliths and an altered refractive index (Piperno 2006).

Phytoliths were first analyzed and recognized in Europe, where early accounts originated from Germany and England (Piperno 2006; Powers 1992). Generally, European applications of phytolith analysis changed from simple plant identification to paleoeconomic and paleoenvironmental reconstruction (Lu et al. 2006; Piperno 1988). One of the first accounts of phytolith observation was made by Christian Gottfried Ehrenberg, who wrote about microscopic flora, which he termed “phytolitharia” or silicified plant material. Even earlier than this, Struve submitted the first publication of phytolith research to the University of Berlin in 1835. From the 1960s to the 1980s, publications such as those in the *Annals of Botany* dealt specifically with cell silification and drew more attention to the topic. Microfossil research during the late nineties focused on various grass species, phytoliths originating from different plant parts, and morphological differences (Powers 1992). These examples of botanical research laid the groundwork for future archaeologists

interested in subsistence strategies and food economies.

Intense interest in phytolith research began around 1960, with one of the first projects taking place in Peru (Pearsall 1982). Since the 1960s, the identification, classification, and processing of phytoliths has developed allowing for more reliability and validity in plant identification (Rover 1971; Twiss et al.1969). Currently, researchers are focused on plant identification, the migration/diffusion of plant species, reconstructions of past environments, and limitations. Limitations associated with phytolith analysis include assemblage bias, different counts used by various labs, species identification, classification schemes and the understanding of taphonomic processes (Pearsall 1982; Rovner 1971; Shillito 2011).

There are two debated mechanisms explaining how plants absorb soluble silica, and Piperno (2006) maintained that both mechanisms are in fact correct. These mechanisms involve the active transport of monosilic acid by metabolic processes, and the nonselective flow of monosilic acid from groundwater with other elements in the transpiration stream. With the first described pathway the plant expels energy metabolically during silica absorption, and with the second mechanism, plants do not expel energy. Once the monosilic acid enters the plants' vascular system, a chemical/biological process begins the transformation into silicon dioxide (SiO₂) (Piperno 2006).

Over the past three decades, research has established that phytoliths are identifiable taxonomically and are present in pollen and spore producing plants (Rover 1971). Similar shapes can also be found from plants in the same genera, species and family. Two factors determine how phytoliths are shaped: the first is the

kind of cell accumulating silica and where it is located within the plant; the second refers to incomplete silification of a part of the lumen resulting in nonconforming cell shapes. Classification systems and phytolith terminology were not well standardized in the past; however, current research is addressing these limitations. Phytoliths can be identified by specific characteristics including dimensions, size, shape, orientation of cells, their relation to surrounding structures, ornamentation of walls and thickness of cell walls (Brown 1984; Rover 1971). The Society of Phytolith Researchers established a standard code for phytolith identification, which includes using anatomical origins, descriptors for surface and shape attributes (Piperno 2006). To summarize Piperno (2006), the only way researchers will be able to confidently identify phytoliths is to develop rigid keys and have a grasp on the regional flora.

Different types of phytoliths have been identified based on certain morphological characteristics. C3 and C4 grass phytoliths comprise a number of grass species, which inhabit different climatic regions and which take two forms of phytoliths. C3 species are concentrated in regions of high latitudes and elevations. Pooid phytoliths, the most common type of C3 grass phytoliths, are crescent, elliptical, circular or oblong. C4 species include Chloridoid and panicoid phytoliths, Chloridoid phytoliths are saddle-shaped and present in arid to semi-arid warm regions with low soil moisture, while panicoid phytoliths comprise dumbbells and crosses that are found in warm, tropical to sub-tropical environments (Twiss 1992). Some of the major phytolith types found in the grass family (Poaceae) are short cell phytoliths or silica bodies, which can be divided into three subfamilies native to the

Great Plains: namely, bilobates/crosses (subfamily: Panicoideae), saddles (Chloridoideae), and circular/oval/rectangular forms (Pooideae) (Bozarth 1992; Piperno 2006; Twiss et al. 1969). Ehrhartoideae forms are located in forested and aquatic regions, and Panicoideae forms can be recovered from tall tropic grasses and prairie grasses in the United States. Bambusoideae grasses reside in forested areas containing Centothecoideae, Danthonioideae, Aristidoideae and Arundinoideae (including *Phragmites* and *Arundo*). Three subfamilies found in forest understories include Pharoideae, Anomochlooideae and Puelioideae (Piperno 2006).

Although it is possible to discern phytolith subfamilies, some overlap exists between taxonomic levels, caused when plants produce morphologically different phytoliths (Brown 1984; Piperno 2006). Glumes, lemmas, and palaeas contain phytoliths different from ones found in the sheaths, leaves, floral bracts and culms of plants. Asteriform and dendriform are two shapes found specifically in the bracts of plants. Gymnosperms contain less silica and phytoliths from needles such as *Pinus* spp., *Picea*, *Tsuga* and *Pseudotsuga*. Basal Angiosperms produce phytoliths of various sizes, and include species such as, *Amborellaceae* and water lilies. Monocotyledons diverged from basal angiosperms and are mostly aquatic (Piperno 2006).

Seeds and fruits from nongrass monocotyledons, eudicots and basal angiosperms produce many phytoliths identifiable at the genus level. Certain families produce distinctive seed and fruit phytoliths such as Cucurbitaceae, Musaceae, Ulmaceae, Euphorbiaceae, Cyperaceae, Burseraceae, Moraceae and

Marantaceae (Bozarth 1987; 1992; Piperno 2006). Phytoliths can also be found in wood, specifically in xylem vessels and/or parenchyma cells. These form three different phytoliths, including irregularly shaped particles covered with tiny protuberances, aggregate grains, and spherical grains with small projections (*Protium panamense*) (Bozarth 1992; Piperno 2006).

Piperno (2006) describes three less common phytoliths as Mesophyll phytoliths, vascular tissue and epidermal phytoliths. Mesophyll phytoliths are found in the ground tissue of leaves under the epidermis; the two types of tissue silicified include spongy Mesophyll and palisade Mesophyll. Vascular tissue is composed of the phloem and xylem, the area of the plant dealing with food storage and water conduction. Epidermal phytoliths form a continuous layer of plant surfaces, and are commonly silicified and are either sinuate or wavy. Epidermal seed and fruit phytoliths are planar with sinuous outlines of 4 to 8 sides. Uncommon types of phytoliths are less useful because they are not taxonomically relevant (Bozarth 1987; Piperno 2006).

Multiplicity and redundancy in the context of phytolith production in plants can cause misinterpretations of climatic data. Twiss (1992) provides an example of how *Aristida* and *Zea* produce both Panicoid and Poid phytoliths. Although one type of phytolith may be abundant in one subfamily, it can occur in taxa throughout different subfamilies. Twiss (1992) emphasizes that phytoliths are an indicator of the grass kind and in order to identify specific taxa, different parts of preserved plants are needed. C3 and C4 plants can grow in the same environment and this is common in areas where temperatures fluctuate with a cool, moist season and a warm, dry

season (Twiss 1992).

5.3 STARCH GRANULES

Starch granules have been recovered from a variety of well to poorly preserved contexts with some associated deposits two million years old. Starch can be recovered from archaeological food residues, dental calculus, charred tubers, preserved bread, stone tools, coprolites and soils, among other contexts. In Roman times, starch was first recorded; however, it is only within the past 20 years that it has been studied as a form of dietary evidence (Haslam 2006; Loy 1994; Torrence and Barton 2006). Plant domestication, mobility patterns, diet, artifact function, and vegetation histories are some of the different areas of starch research (Torrence and Barton 2006).

Different parts of plants produce starch as a form of energy storage. Starch production begins when photosynthesis converts sunlight into energy within the chloroplasts of plants, prompting a few reactions that split water into hydrogen and oxygen. The initial reaction recombines free hydrogen with absorbed carbon dioxide forming glucose. Glucose is the base on which complex carbohydrates (cellulose and starch), proteins and fats form. Some glucose is transported from chloroplasts to specialized organs of plants, where it is converted within amyloplasts to storage or transitory starch. Starch begins to form at the hilum where layers are laid down on top of each other each day with normal growing conditions (Gott et al. 2006; Haslam 2004). When the plant requires energy, the starch is converted to sugar and is transferred to the necessary areas. Temporary, transient or transitory starch is formed in the chloroplast when photosynthesis rates are high (Haslam 2004).

Transient starch is converted to sugar during the night and moved to necessary areas of the plant or transformed into storage starch in the amyloplasts.

Donald Ugent pioneered systematic starch analysis in the 1980s when he recognized various starch types with diagnostic characteristics. He also experimented with chromatography, staining, spectrophotometry and microscopy. Unlike phytolith analysis, starch has been thoroughly studied by botanists (Torrence and Barton 2006). Critical studies by Loy et al. (1992), Liu et al. (2013), Piperno et al. (2004) and Pearsall et al. (2004) focused on individual granules derived from stone tool residues.

Starch consists of alternating amorphous and crystalline shells of hard and soft material about 120 to 400 nm thick. Towards the granule surface, some starches have higher concentrations of amylase. Amylose chain and amylopectin clusters protrude from the center of a granule as the foundation for the next growth layer (Gott et al. 2006). Lipids, proteins, and phosphorous are sometimes found in trace amounts either in the interior or on the surface of starch and these components impact starch characteristics (Gott et al. 2006). Glucose units of amylose and amylopectin molecules are essentially a ring of six carbon atoms numbered one to six. With amylose, the first and fourth carbon atoms of each glucose unit are linked together. In amylopectin, while most of the glucose units are joined by the first and fourth carbon atoms, four to six percent of the glucose units have a link with the sixth carbon atom and form a separate branch point. Amylose is composed of 1,500 glucose units, while Amylopectin is composed of 600,000 glucose units. Gelatinization and the starch granules' reaction to staining are dependent on the

ratio of amylopectin to amylose, which is controlled by environmental and genetic factors. Amylose content of 20 to 30 percent can be found in most economic plants (Gott et al. 2006).

Starch grain morphology is largely dependent on the plant's genetic composition, while modifications can be made to grain shape and size by external and internal factors (Gott et al. 2006). Similar to phytoliths, different parts of a plant will produce morphologically distinct starch granules. Starch granules have a central hilum, which may contain non-starch amyloplast material and fissures radiating from the hilum (Henry et al. 2009). Large starch granules have visible lamellae or growth layers, and open hila or vacuoles are evident with some plant species. Equatorial grooves are present in barley, wheat and rye, while pores cover starch surfaces in the subfamily Panicoideae (e.g., millet, corn, and sorghum) (Gott et al 2006; Haslam 2004, 2006).

The shape classes that assist with identifying starch granules are spherical, oval, rounded, kidney-shaped, irregular, disc, elongated and polyhedral. Often, multiple shapes are produced within a single plant. For example, the Triticeae (wheat, barley and rye) exhibit two forms of granules: small spherical ones or large disc-shaped lenticular ones. Starch sizes can be anywhere from one to 100 microns, with some rare exceptions. High water concentrations in the granules can account for an increase in size and the location from which the starch originates in the plant. Starch originating from the center of the plant will be elongated, while starch found near the periphery of the stem will be small and round. Granule age also impacts size: older granules are typically larger than younger granules of the

same species from the same storage site. Depending on the environment, a more stressed organism with lower nutritional status will yield fewer and smaller starch granules because of limited carbohydrate intake (Gott et al. 2006).

Starch granules have been classified into three categories based on the way they form in the amyloplast: simple, compound and semi-compound (Gott et al. 2006). Simple granules have only one component in the amyloplast, while compound granules contain subgranules or granula that form within a single amyloplast and have a polarizing cross. Sweet potato, rice, oats, other edible grasses, cassava and quinoa are all examples of plants with compound granules (Figure 5.1). Semi-compound granules start as compound, but the separate subgranules fuse together forming a layer of amorphous starch. Semi-compound granules from *Amaranthus retroflexus* (American pigweed) and *Scilla ovatifolia* (Hyacinthaceae) bulbs exhibit two or more hila, and one exterior surface (Gott et al. 2006).

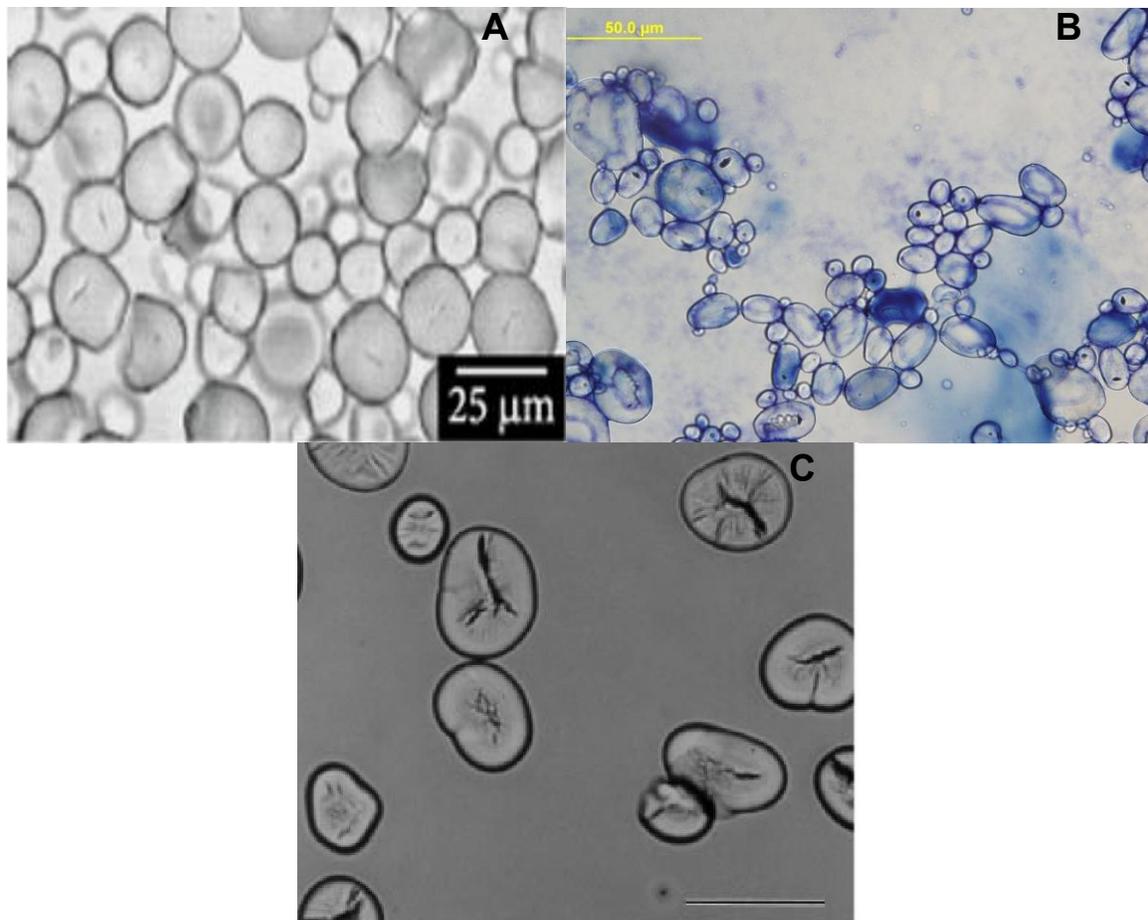


Figure 5.1: (A) Cassava starch, an example of a compound starch type (Rocha et al. 2010). (B) Mouldy potato starch granules exhibiting staining. (C) Gelatinized azuki bean cv. Erimo starch granules (Hsieh et al. 2000).

The shoots, stems, roots, leaves, fruit and even pollen grains of plants contain starch. Reserve starch is concentrated in storage organs such as seeds, fruits, tubers and roots; therefore, the identification of reserve starch provides evidence of what plant parts were exploited in the past. Nonedible plant parts also contain minor amounts of starch and these may appear on tools for example, in fibres used to make rope. Storage starch is found in leaf tissues, and this in addition to transient starch could isolate places where leaves are used for bedding and/or roofs at archaeological sites (Gott et al. 2006).

5.3.1 STAINING

Depending on the type of stain, staining is used to change starch color and help identify damaged starch granules (Figure 5.1, Gott et al. 2006; Haslam 2004; Lamb and Loy 2005). The amylopectin-amylase ratio causes a colour change reaction when iodine staining is applied to transform starch to red-purple colour. Gott et al. (2006) found that iodine-staining starch is a useful identification tool, with plants such as potato with a high amount of amylose turn a purple color, while starch from maize with high amount of amylopectin will stain red. Lints (2012) tested both Trypan Blue and Congo Red stains, discovering that both agents were equally effective identifiers of damaged starch grains.

5.3.2 BIREFRINGENCE

Birefringence refers to measured differences in the refractive index of optically isotropic solids, which is apparent when viewed under cross-polarized light (Olympus Microscopy Resource Center, 2012). Starch appears white and illuminated contrasting the surrounding darker microfossils, and this contrast is reduced by the starch extraction process (Barton and Fullagar 2006). Birefringence occurs because the semicrystalline nature of starch and a highly ordered molecular structure causes polarised light to travel at different velocities through the granules. Chemical processes can cause the lamellae to also appear less marked and the hilum may have centrally developed cracks. These cracks have to be differentiated from fissures radiating from the hilum, because this can lead to misidentification (Gott et al. 2006). Birefringence also allows for the detection of an extinction cross or Maltese cross in the starch granule centre. The arms of the cross rotate when

the polariser is turned, and arm length and angle vary between plant species (Gott et al. 2006). Birefringence allows for precise identification due to the contrasting pattern and illuminated aspects of the starch (Barton and Fullagar 2006).

5.3.3 GELATINIZATION

Damage to starch granules during cooking can result in gelatinization. Starch is insoluble, but permeable to water and at low temperatures with water contact, starch begins to swell in a reversible process. With the application of heat, swelling remains reversible until the point of gelatinization when the hydrogen bonds holding together the linear molecular chains of amylopectin and amylose are disrupted. Salts, alkali and acids can also cause gelatinization at room temperature. Starches with greater amounts of amylose generally have a raised temperature of gelatinization, meaning that more heat is needed to gelatinize the granules.

Gelatinization causes the loss of native structure and morphology, and once granules are gelatinized fully they become extremely difficult to identify microscopically and classify taxonomically (Figure 5.1, Haslam 2004; Zarrillo et al. 2008). Baked starch granules will have sharp crosses, strong birefringence, and intact forms compared to boiled and/or steamed starch granules (Crowther 2012). How starch granules gelatinize and change shape depends on the species of interest; for example, cereal granules will swell but not burst while those of potatoes will swell to a large size and then burst (Gott et al. 2006). Although it is difficult to identify gelatinized starch, finding cooked starch is evidence of plant preparation processes.

5.4 LIMITATIONS

Phytolith and starch analyses are recent applications to the archaeological discipline and although many studies have shown the value of applying these methods, some limitations have surfaced over the years. This can include: deterioration of grains due to mechanical wear, taphonomic processes, poor preservation, contamination of archaeological samples by modern starch, and unidentified species.

Mechanical Wear

Microfossil damage can result in misidentification because changes can alter the diagnostic features of microfossils, either rendering them completely unidentifiable, or altering their appearance to resemble starch from another plant species (Zarrillo et al. 2008). The interaction with enzymatic saliva caused by chewing has a significant effect on starch breakdown. Some forms of starch, which are found in coprolites, are able to avoid being broken down by amylase in stomach acid and the mouth (Torrence 2006). Milling, pounding or the grinding of plant material with groundstones can also cause mechanical wear. The harder the plant material is processed, the more likely microfossil damage will occur (Babot 2003). Under cross-polarized light, this wear takes the shape of tears, a warped extinction cross and/or a loss of birefringence. Under both plain-polarized light and cross-polarized light, the starch granules may appear collapsed, incomplete, truncated, burst, and/or joined to surrounding plant material (Babot 2003). When maize starch exhibits signs of grinding, the extinction cross of 90° will appear to have shifted, and the microfossil may be covered in fissures or holes (Figure 7.10). Damage can be

identified by applying Typan Blue to samples, which penetrates small cracks and darkens areas of damage (Barton 2007; Haslam 2004; Lints 2012).

Taphonomic Processes

Taphonomy, in this context, refers to the chemical and physical processes influencing starch and phytolith preservation, degradation and postdepositional movement (Haslam 2006). The different aspects of taphonomy impacting phytolith and starch analysis include effects of bacteria, fungi, enzymes, soil movement and mechanical wear.

Starch is able to survive in a variety of environments and has been recovered from ceramic sherds, stone tools, dental calculus, sediment and soil (Boyd et al. 2014; Hardy et al. 2009). Although this may be so, many factors can implement the breakdown of starch. Fungal and microbial enzymes are the main sources of starch degradation (Haslam 2004; Torrence 2006).

Fungi and bacteria affect starch because like other soil microorganisms they breakdown soil components over time. Fungi can grow hyphae, which extends microhabitats where enzymes are secreted to decompose organic matter. Bacteria growing in clusters on surfaces can occupy a few cubic millimeters of soil and are dependent on root growth, tillage for movement and rainfall (Haslam 2004). Haslam (2004) notes that starch rapidly degrades in soil, due to fungal, microbial, and enzyme activity close to the surface of soils. Haslam (2004) describes enzymes as necessary components to the fungal and bacterial decomposition of starch, and the biological catalysts responsible for lowering the activation energy required for chemical reactions. Amylases are the enzymes related to starch breakdown, and

these enzymes are derived from microbial or animal cells, bacteria, fungal spores, enzymes enclosed in dead cells and active plant matter. Depending on the type of soil, different enzymes will be present acting to breakdown starch (Haslam 2004).

The soil pH, oxygen content, temperature, and physical dispersal are the main physical and chemical processes behind the degradation and movement of starch in soils (Haslam 2004; Torrence 2006). Preferential decay of starch in sediments, as opposed to protected surfaces and niches on archaeological material may also be another factor in the rapid decay of starch in soil (Haslam 2004). Only recently have studies attempted to discern the degree of starch movement in soil over time. The recent popularity of microfossil analysis has its detractors with researchers such as Haslam (2004), claiming issues of possible contamination due to starch movement in soil.

Similar to starch, phytoliths can be deposited into soils and sediments in a number of ways. Piperno (2006) first addresses plant decomposition, which deposits phytoliths in the upper soil horizons (A horizon). Fire, wind, human transport, animal droppings and various other scenarios also deposit phytoliths in soil. Conducting residue analysis on the surrounding sediment within the matrix is one way to avoid contamination and test for movement in soil (Piperno 2006).

Jenkins (2009) describes aeolian and alluvial forces, which act to pit, and/or corrode single-celled forms and breakdown multi-celled forms. Phytoliths post-burial are susceptible to soil conditions, and do not survive as well in alkaline conditions or when pH is above nine. It has also been shown that illuviation or the downward movement of phytoliths in soil is possible from the A to B horizon depending on soil

characteristics (Jenkins 2009).

Preservation

The analysis of microfossils is valuable because phytoliths and starch granules can survive in areas of poor preservation such as the neotropics, or boreal forest (Boyd and Surette 2010; Zarrillo et al. 2008). Despite the exceptional preservation of these microfossils, the phytolith and starch granules are preserved in different ways that are not fully understood as of yet. Starch granules can collect on artifacts and microorganisms, while the build-up of sediment or plaque on residue preserves and protects the microfossils from decay (Torrence 2006). Plaque, for example, traps starch before it can be dissolved by amylase in dental calculus (Hardy et al. 2009). In addition, starch has a microcrystalline structure that serves to protect it from degradative elements (Torrence 2006).

Phytoliths survive in environments of poor preservation because they are inorganic and very durable. Phytoliths have a tendency to preserve better in dry, terrestrial, arid soils, whereas pollen grains and other organic microfossils do not (Boyd 2005). Piperno (1988) describes phytoliths as robust and capable of being preserved in adverse conditions, whereas other microremains may degrade from dissolving or burning. Phytoliths are composed of calcium oxalate or silica so they can survive conditions that would destroy organics (Piperno 2006). Despite the excellent preservation in some locations, taphonomic processes described above affect starch and phytolith survival and identification (Jenkins 2009). Preservation of phytoliths and starch granules factors in how well the remains can be identified. Another factor affecting identification is contamination, which can occur in the field

or lab.

5.5 CASE STUDIES

Despite the limitations, current research applying phytolith and starch granule analyses to archaeological contexts demonstrates the value of using this methodology. This is especially the case in areas of poor preservation like the boreal forest (Boyd et al 2014). Various studies use alternate methods for extracting plant microfossils; however, they achieve the same objective of identifying new aspects of paleodiet.

Using a variety of proxies including phytolith and starch granules, Boyd et al. (2008) were able to interpret the northern geographic limits of maize consumption in North America. This particular study looked at maize phytoliths and starch granules from ceramic and soil residue. Recovered maize phytoliths includes diagnostic wavy-top rondels with entire bases, which is a unique form found in *Zea mays* and produced in the cob portion of maize. Starch granules are positively identified as maize if they are 20 μm in size, have a polygonal to rounded shape, a 90° extinction cross under cross-polarized light, and a linear X or Y shaped central fissure (Boyd et al. 2008). In Boyd et al. (2008), the outlined processing methods calls for 5 to 40 milligrams of carbonized food residue. The residue is digested in 50% HNO_3 for 12 to 24 hours, and repeated washing and centrifuging rid the sample of any remaining acid. After processing the sample and isolating the phytolith and starch granules on microscopic slides, the samples are analyzed using high-powered microscopy. The samples yield evidence of both maize and beans, and results show that maize was widespread in the study area by at least AD 700 (Boyd et al. 2008).

Berman and Pearsall (2008) illustrated the effectiveness of starch analysis to reconstruct a diet consisting of *Zea mays*, *Capsicum* and *Manihot esculenta* in the central Bahamas. Maize, sweet potato, beans, and yautía were identified from starch granules extracted from two ground stones associated with Archaic populations in the Caribbean. In the same study, Berman and Pearsall (2008) also analyzed 28 microliths from the Three Dog site and 15 had evidence of residue. The starch and phytoliths were extracted using the piggyback method described in section 6.3 of chapter six. Results interpreted the paleodiet of Archaic populations and showed how and why these Caribbean inhabitants used domesticates (Berman and Pearsall 2008).

Food residue analysis applied in a variety of regions has served to expand knowledge of early plant use and consumption (Boyd et al. 2014). Methodological applications include the use of food residue analysis on ceramics, lithics and matrix samples. Recent studies have shown that these methods are successful in pointing to when and where domesticates were consumed in the past (Boyd et al. 2014; Piperno 2009; Piperno et al. 2009). Starch and phytolith analyses are advantageous methods that allow for accurate plant identification. The questions of what people were consuming and when are difficult to answer in situations of poor site preservation, bad context, a lack of historical texts, and/or ethnographies. Rigorous analyses of starch and phytolith microfossils allow archaeologists to compare samples spatially, and provide information on plant exploitation and subsistence strategies. Overall, both the developing theoretical frameworks and methodological applications are changing past notions of subsistence.

6.0 METHODS

6.1 OVERVIEW OF FOOD RESIDUE ANALYSIS

The botanical components of past subsistence strategies have become an important aspect of archaeological inquiry. Recent studies show the utility of applying food residue methods to archaeological samples, because results allow for new interpretations about site inhabitants and subsistence strategies (Haas et al. 2013; Henry et al. 2014; Liu et al. 2010; Madella et al. 2013). Current research in this field focuses on strategies of identifying when and where cultigens have been adopted (Blake 2006; Boyd and Surette 2010; Staller et al. 2006).

Plant microfossils such as starch granules and phytoliths are examined to identify flora presence and use at archaeological sites. These microfossils are present in archaeological contexts as carbonized or non-carbonized food residues, soils, and dental calculus (Henry and Piperno 2008; Horrocks 2005; Piperno et al. 2009; Rosenswig et al. 2014). Ceramics and fire-cracked rock may yield carbonized residue, while fire-cracked rock, lithics, and sediment samples may yield non-carbonized plant remains. This analysis will be applied to specifically chosen samples from Middle Woodland sites within Northern Minnesota.

6.2 SELECTION OF ARCHAEOLOGICAL SAMPLES

Several few factors dictated which archaeological samples were suitable for food residue analysis in this thesis. The first factor is whether the samples come from a dated component, and whether they fall within a reasonable range for the Middle Woodland period. AMS dates on residue, charcoal and bone, in addition to samples directly associated with Middle Woodland ceramics and lithics, place samples in an appropriate age bracket for this study.

A second factor pertains to the nature of the samples. Specifically, the ceramics must contain evidence of residue and the lithics should have a visibly worked surface. Suitable samples include ceramics, lithics, fire-cracked rock and matrix from archaeological features. Published material describes these contexts as strong indicators of plant processing, preparation, and consumption (Boyd et al. 2014; Yost et al. 2013; Zarrillo and Kooyman 2006).

The third and last major factor is the quality and amount of archaeological information on the sites chosen for this study. Site forms and reports have been accessed for eight out the nine sites in the study area. The ninth site was included because of residue weight on the obtained ceramic samples. Some alternate material has been published on the sites; however, it is not a significant amount and relates to larger studies of Brainerd and Laurel ware in the Upper Midwest (Hohman-Caine et al. 2012; Mulholland 1997).

6.3 LABORATORY PROTOCOLS

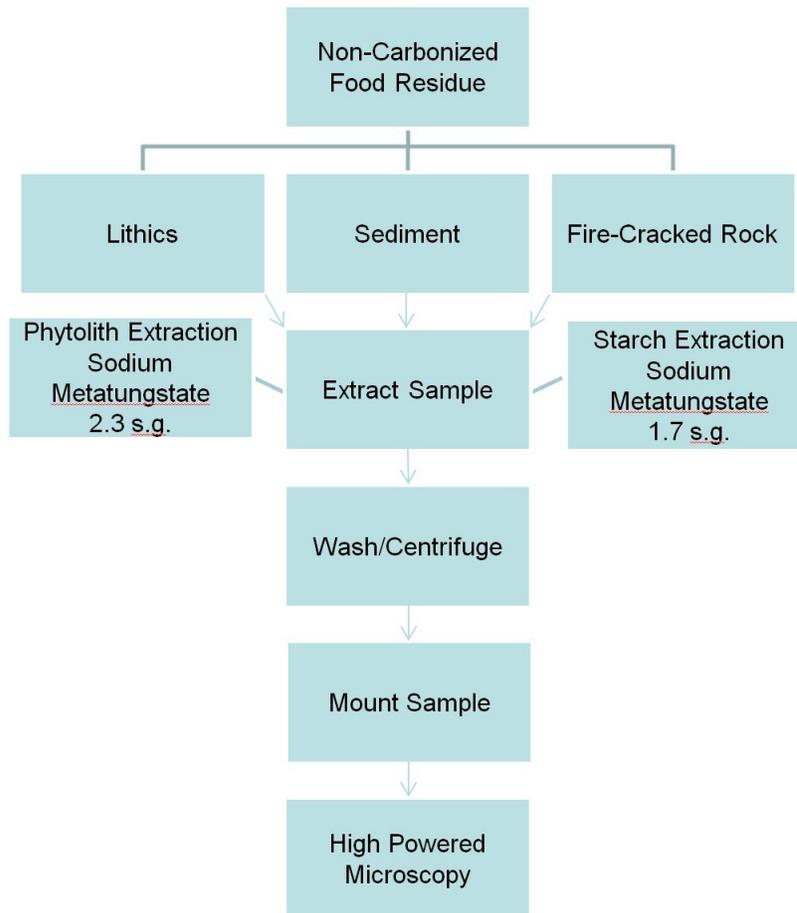


Figure 6.1: Flowchart of methods for non-carbonized food residue.

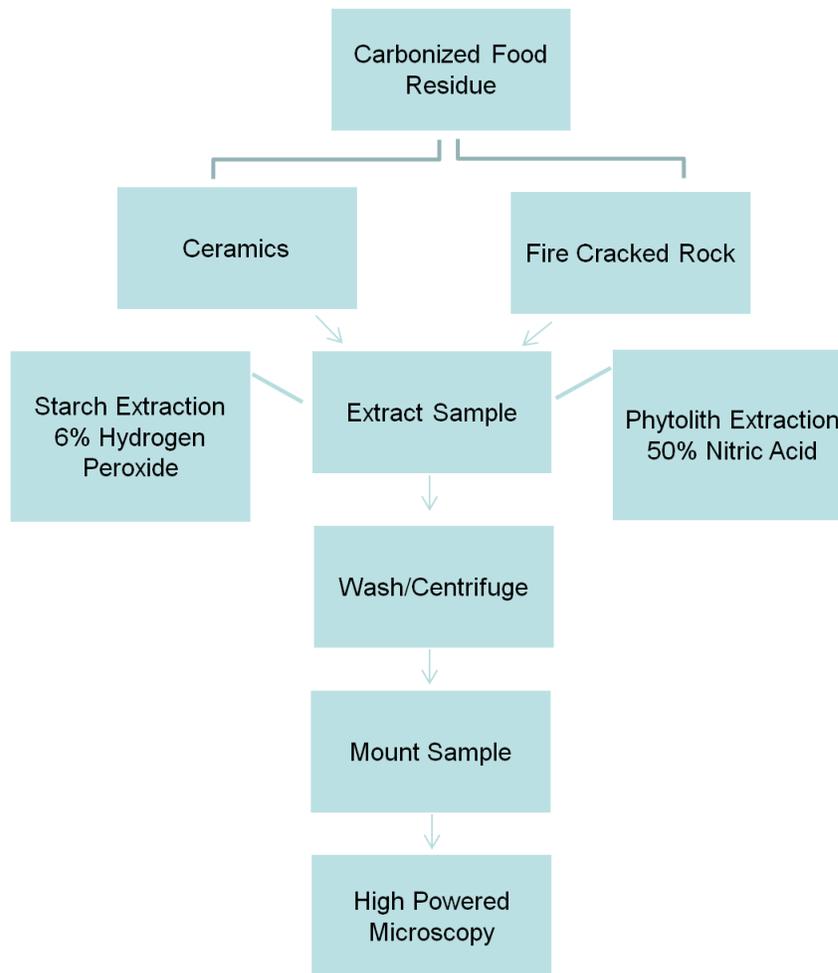


Figure 6.2: Flowchart of methods for carbonized food residue.

A specific set of laboratory procedures was used to process the microfossils adhering to the archaeological samples (Figures 6.1 and 62). Before the methods are described in detail, it is necessary to review preliminary procedures. Two types of tests were completed prior to processing, to rule out any risks of contamination in the lab. The first test considers airborne contaminants in the processing laboratory. Five slides were placed in strategic locations around the lab in weigh dishes and two drops of silicone oil are added to trap any airborne particles. After 24 hours a cover slip was placed on the silicone oil and the slides were analyzed with a high powered

microscope under a magnification of 20 times. The results were some fibres, and dust particles, nothing significant such as microfossils to warrant re-testing the lab for airborne contaminants. The second test consisted of, or involved, blank samples that were run through the normal laboratory procedures for processing sediment and residue samples (Figures 6.1 and 6.2). Most of the steps were included to utilize laboratory equipment, thereby testing the cleanliness of the equipment and laboratory environment. Similar to the test for airborne contaminants, the results yielded some fibres and dust particles, but microfossils were not recovered. After finding the test results contained no contaminants of concern, archaeological material could be processed.

Methods used at Lakehead University were adapted by Surette (n.d.), and based on Chandler-Ezell and Pearsall (2003) and Horrocks (2005). The extraction procedures vary depending on the type of collected sample (Figures 6.1, 6.2, and 6.3).

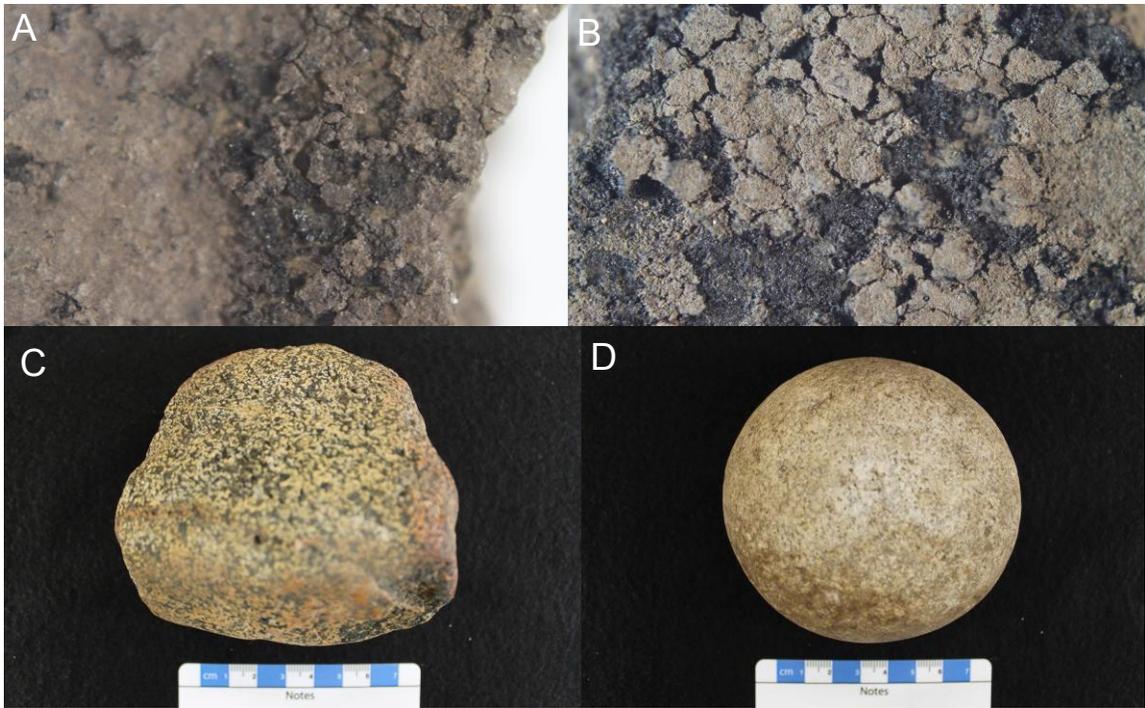


Figure 6.3: Carbonized food residue on ceramics from the Windy Bead site (A), and the No Beard site (B). Non-carbonized food residue on lithics (grinding stones) from the No Beard (C) and Windy Bead sites (D).

Non-Carbonized Food Residue

Non-carbonized food residue develops from food remains that are not burnt, although cooking could still produce this form of residue. This form of residue can be found within archaeological contexts such as matrix samples, fire-cracked rock and lithics. Fire-cracked rock can contain carbonized and/or non-carbonized residue, and the methods used to extract the microfossils are similar to lithic extraction so fire-cracked rock is included under the non-carbonized section.

The analysis of soil samples begins with clay removal. If the sample contains a large amount of clays, deflocculation and gravity settling are necessary. If not, a graduated cylinder is filled with pure water up to the 100 millilitre mark and then the sample is added until the water rises to the 150 millilitre mark, yielding 50 ml of soil

sample to work with. The sample is rinsed out with pure water to remove it from the graduated cylinder into a new beaker. This is covered with calgon, which is a water-softening agent and pure water is filled up to a measured 8 cm line drawn on the beaker. The beaker is placed on a hot plate with a magnetic stirrer to mix the soil sample. A pipette is used to remove and discard the supernatant; this process is repeated until the supernatant is clear. Using a 118 μm disposable Nitex™ cloth sieve, the contents of the beaker are filtered into a new beaker, and the sample is rinsed from the original beaker and through the sieve. In some cases the remaining larger particles are kept for macrofossil analysis. The rest of the sample is poured from the beaker into centrifuge tubes.

The tubes are filled with the sample and pure water is filled to the 50ml line. The tubes are centrifuged, the supernatant is removed with a pipette and the sediment is concentrated in a single tube. After these steps, the starch granules are extracted from the sample using density separation. Sodium metatungstate at a specific gravity of 1.7 g/L is added to the 50 millilitre centrifuge tube, and filled up to the five millilitre line. After centrifuging and pipetting the sample, the supernatant is added into a new centrifuge tube and the remaining sample in the first tube can be used for phytolith analysis.

Sodium metatungstate at a specific gravity of 2.3 g/L is added to the phytolith samples; both phytolith and starch granule centrifuge tubes are filled up to the 50 millilitre line with pure water and centrifuged three times. After the last wash both sets of microfossil samples are added to 1.5 ml microcentrifuge tubes with enough ethanol to cover the samples. This is later deposited on microscopic slides.

Before groundstone residue is processed, four different samples are taken from the tool. The four different samples are collected to extract as much residue as possible from around and within the tool; thereby increasing the potential microfossil counts and information on floral material (Surette n.d). Sample one is the sediment in contact with the stone tool, sample two is the sediment deriving from dry brushing of the stone tool surface, sample three is sediment from wet brushing and rinsing of the stone tool surface, and lastly sample four is the sediment recovered from sonication of the stone tool. Sample one is from a separate sediment bag collected in the field or directly from the bag containing the stone tool. Sample two is extracted by dry brushing the stone tool with a toothbrush in a tray large enough to accommodate the artifact. Sample three is extracted by washing the stone tool with water and gently brushing it with a toothbrush in a tray. Sample four is extracted by immersing the stone in a dish filled with water inside the sonicator, and sonicating for 30 minutes. Once the materials from each tube are dried, the sample weights are measured.

The phytolith and starch granules from stone tools are processed using density separation. A metal spatula is used to place 60 mg of each sample into a new centrifuge tube. Five millilitres of sodium metatungstate solution at a specific gravity of 1.7 g/L is placed in each tube, which is centrifuged. A pipette is used to remove the supernatant into a new centrifuge tube. This is re-centrifuged and re-pipetted to increase starch extraction, which yields zero to ten millilitres of extracted sample. The remaining material in the first centrifuge tube can later be used for phytolith extraction. Each tube is filled up with distilled water, and centrifuged; this is

repeated two more times to remove all of the sodium metatungstate. Ethanol is added to the tubes with a squeeze bottle and the samples are pipetted into microcentrifuge tubes to be later applied to microscopic slides.

After the starch extraction is finished the phytoliths can be extracted; sodium metatungstate at a specific gravity of 2.3 g/L is poured in each tube with the remaining materials from starch extraction. A pipette is used to move the supernatant into a new centrifuge tube, then centrifuged and pipetted to increase the amount of phytoliths extracted. Each tube is filled with distilled water, centrifuged and the supernatant removed with a pipette. This is repeated two or three more times until all of the sodium metatungstate is removed. Ethanol is added to the centrifuge tube, and the remaining samples are pipetted from the bottom of each tube and placed in microcentrifuge tubes.

Carbonized Food Residue

Carbonized remains are formed from the release of carbon, which is later preserved as residue on ceramics surfaces, and/or fire-cracked rock. The carbonized residue adhering to ceramics is gently scraped off with a small dental pick or scalpel under a stereoscopic microscope (Figure 6.3). The residue is then placed in a Petrie dish and from there into a microcentrifuge tube where the starch granules can be extracted first followed by the phytoliths.

All the residue is used for starch extraction to reach a microfossil count of 250. The samples are broken apart to make the extraction easier; afterwards, 6% hydrogen peroxide is added to each centrifuge tube. After they are placed in the orbital shaker, the samples are washed and centrifuged. If the sample still reacts

after this step, it is split into two samples and washed, centrifuged again. The sample is then filtered with a 118 μm Nitex™ cloth and placed into microcentrifuge tubes; at this point, ethanol is added to each tube and it is ready for mounting on microscopic slides. The sample that did not go through the 118 μm Nitex™ cloth the first time can be used for phytolith extraction; the larger particles are rinsed into the centrifuge tube. Both the phytolith and starch extracts are centrifuged and washed, the starch is placed into microcentrifuge tubes with ethanol for mounting, and the phytolith sample is allowed 24 hours to dry.

After drying, 50% nitric acid is added to cover the samples and placed in a water bath at 55 degrees Celsius for 12 to 24 hours. Durafilm is placed over the glass openings and the rack is then added to the water bath under the fumehood. Twelve to 24 hours are needed to sufficiently digest the residues; afterwards, the samples are washed and centrifuged to remove any excess acid. The samples are pipetted into microcentrifuge tubes where ethanol is added. At this point, the samples are ready to be mounted (Surette n.d).

After the extraction process the extracted material is mounted. Using a new pipette, one to five drops from each sample are placed on a clean, labelled slide. Starch samples can be stained with Trypan blue using only 10 ml of the agent. The samples dry under the fumehood, four to six drops of Entellan are added to the slides and a cover slip is placed on top. The phytolith and starch samples are mounted with 30% thiodiethanol, because it has refractive properties that make the microfossils more detailed. Toothpicks are used to manoeuvre the cover slips and help clean the excess Entellan around the slide. Slides dry under the fumehood for

three days to ensure that samples do not get contaminated by airborne particles. After the three days, samples can be analyzed using high powered microscopy.

6.4 IDENTIFICATION OF SAMPLES

High-powered microscopy was conducted with an Olympus Differential Interference Contrast (DIC) microscope. This type of microscope was chosen because it allows for precise identification of diagnostic microfossil features (Shillito 2011). Phytolith identification is based on the Brown (1984) key for phytolith identification with the exception of rondels. This particular key uses three classes to divide phytoliths into eight shape categories, which are further sub-divided into minor shape categories. The three main classes are trapezoids, bilobates and saddles, and they differ considerably when looking at tribes and subfamilies. The key represents 52 genera, 112 species of grass, and 16 tribes; there is also identification information for 12 non-grass species. For rondel phytoliths, a key developed by Surette (2008) is used for identification. Phytolith types are variable within different plants and different plant parts. A range of phytolith shapes is present depending on whether one is looking at the culms, leaves, roots and/or inflorescence (Shillito 2011; Surette 2008). Phytoliths are identifiable at higher taxonomic levels, and although many families have not been identified, cross-analyzing reference collections, and comparative collections assist in identifying species to low taxonomic levels.

Starch granules are identified by examining grain size and thickness, shape and position of hilum, presence or appearance of lamellae, and polarization cross type (Boyd et al. 2008; Torrence 2006; Zarrillo et al. 2008). For successful identification, both cross-polarized light and plain light are used. With starch

granules, taxonomic identification often relies on comparisons with individual granules and reference granules (Wilson et al. 2010). Lints (2012) developed a key for starch identification based on 45 plant species native to the boreal forest and northeastern prairies, separated into five different classes: bell-shaped, circular, elongated, angular, compound, basal and lastly irregular. Along with the phytolith and starch identification, diatoms, and pollen grains are counted and identified if possible. Phytoliths and starch granules have been shown to be more useful for identifying plant remains than pollen in some cases, because they can be found in larger quantities on archaeological material. Phytolith and starch assemblages from domesticated plants such as maize, squash and beans will be described below, in addition to native flora. Some starch granules from genera such as *Cucurbita* sp., *Phaseolus vulgaris* sp. and *Zizania* sp. are insufficiently distinctive from wild plant confusers so in these cases, they are considered possible identifications. Table 4 is composed of different plant species studied in this thesis and the diagnostic characteristics that allow for confident identifications.

Table 4: Plant taxon and diagnostic characteristics of phytoliths, starch and pollen.

Taxon	Phytolith Criteria	Starch Criteria	Pollen	Source(s)
<i>Zea mays</i> ssp. <i>Mays</i>	<ul style="list-style-type: none"> • Wavy-top • Ruffle-Top • Concave side • Entire base 	<ul style="list-style-type: none"> • 90 degree extinction cross • X or Y shaped fissure • 18-25 mm • Six compacted sides 	<ul style="list-style-type: none"> • 55-100 mm • Exine pattern • Single pore 	<ul style="list-style-type: none"> • Boyd and Surette 2010 • Fearn and Liu 1995 • Holst et al. 2007 • Pearsall et al. 2003 • Zarrillo et al. 2008
<i>Zizania</i> spp.	<ul style="list-style-type: none"> • Four spikes or more • Indented base 	<ul style="list-style-type: none"> • 3-8mm • Circular 		<ul style="list-style-type: none"> • Surette 2008 • Boyd et al. 2014 • Yost et al. 2013
<i>Cucurbita</i> sp.	<ul style="list-style-type: none"> • Honeycomb Texture • Circular 	<ul style="list-style-type: none"> • 10-20 mm • Circular • Rounded cross-arms 		<ul style="list-style-type: none"> • Bozarth 1987 • Duncan et al. 2009
<i>Phaseolus vulgaris</i> sp.	<ul style="list-style-type: none"> • Hook-shaped 	<ul style="list-style-type: none"> • 25-40mm • Elongated to Oval • Touching Extinction Cross 		<ul style="list-style-type: none"> • Bozarth 1990 • Piperno and Dillehay 2008 • Boyd et al. 2006

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

Maize (*Zea mays* ssp. *mays*) is identified based on a set of diagnostic features found in phytoliths and starch granules. Over 40 different species of domesticated maize have been identified, and 500 wild species may contribute maize-like

phytoliths, and because of this, a number of morphological characteristics are used to validate the presence of maize in archaeological samples (Piperno 2009). Maize rondel phytoliths will have either a wavy-top, or ruffle-top with concave sides and an entire base (Figure 6.4, Bozarth 1993; Pearsall et al. 2003; Boyd and Surette 2010).

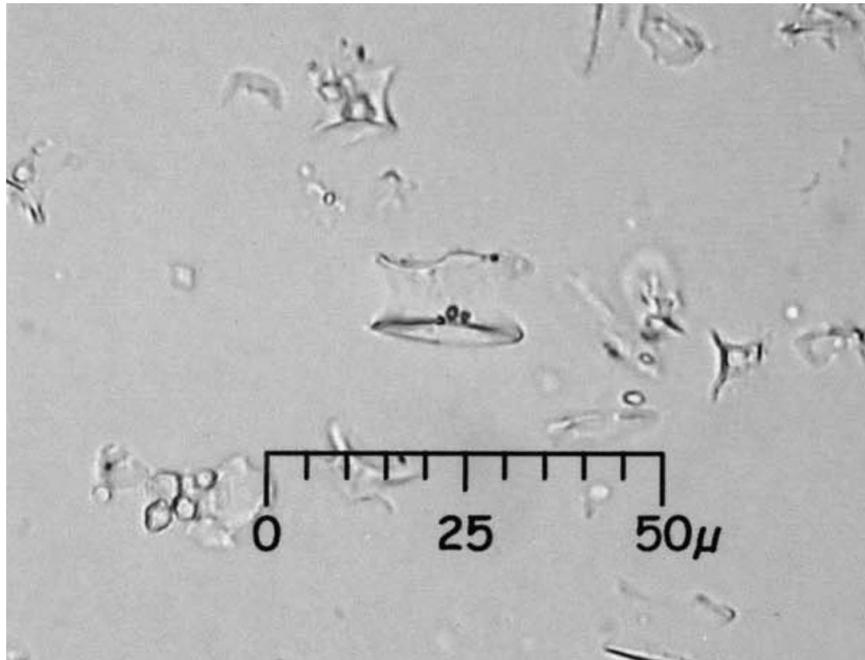


Figure 6.4: Maize wavy-top rondel phytolith (source: Pearsall 2004).

Wavy top and ruffle top are two types of rondels used to differentiate maize from wild grasses, and they occur in the cupules and glumes of cobs (Pearsall et al. 2003; Piperno 2009). Piperno (2009) has defined the three major indicators of maize rondel phytoliths as a ruffle-top, wavy-top, and half decorated, though many other phytoliths can be found in maize, some of which are also present in other plants. The wavy-top is the only phytolith found solely in maize and the major indicator used in this thesis (Boyd and Surette 2010; Haas et al. 2013; Pearsall et al. 2003; Zarrillo et al. 2008).

Grass seeds, especially maize kernels, produce large quantities of starch granules, with morphological characteristics unique to Poaceae (Piperno et al. 2004). In areas where teosinte is not present, maize starch granules can be distinguished from native grasses in these regions. Maize starch granules commonly range in size from 18 to 25 micrometers (μM) in length. In many of the native grasses, granule size ranges from a maximum length of two to 18 μm , and an average of three to 11 μm (Haas et al. 2013; Holst et al. 2007). Maize starch exhibits a y, or x fissure, contains up to six compacted sides and a 90° extinction cross (Figure 6.5). Based on the reference collection developed at Lakehead University, these features are unique to maize and are not present in any native flora (Lints 2012).

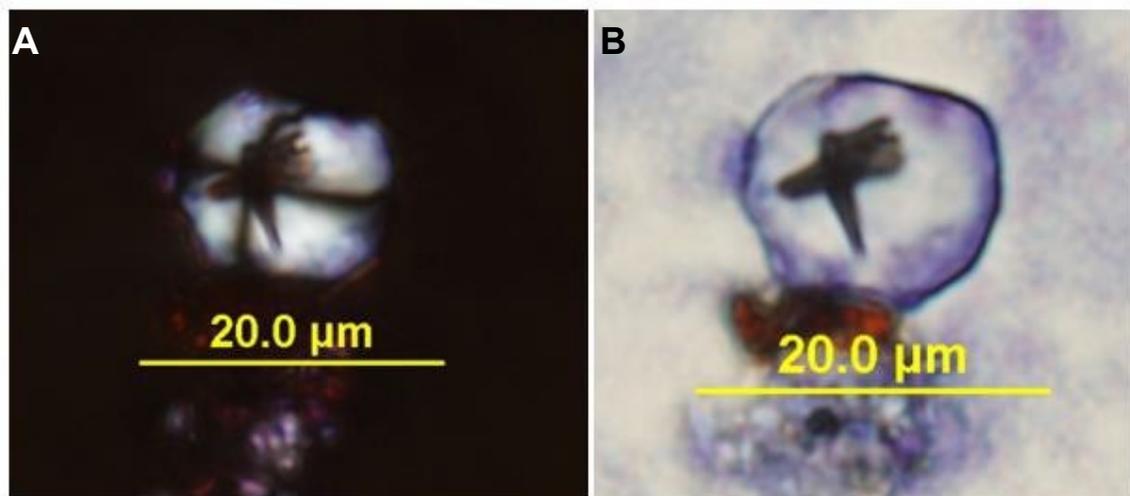


Figure 6.5: Maize starch grain under Cross-Polarized Light XPL (A) and Plain-Polarized Light PPL (B).

Squash (*Cucurbita*)

The main identifying feature of squash is large circular shaped phytoliths with a honeycomb texture (Figure 6.6). Bozarth (1987) describes the diagnostic features

of squash as hemispheroidal and spheroidal phytoliths that have scalloped surfaces with concave depressions. The phytoliths extracted from squash are produced in the fruit and can be found in the seeds, peduncles and rinds of the plant (Bozarth 1987). The lack of these phytoliths in the flesh of the fruit means that squash will tend to be under-represented or invisible in archaeological cooking residues (Bozarth 1987).

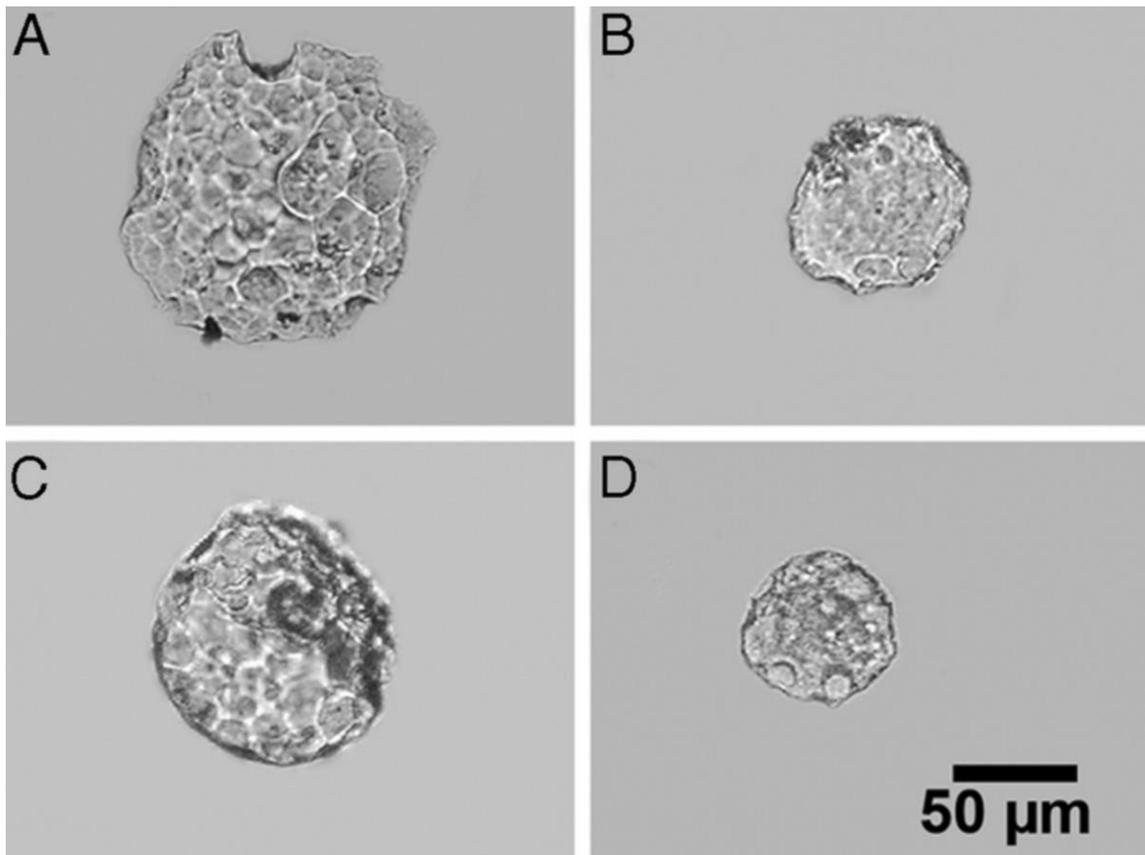


Figure 6.6: Squash phytoliths, A-D illustrate different samples (source: Piperno et al. 2007)

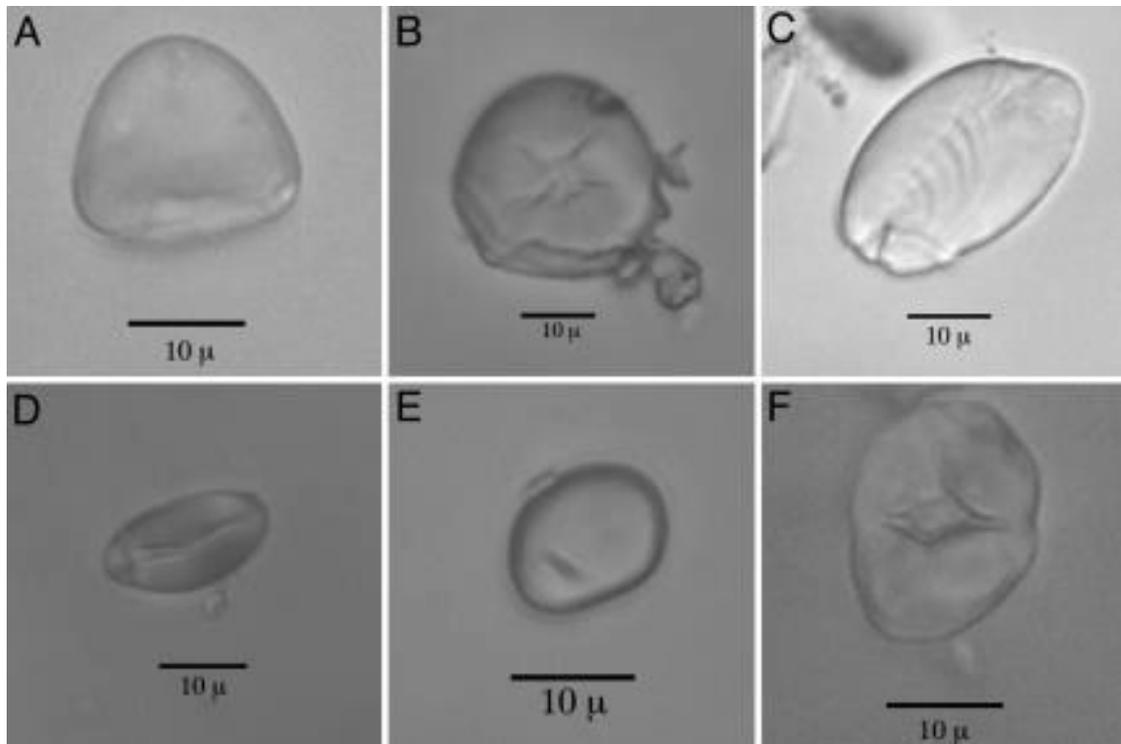


Figure 6.7: Starch granules identified as squash, A to F illustrate different samples of squash (source: Duncan et al. 2009)

Squash starch grains are easily identified from the cross-arms viewed under XPL (Duncan et al. 2009). However, the grains appear identical so it is impossible at this time to identify different varieties of squash from starch granules (Figure 6.7). As well, there are some wild plants that produce similar looking granules.

Common Bean (*Phaseolus vulgaris*)

Common bean or *Phaseolus vulgaris* yields phytoliths that are recognizable by large hook shaped microfossils, as illustrated in figure 6.8 (Bozarth 1990). Bozarth (1990) described a few varieties of beans that all take on this hook shape; these varieties include *P. vulgaris* and *P. lunatus*. *Phaseolus lunatus* and *P. vulgaris* starch range from 25 to 40μm in length, and are typically elongated in shape. A diagnostic feature of bean grains is the touching extinction cross (Figure 6.9).

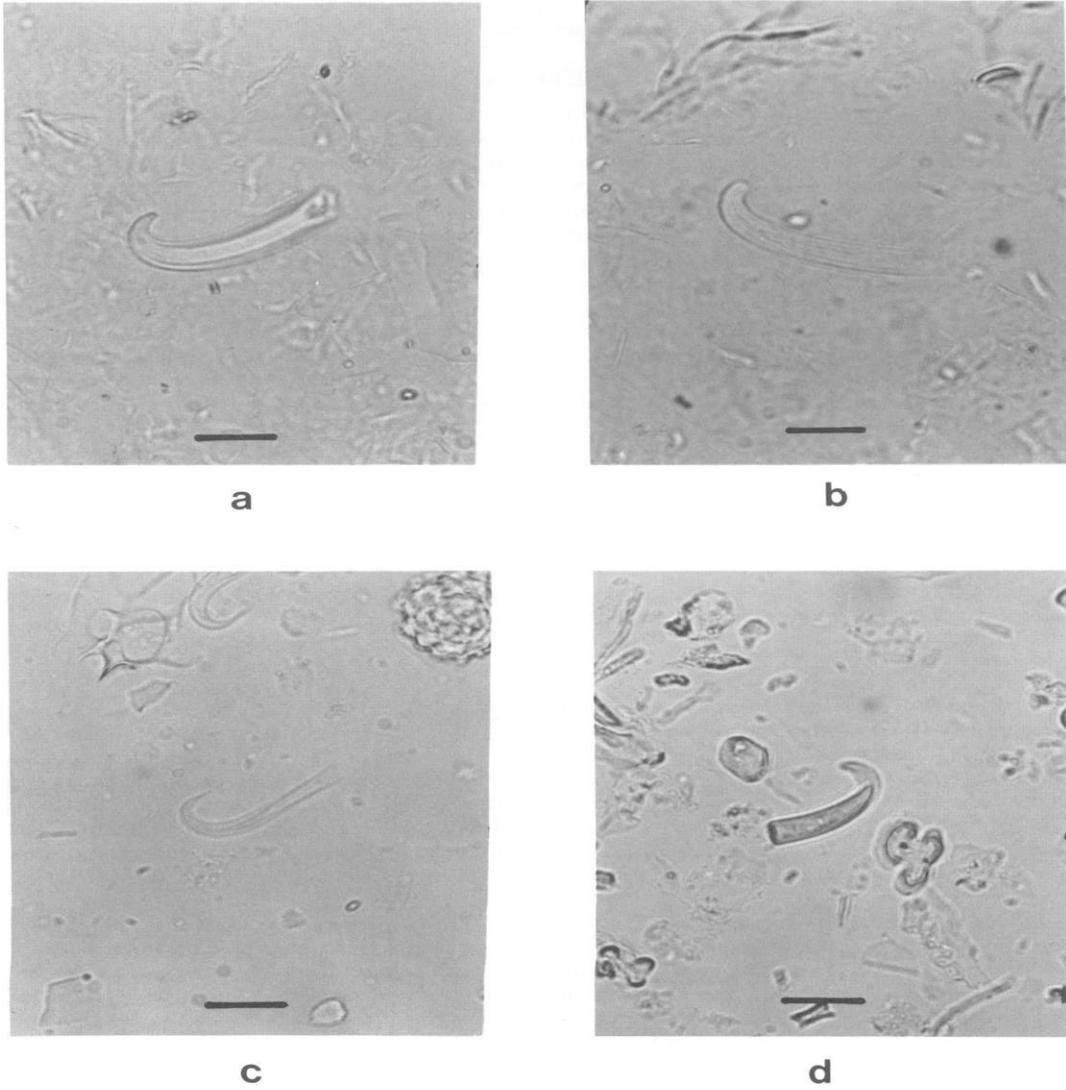


Figure 6.8: Hook shaped phytoliths of *Phaseolus vulgaris*, A to D illustrate different samples (Bozarth 1990)

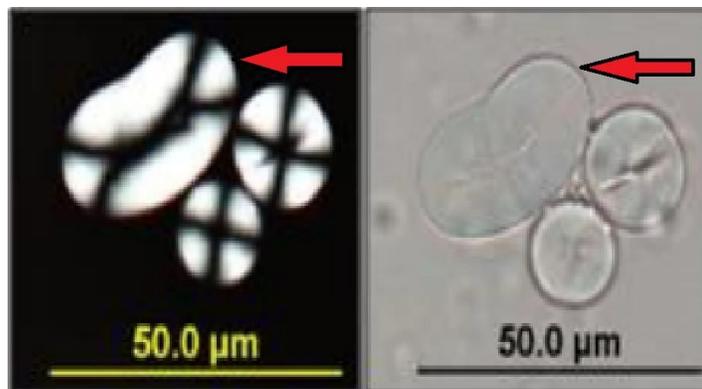


Figure 6.9: *Phaseolus* starch grain (Lints 2012).

Wild Rice (*Zizania* sPp.)

Wild rice (*Zizania* ssp.) phytoliths are identified by the presence of a variety of morphological features. The criteria for identification are that the rondels must have an indented base, with multiple spikes on the top (Surette 2008).

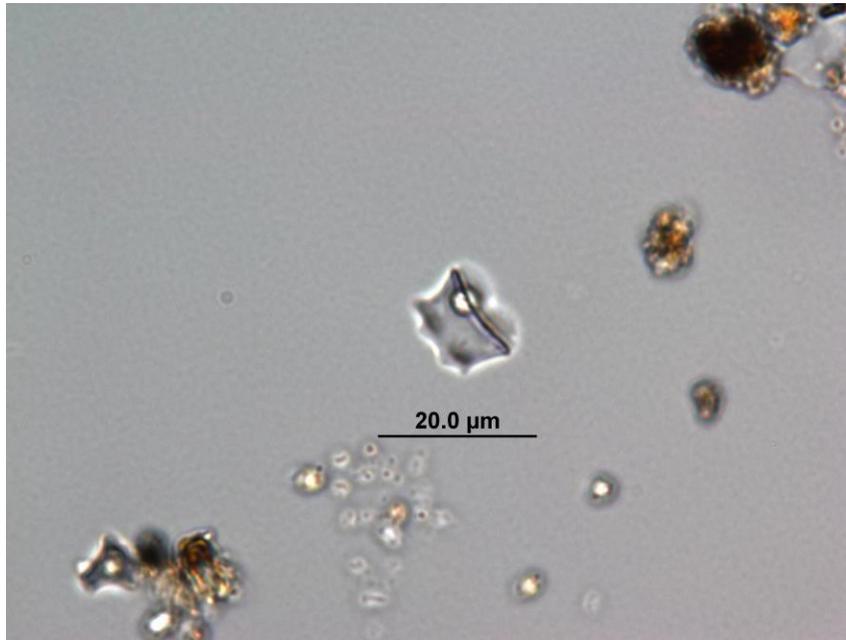


Figure 6.10: Wild rice rondel phytolith from the MacGillivray site, Ontario.

Various forms of wild rice can be identified down to the species level, these wild rice rondels exhibit four spikes, and three indentations (Figure 6.10). Wild rice will also produce rondels with only three spikes and an indented base, although this is not considered diagnostic because native flora can also produce similar rondels. *Zizania* starch was described in the comparative starch key produced by Lints (2012), however; this example has shown the difficulties in applying the key to archaeological samples. *Zizania* starch is only 3 to 8µm in size and a wide variety of native plants contain morphologically similar traits.

Native Flora

A wide variety of native plants, other than wild rice, cannot yet be identified because comparative studies of native species have not yet been developed, and such work is beyond the scope of this thesis. Although the comparative reference collection at Lakehead contains over 300 plant species from the Boreal Forest and north-eastern Plains, many native plants from the Minnesota area could not be identified with the current reference collection. Native plants are able to be identified from rondel phytoliths with the key developed by Surette (2008); however, starch granules are more difficult to identify because many native plants produce starch that is similar in shape and size.

As summarized in Appendix 1, some of the native flora identified from Middle Woodland sites in Northern Minnesota includes *Chenopodium gigantospermum*, raspberry (*Rubus idaeus*), blueberry (*Vaccinium angustifolium*), wild strawberry (*Fragaria virginiana*), elderberry (*Sambucus*) and smartweed (*Polygonum sp.*). The distribution of *Chenopodium gigantospermum* (*Chenopodiaceae*) (mapleleaf goosefoot) is found over most of North America (University of Minnesota Herbarium n.d; Smith 2006; Personal Communication with Surette, Lakehead University, 2012). This common plant spreads easily and macroremains were recovered at the Big Rice site (Shafer 2003). Wild raspberry (*Rubus idaeus*) is a common plant found at some Woodland sites in Northern Minnesota (Shafer 2003). Raspberries have red fruit that grows from hollow shells when stalks are separated and they are found in thickets (Peterson 1977). *Vaccinium angustifolium* (*Ericaceae*) or blueberry is also

found in the Northern Minnesota area (Shafer 2003). This perennial shrub is common in low and high thickets and can be eaten fresh, dried or cooked. The berries form a star pattern with five calyx lobes (Peterson 1977; University of Minnesota Herbarium n.d). Wild strawberry or *Fragaria virginiana* (*Rosaceae*) is also native to Northern Minnesota (University of Minnesota Herbarium n.d; Shafer 2003). Strawberry starch granules have a platy structure within a larger oval enveloping shape (Knee, n.d). These low lying plants can be dried, eaten fresh or cooked; the leaves can also be eaten raw or boiled (Peterson 1977). *Sambucus canadensis* or elderberry macroremains have been found at archaeological sites (Shafer 2003) in the study area. Juicy, purple or black berries top flowers with five petals, and they are mostly eaten raw (Peterson 1977). Some varieties of smartweed or *Polygonum sp.* (*Polygonaceae*) are considered invasive weeds and wetland species (University of Minnesota Herbarium n.d; Shafer 2003). *Polygonum sp* starch granules are shaped like teardrops and roughly 0.15 mm (Hart 2011).

6.5 COMPARATIVE REFERENCE KEY

Reference collections derive from modern flora, sometimes sampled near archaeological sites, and from these plants of known species, phytoliths and starches are extracted to compare to archaeological samples. These collections provide background information on modern plants and morphological characteristics of plant microfossils. Detailed descriptions and comparisons of phytolith and starch morphology and size allows for the recognition of squash and gourds (*Curcubita ssp.*), wild rice (*Zizania spp.*), beans (*Phaseolus ssp.*), maize (*Zea mays ssp. mays*), and various native flora. Comparative and experimental studies can help extend

reference collections by adding in modern plant species that may have been present and used in the past (Ollendorf et al. 1988). Different regions produce variations in native vegetation based on climate and topography so it is important to become familiar with regional vegetation. This study includes two different reference collections at Lakehead University to cover both Parkland and Plains ecological zones. The first reference collection is an assortment of Plains flora and was compiled by Lints (2012), while the second collection focuses on Boreal Flora and this is supplied by Lakehead University (Figure 6.11).

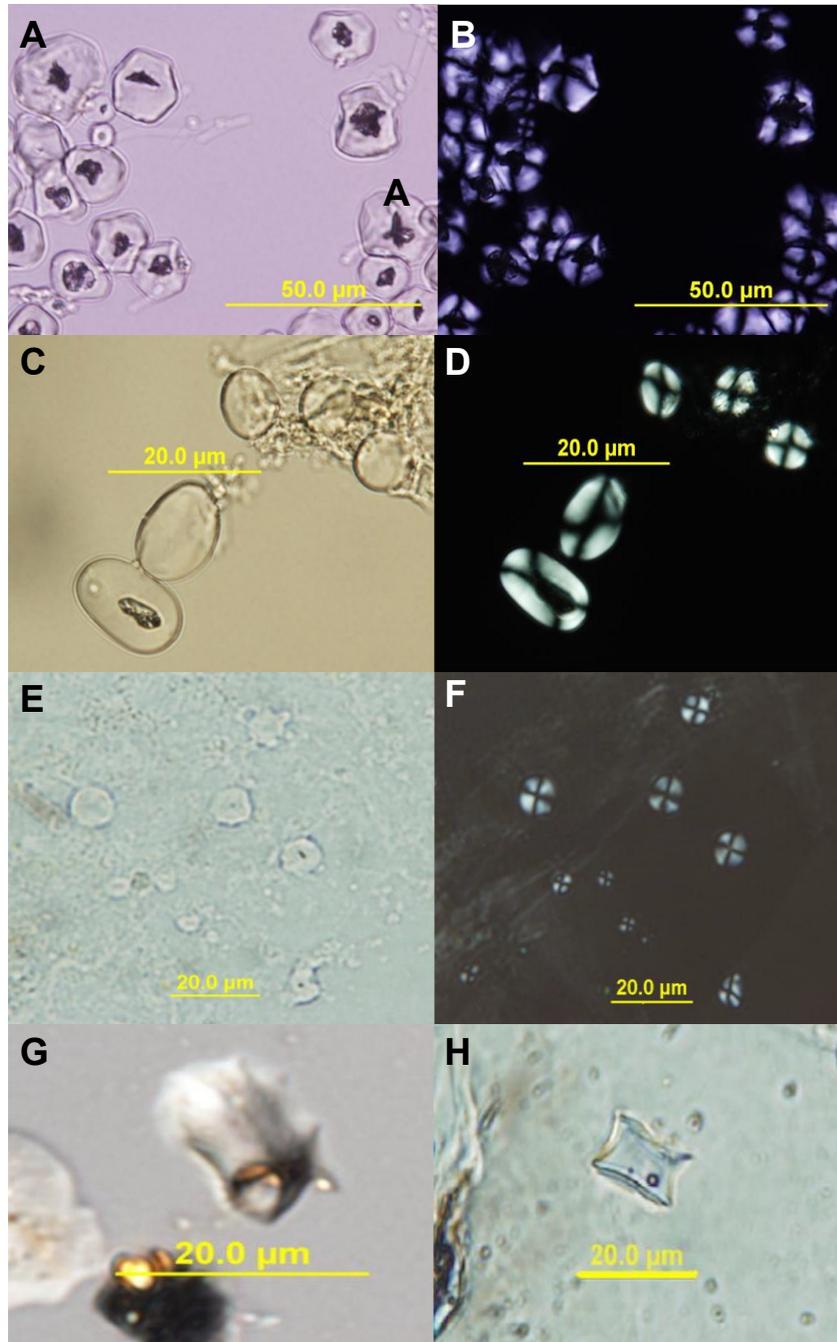


Figure 6.11: Comparative plant microfossils. A (PPL) + B (XPL) maize starch granules; A (PPL) + B (XPL) bean starch granules; E (PPL) + F (XPL) squash starch granules; G (PPL) wild rice rondel phytolith; H (PPL) maize rondel phytolith.

6.6 UNKNOWN SPECIES

The inability to identify certain species simply because they have not been added to reference collections is another limitation that over time will be lessened. In order to identify unknown species for this study, different reference collections were cross-referenced and modern collections were assessed. The cross-referenced databases include several online sources such as Plants for a Future, United States Department of Agriculture Plants Database (<http://plants.usda.gov>; <http://www.pfaf.org>), and the University of Minnesota Herbarium. The comparative reference collection at Lakehead University was also used to compare unknown microfossils in archaeological samples to comparative samples from the Canadian Plains and Boreal Forest.

The application of phytolith and starch analyses with the methods described above are an effective means of identifying non-native and local plants in archaeological contexts. Archaeological contexts include ceramics, lithics or sediment samples containing carbonized and/or non-carbonized food residue. The procedures for carbonized and non-carbonized food residue vary primarily because of the chemical agents used for density separation and the initial steps used to extract the microfossils. The analysis of microscopic slides with an Olympus (DIC) microscope allows for the precise identification of plant microfossils based on diagnostic traits.

6.7 CONTAMINATION

Contamination is the result of a number of factors attributed to human error in the field or lab (Crowther et al. 2014). In the field, contamination can result from not keeping excavated archaeological materials separate, resulting in the mixing of surface soils and sediments from different layers. A way to test for sediment mixing is to use control samples from within archaeological layers and the surrounding area to determine the presence of contaminants in the archaeological samples. Another form of contamination occurs when excavators do not take the necessary precautions to wash their hands after breaks, which can cause artifacts to be exposed to food remains (Cummings 2007; Personal Communication with Megan Wady, Lakehead University, 2012).

In the lab, contamination can result from airborne starch and poor control over people entering the laboratory (Crowther et al 2014). Monitoring for the presence of airborne starch can be done by taking samples of areas where airborne starch may come to rest and testing for their presence/absence. Although Crowther et al. (2014) describes the low statistical validity and unreliable results with passive starch traps, passive traps coupled with blank contamination tests are routinely used at Lakehead. By using multiple tests for contamination there is a decreased risk of undetected cross-contamination by airborne microfossils, or microfossils entrapped in laboratory equipment. The laboratory should be kept as clean as possible to eliminate risk factors, and this includes daily wipe downs. As well, all used materials should be cleaned in a sonicator or by hand with industrial soap. When experiments are in progress, a sign should be posted on the doorway asking people not to enter

the laboratory, thereby controlling in and out traffic. Results from Crowther et al. (2014) on starch contamination showed that items such as non-powdered gloves and Calgon could cause starch contamination. In addition, the uses of bleach or weak acids to decontaminate the laboratory are ineffective (Crowther et al. 2014). At Lakehead University, the deflocculent that we use for soil processing tested negative for starch contamination; therefore, the results obtained in this study are not affected by lab contamination. With contamination in mind and the proper procedures followed to maintain a clean environment, it is unlikely samples have become compromised in the lab (Crowther et al. 2014).

7.0 RESULTS

7.1 INTRODUCTION

The following chapter presents the results from carbonized and non-carbonized food remains found adhering to ceramics, residue on lithics and soil samples. These remains are from the nine sites described in Chapter one, which date primarily to the Middle Woodland and are associated with Brainerd and/or Laurel pottery contexts. Images collected from the comparative collection at Lakehead University in Chapter six can be cross-referenced with the archaeological microfossils described in the following chapter.

7.2 RESIDUE SAMPLE SIZES

Sample sizes varied between carbonized and non-carbonized residue at all nine sites, with some samples weighing less than five milligrams, while others yielding over 70 milligrams (Figure 7.1, Table 5).



Figure 7.1: Examples of Brainerd and Laurel ceramics analyzed in this study. (A), (B) Brainerd sherds from the Third River Borrow Pit site, (C) Brainerd sherd from the Windy Bead site, (D) Brainerd sherd from the Saga Island site, (E) Laurel rim from the Saga Island site, and (F) Laurel sherd from the Lost Lake site.

Table 5: Sample weight of carbonized residue from ceramics, non-carbonized residue from lithics and soil, along with provenience information.

Site	Sample Code	Sample Size mg (Ceramics)	Sample Size mg (Lithics)	Sample Size mg (Soil)
Third River Borrow Pit	1 or 1-355-229.1-4 2 or 1-355-276.1-4 3 or 1-355.274.2 4 or 1-355-266.2-13 5 or 1-355.300.1 6 or 1-355-298.1-4 7 or 1-355-295.1-2 8 or 1-355-216.1 9 or 1-355-296.3-5 10 or 1-355-285.1	1 (78.1) Unit 25/1E Level 4 SE quad 2 (5.0) Unit 25/0.5 E Level 5 NW quad 3 (50.2) Unit 25/0.5 E Level 5 SW quad 4 (2.1) Unit 25/0.5E Level 3 SW quad 5 (6.5) Unit 35/0 Level 5 SE quad 6 (13.6) Unit 35/0 Level 4 NE quad 7 (22.5) Unit 35/0 W Level 4 NE quad 8 (23.7) Unit ON/1W Level 6 SE quad 9 (13.0) Unit 35/0 Level 4 SE quad 10 (9.4) Unit 25/0.5 E Level 8 W ½ of NE quad		
Big Rice	1 or 09-034-1B15 3 or 09-034-385 2 or 09-034-335	1 (5.9) 2 (1.2) Lot 225 ACC 112 3 (5.9)		S1 (27.54) 98/94 LV. 4 LOT #201 S1 S2 (34.44) 85/42 Lv 3. Area 2 S2
Windy Bead	AB37 or 0537335AB37 AB36 or 78AB36 AB24 or 0537378AB24 AB41 IS AB41	AB37 (24.5) Unit 1 Level 7 NE quad AB36 (6.6) Surface ACC #565 Lot 78 AB24 (18.6) Surface ACC #565 Lot 78 AB41 (34) Unit 1 Level 4 SW quad Lot 20	Lithic 1 Unit 3 Level 6 Lot 98 SE quad ACC #565 L5: Wetbrush (59.0) L6: Sonicate (19.6)	S3 (50.0) Unit 5 S4 (50.0) Unit 4 S5 (50.0) 914-03
No Beard	AB61	AB61 (5.1) Unit 14 ACC #317	Lithic 2 Unit 11 Level 11 Lot 501 SE quad ACC #317 L1: Working Edge Sonicate (64) L2: Wetbrush (166.8) L3: Sonicate (56.7) L4: Dry Brush (67.8)	
Kyleleen's Bent Pine	AB5 AB6 AB11	AB5 (>7) Surface AB6 (<7) Surface AB11 (20) Surface		
Kyleleen's Tall Pine	AB62	AB62 (11.5) Surface ACC #996 Lots #1-3		
Saga Island	AB45 AB90	AB45 (45.6) Unit 4 Level 6 SE quad AB90 (44.8)		
Lost Lake	814AB16 or AB16 814AB18 or AB18 814AB19 or AB19 AB43	AB16 (21) AB18 (7.4) AB19 (5.2) AB43 (49.5)		

Winnie Cottages	AB60 AB40 AB44	AB60 (45.6) 5N 11W 20-25 cms SW quad AB40 (51.5) 10N 75W 10-15cms NW quad AB44 (9.3) 0N 13W 10-15cms SW squad		
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The sample weight from ceramic residue was not high enough to include any additional studies such as AMS dating. The Windy Bead, Saga Island and Lost Lake sites produced ceramics with the thickest residue, while the Kyleleen's Bent Pine and Big Rice site had thinner layers of ceramic residue. The ceramic sherds analyzed from the other five sites had varying amounts of residue. Most ceramics are either Horizontally Corded, Net Impressed Brainerd ware, and/or a type of Laurel decorated ware (Table 6). Different native plant species were identified from rondel phytoliths, in addition to non-native flora (Appendix 9). These are only possible identifications that were counted based on the reoccurrence of rare rondel types in the plant assemblage. A comparative key is not available for Northern Minnesota flora; therefore, the possibility that a native plant exhibits similar characteristics as the identified rondel phytoliths cannot be ruled out.

Table 6: Ceramics from the ten chosen study sites.

Site	Sample Code	Ceramic Attributes
Third River Borrow Pit (211C176)	1 or 1-355-229.1-4 2 or 1-355-276.1-4 3 or 1-355.274.2 4 or 1-355-266.2-13 5 or 1-355.300.1 6 or 1-355-298.1-4 7 or 1-355-295.1-2 8 or 1-355-216.1 9 or 1-355-296.3-5 10 or 1-355-285.1	1: Thick-walled ware. Brainerd Net or Fabric Impressed. 2: Brainerd Net Impressed with clear knotholes. 3: Unsmoothed surface finish, Fabric or Net Impressed. 4: Questionable. Middle Woodland. 5: Textile Impressed, probably not Brainerd ware. Late or Brainerd Cord: Impressed surface finish. Dates to the Woodland. 6: Brainerd Net Impressed. 7: Parallel grooved Brainerd ware. Thick, grit tempered Middle Woodland. 8: Might be Net or Fabric Impressed Brainerd Ware. 9: Middle Woodland, Laurel ware. 10: Cord Impressed surface finish, Brainerd.
Big Rice	1 or 09-034-IB15 3 or 09-034-385 2 or 09-034-335	1: Laurel pattern, but it might be Late Woodland (Selkirk?). 2: Probably Net Impressed could also be Fabric Impressed. 3: Weathered Laurel Push Pull decoration.
Windy Bead	AB37 or 0537335AB37 AB36 or 78AB36 AB24 or 0537378AB24 AB41 is AB41	AB37: Laurel Smoothed. AB36: Laurel, thick grit temper. AB24: Brainerd with a tool impression on the lip corner. AB41: Laurel Dentate Stamped, weathered.
No Beard	AB61	AB61: Presumably Laurel. Dentate or verging on Dentate and Pseudo Scallop Shell.
Kyleleen's Bent Pine	AB5 AB6 AB11	AB5: Late Woodland Textile Decoration. AB6: Late Woodland Textile Decoration. AB11: Late Woodland Textile Decoration.
Kyleleen's Tall Pine	AB62	AB62: Presumably Brainerd, Middle Woodland. There is a strange temper.
Saga Island	AB45 AB90	AB45: Laurel Pseudo Scallop Shell, Middle Woodland. AB90: Chevrons, Dentate Stamped Laurel, Middle Woodland.
Lost Lake	814AB16 or AB16 814AB18 or AB18 814AB19 or AB19 AB43	814AB16: Net Impressions, Brainerd. 814AB18: Thin-walled Laurel Stamped. 814AB19: Textile Impressed Late Woodland. AB43: Laurel or Sandy Lake Smoothed Plain.
Winnie Cottages	AB60 AB40 AB44	AB60: Combed Blackduck Late Woodland. AB40: Net Impressed knots, Brainerd ware. AB44: Brainerd Net-Impressed.

Only two groundstone artifacts were analyzed from the Windy Bead and No Beard sites and both produced substantial sample weights (Figures 7.2 and 7.3, Table 5). There were only two grinding stones tested in this study because groundstones dating to the Middle Woodland with evidence of plant processing are

especially scarce. A working edge was visible on the No Beard groundstone, which was sonicated separately to identify differences in microfossils from the worked edge and the rest of the stone.

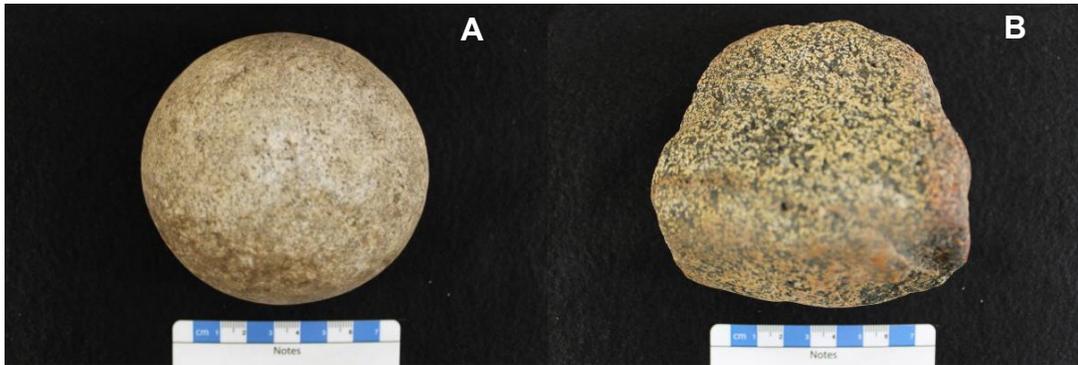


Figure 7.2: Two grinding stones used for residue analysis. A is from the No Beard site and B is from the Windy Bead site.

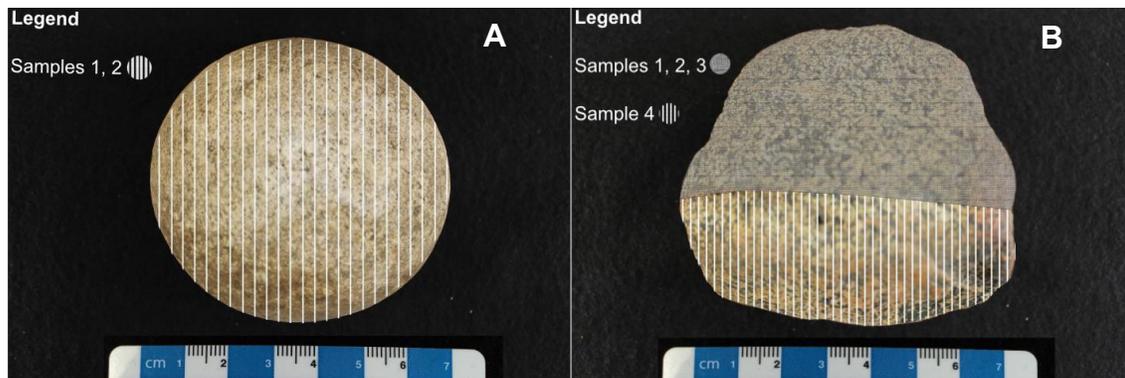


Figure 7.3: Locations of samples extracted from the two grinding stones. (A) No Beard site, sample one is from a dry bush, sample two is a wet brush, sample three is from sonication, sample four is sonication of the worked edge; (B) Windy Bead site, sample one is from a wet brush, sample two is from sonication.

The five soil samples from Big Rice and the Windy Bead site yielded larger quantities of microfossils than the other samples and had substantial sample weights (Table 5). The five soil samples contained a wide array of native plant rondel phytoliths (Appendix 6). Soil samples were collected during the excavation process from archaeological features including two hearths from the Big Rice site.

The following figures (7.4 to 7.9) include results from both carbonized and non-carbonized residue. Figure 7.4 to 7.9 are quantitative diagrams that depict the type of microfossil recovered from ceramics, lithics and sediment samples.

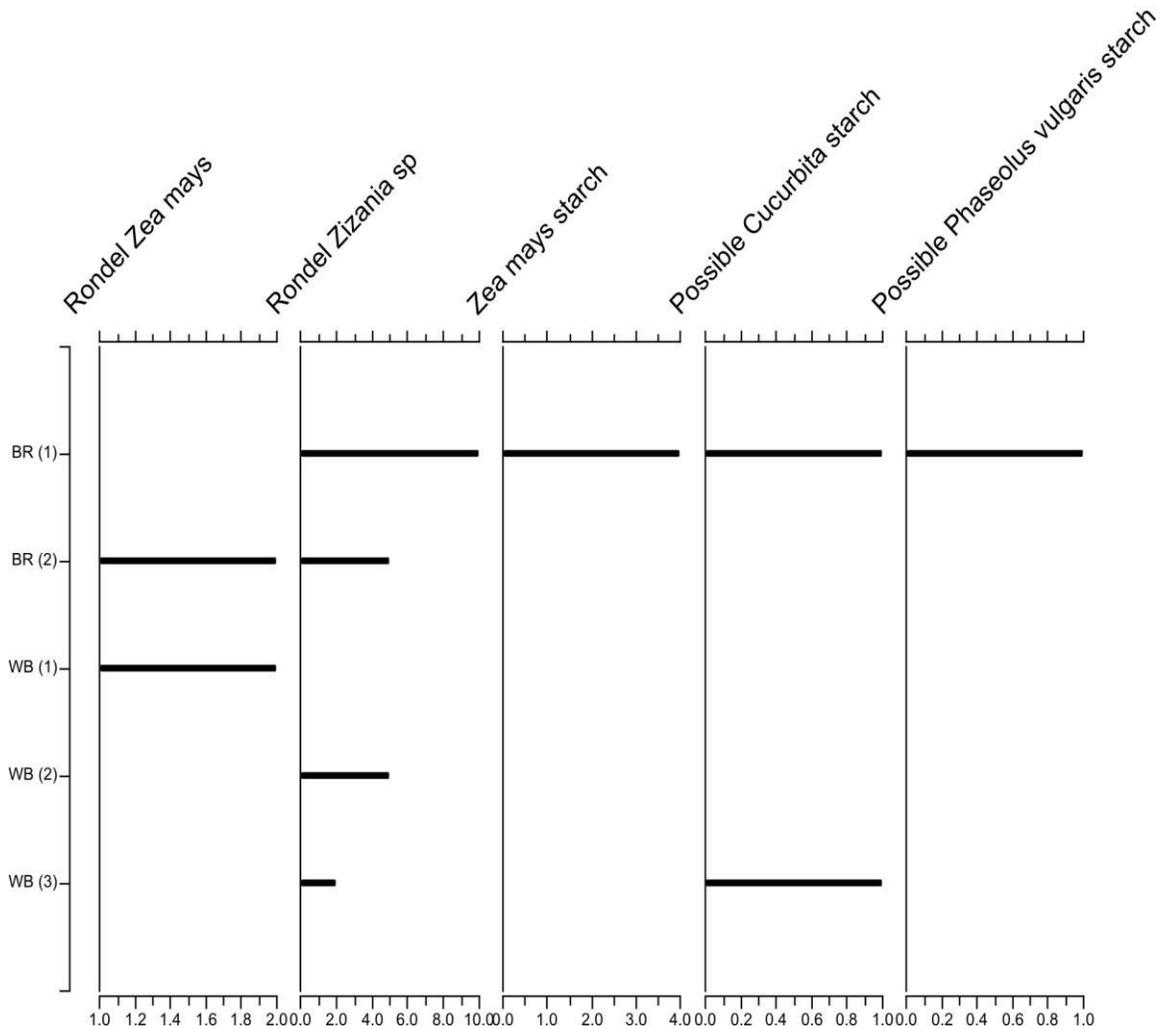


Figure 7.4: Diagnostic phytolith and starch data from sediment samples. Big Rice: BR, Windy Bead: WB. Amounts are expressed as percentages of the total microfossil count (n=250).

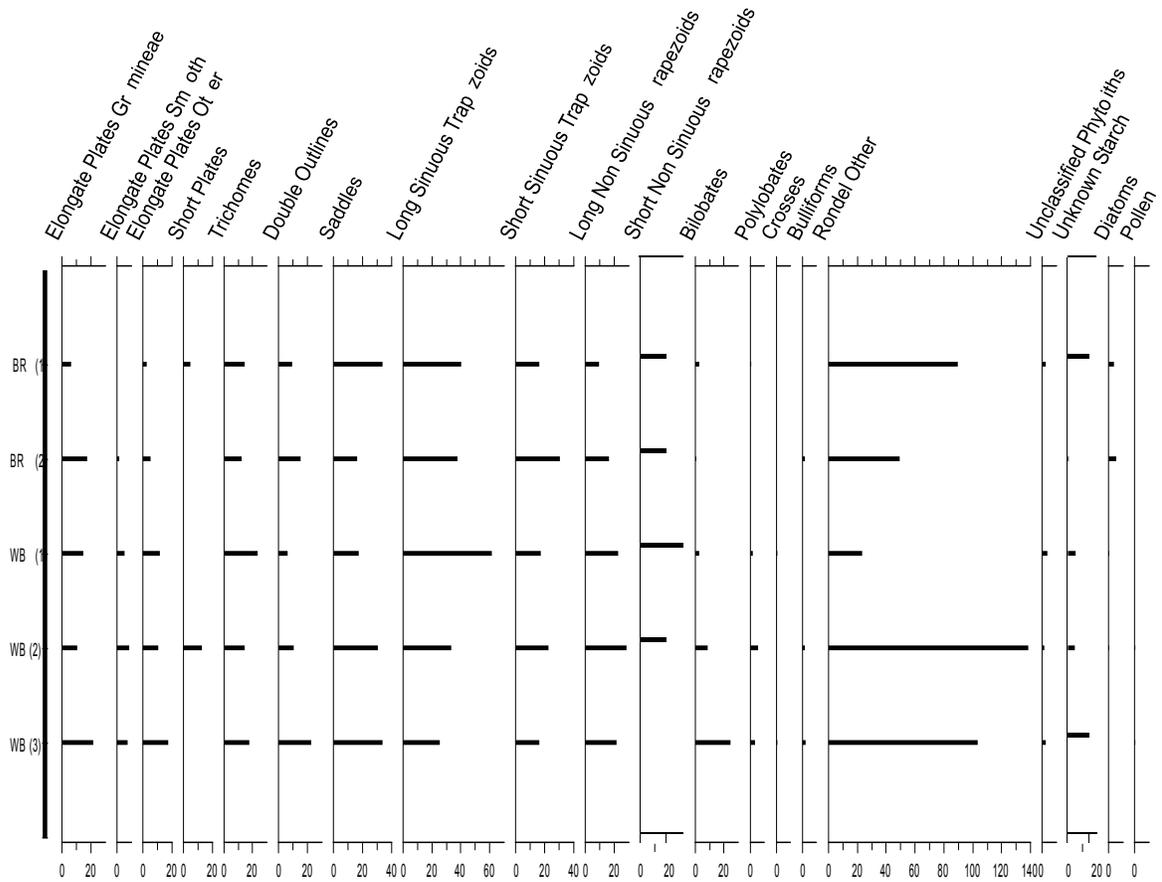


Figure 7.5: Microfossil assemblage from sediment samples. Big Rice: BR, Windy Bead: WB. Amounts are expressed as percentages of the total microfossil count (n=250).

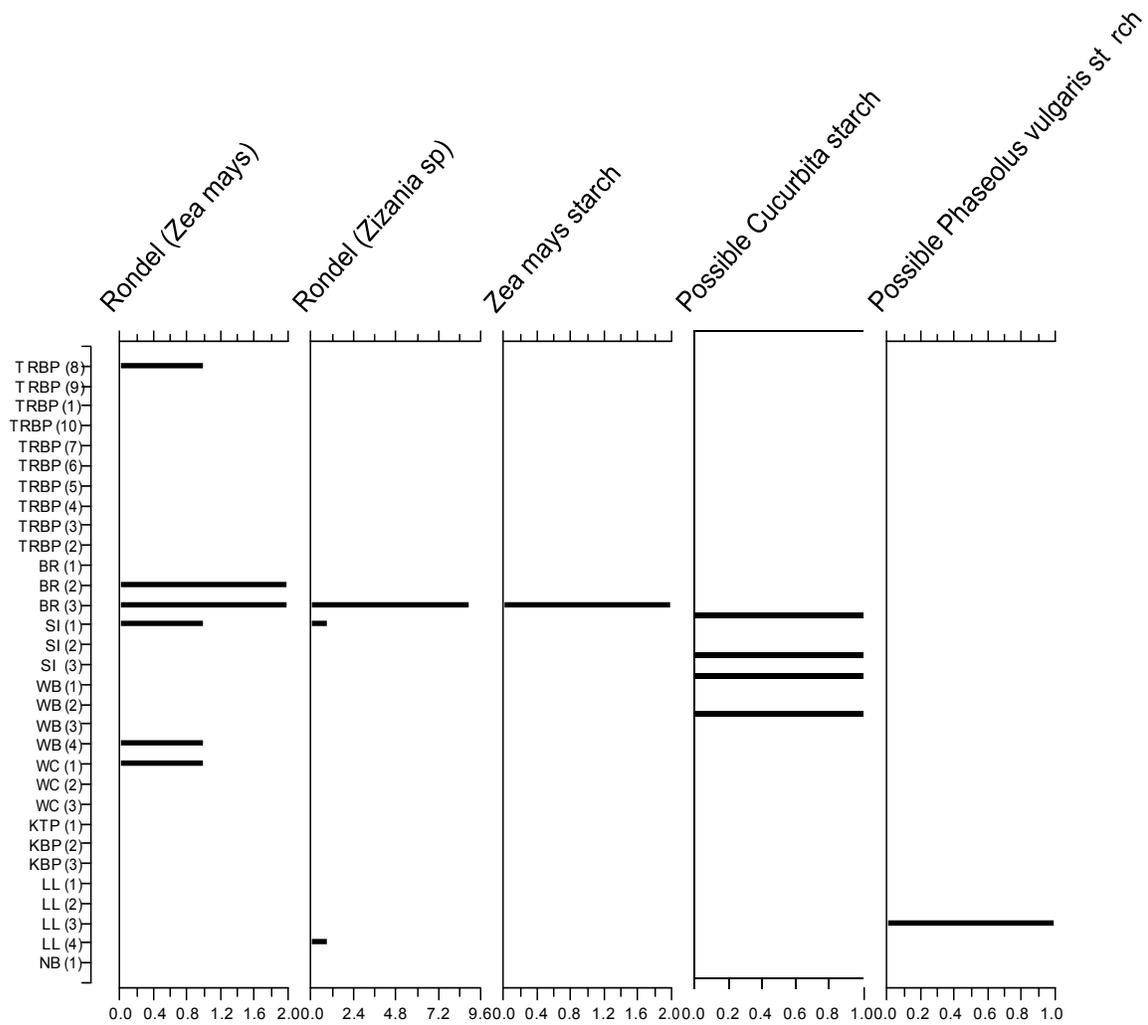


Figure 7.6: Diagnostic phytolith and starch data from ceramic samples. Third River Borrow Pit: TRBP, Big Rice: BR, Saga Island: SI, Windy Bead: WB, Winnie Cottages: WC, Kyleleen's Tall Pine: KTP, Kyleleen's Bent Pine: KBP, Lost Lake: LL, No Beard: NB. Amounts are expressed as percentages of the total microfossil count (n=250).

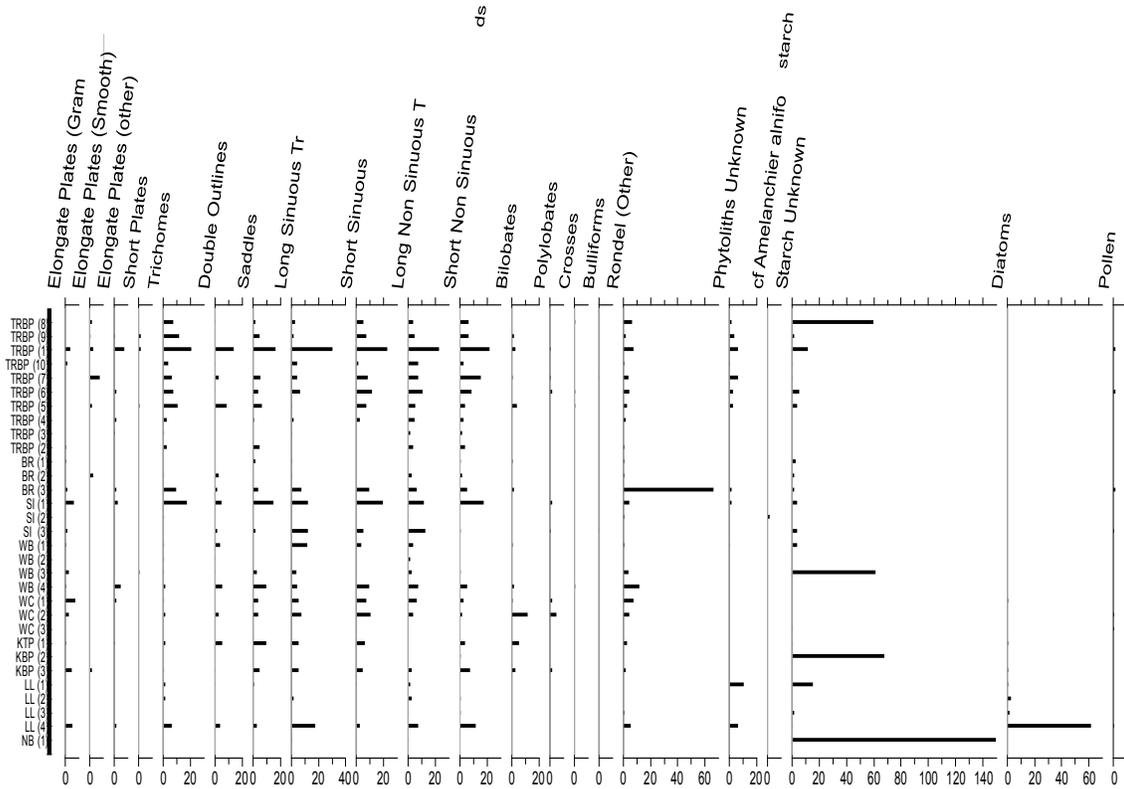


Figure 7.7: Microfossil assemblage recovered from ceramic samples. Third River Borrow Pit: TRBP, Big Rice: BR, Saga Island: SI, Windy Bead: WB, Winnie Cottages: WC, Kyleleen's Tall Pine: KTP, Kyleleen's Bent Pine: KBP, Lost Lake: LL, No Beard: NB. Amounts are expressed as percentages of the total microfossil count (n=250).

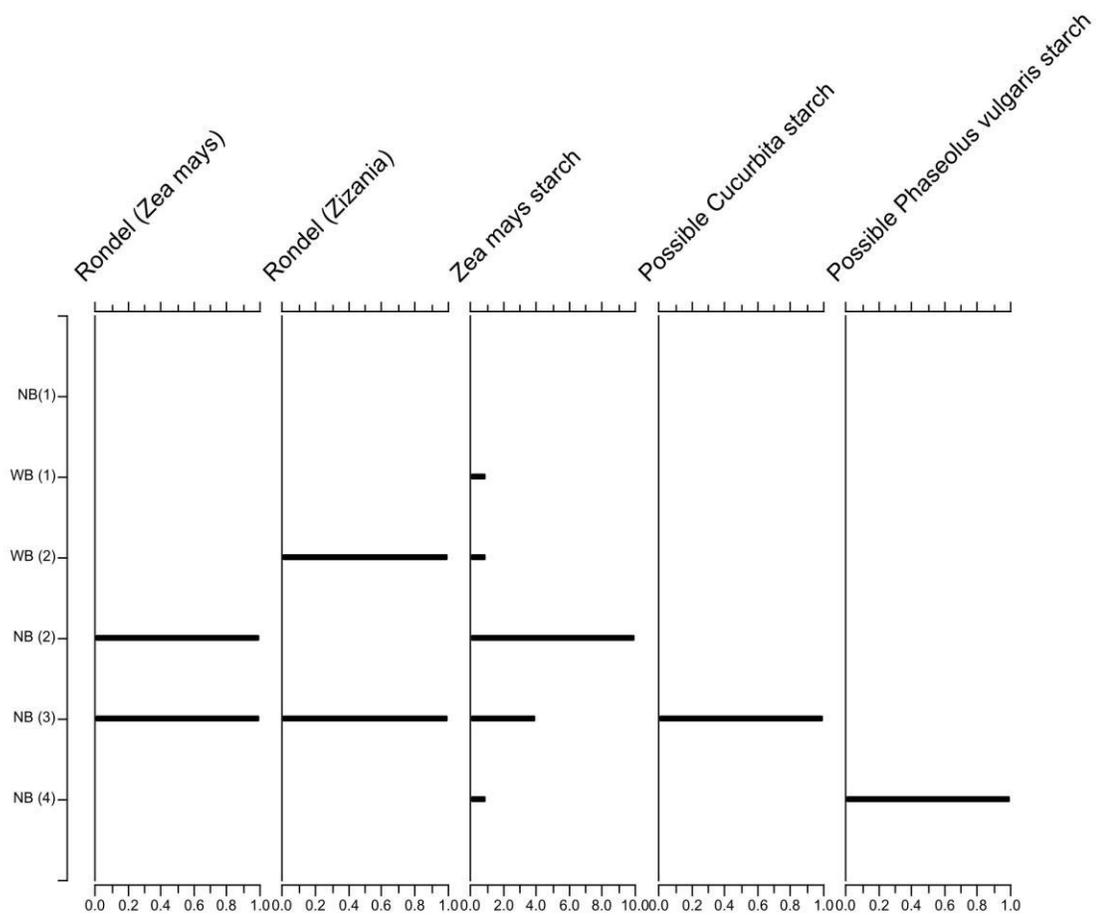


Figure 7.8: Diagnostic phytolith and starch data from lithic samples. No Beard: NB, Windy Bead: WB. Amounts are expressed as percentages of the total microfossil count (n=250).

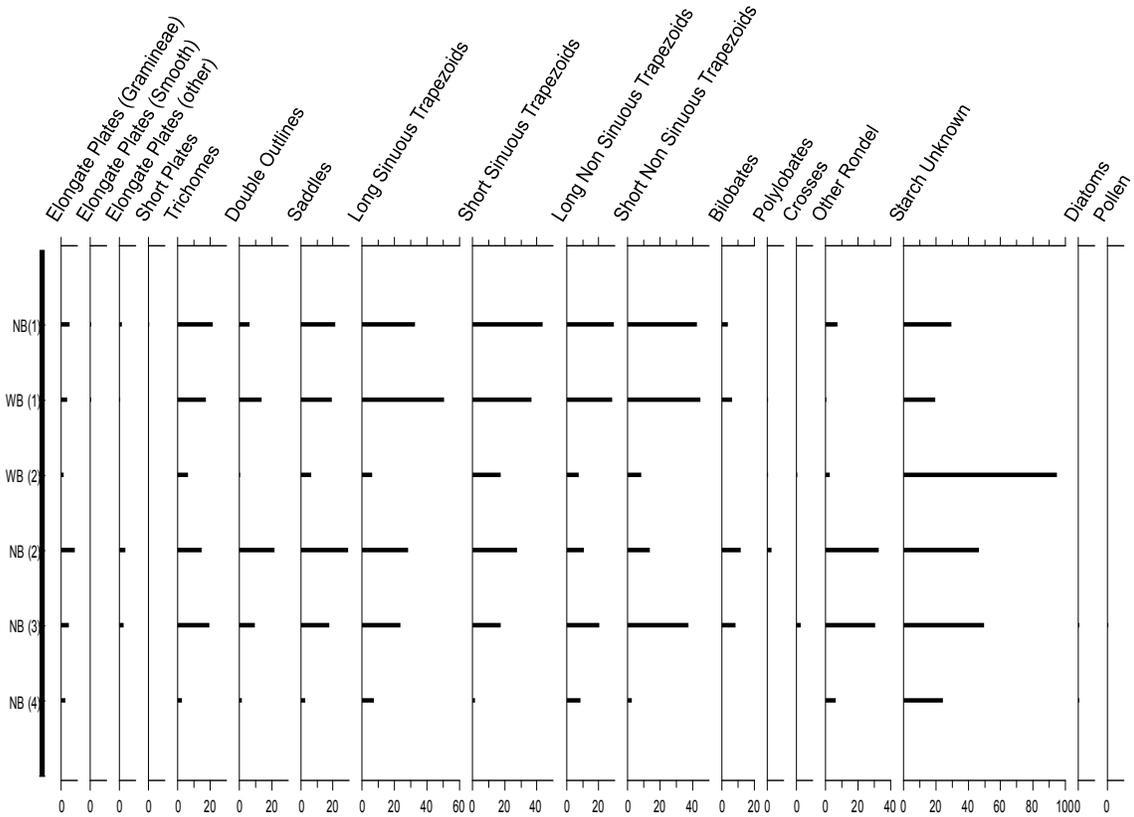


Figure 7.9: Microfossil assemblage recovered from two grinding stone samples. No Beard: NB, Windy Bead: WB. Amounts are expressed as percentages of the total microfossil count (n=250).

7.3 THIRD RIVER BORROW PIT (21-176)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

The Third River Borrow Pit site had ten ceramic sherds analyzed for phytolith and starch granules (Tables 6 and 13). One sherd produced a diagnostic *Z. mays* ssp. *mays*. rondel phytolith, while all the sherds had unknown phytoliths and additional rondel phytoliths (Figure 7.11). One sample yielded 60 unknown starch granules, the other nine samples had fewer than 12 unknown starch granules (Figure 7.7).

7.4 BIG RICE (09-034)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

Three ceramic sherds were analyzed from the Big Rice site (Tables 6 and 13). Two sherds yielded three diagnostic *Z.mays* ssp. *mays*. rondel phytoliths (Figure 7.11). Nine *Zizania* sp. rondel phytoliths were identified on one sherd (Figure 7.12). There were 67 other rondel phytoliths produced by one sherd, while the other sherds had only one unidentified rondel phytolith (Figure 7.7). *Z.mays* ssp. *mays*. starch granules were recovered from one sherd and fewer than three unknown starch granules were located on all three sherds.

Phytolith and Starch Content of Non-Carbonized Food Residue (Figures 7.4 and 7.5)

The Big Rice site had two soil samples analyzed for microfossils; the first sample contained charcoal and possible wild rice, while the other sample was extracted from a hearth rock ring (Appendix 8). Charred wild rice was recovered in substantial quantities from the site, some of which was radiocarbon dated (Figure 7.16). The sample from the feature containing charcoal and possible wild rice is in level four, and the sample from the feature containing a hearth rock ring is in level three (Peter and Motivans 1983). The highly disturbed sediments at depth suggest cultural mixing between Middle and Late Woodland occupation layers. Both samples contained *Z.mays* ssp. *mays*. rondel phytoliths. There were also four *Z.mays* ssp. *mays*. starch granules recovered from one sample (Figure 7.4). Between the two samples, 15 *Zizania* sp. were identified (Figures 7.4 and 7.12). A single possible *Phaseolus vulgaris* or common bean starch was recognized, although it is smaller in size than the grains that appear to be characteristic of

Phaseolus (Figure 7.14). A possible *Cucurbita* sp. starch granule was also identified from the same soil sample, although starch evidence for squash is inconclusive as discussed above (Figures 7.4 and 7.15). Both samples contained a large amount of other rondels, with one sample having a count of 90 and the other a count of 50. Diatoms of different algae species were recovered from both Big Rice site samples (Figure 7.5).

7.5 KYLELEEN'S TALL PINE (07-505)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

Only one ceramic sherd was analyzed from Kyleleen's Tall Pine and three unknown rondels, an unknown starch and a diatom were recovered, in addition to a low number of phytoliths (Figure 7.7).

7.6 WINNIE COTTAGES (02-526)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

Three sherds were analyzed from the Winnie Cottages site and all three had variable sample weights compared to samples from other sites. One ceramic sherd had 9.3 milligrams of residue and the other two sherds had around 48 milligrams of residue. One maize rondel phytolith was identified and two of the samples contained five to eight other rondel phytoliths (Figures 7.6 and 7.7). One unknown starch, a diatom and two pollen granules were recovered from all three samples (Appendix 7).

7.7 WINDY BEAD (05-373)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

Four ceramic samples were analyzed from the Windy Bead site. One Laurel sample contained a diagnostic maize rondel phytolith (Figure 7.11, Appendix 7).

Possible *Cucurbita* starch granules were identified from one Laurel and one Brainerd sherd (Figures 7.6). Fewer than 12 unidentifiable rondels were recovered, as well as four unknown starch granules from one sample and 62 on another (Figure 7.7).

Phytolith and Starch Content of Non-Carbonized Food Residue (Figures 7.5, 7.5, 7.8, and 7.9)

There are three soil samples associated with the Windy Bead site, all of which produced over 300 microfossils (Figure 7.5, Appendix 8). The rondel count was especially high for all three Windy Bead soil samples, with individual sample counts ranging from 24 to 139 rondels (Table 5) (mean=89). The three samples contained *Z.mays* ssp. *mays*. rondel phytoliths (Figure 7.4). *Zizania* sp. was identified on two out of the three samples from rondel phytoliths (Figure 7.12). In addition, a possible *Cucurbita* starch granule was identified in a single soil sample. Diatoms and unknown pollen were located in two out of the three soil samples (Figure 7.5). Raphides, which are thin calcium oxalate rods or crystals commonly found in some native wild plants such as plants of the families *Amaranthaceae*, *Araceae*, *Asteraceae*, and *Poaceae* were recovered from one sample (Arnott and Webb 2000).

The stone tool analyzed from the Windy Bead site (Figures 7.2, 7.3, 7.8, and 7.9) was wet-brushed and sonicated, producing less microfossils than the No Beard stone tool, but still containing a much higher microfossil count than most ceramic samples. Very few rondel phytoliths were recovered, although one is diagnostic of *Zizania* sp. Among the 121 starch granules was one maize phytolith and one maize

starch granule (Figures 7.8, 7.9, 7.11, and 7.13).

7.8 SAGA ISLAND (02-162)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

Two sherds were analyzed from the Saga Island site, both with sample weights around 45 milligrams (Table 5, Appendix 6). A maize rondel phytolith was recovered, along with a *Zizania* sp. phytolith from the same Laurel sherd. Both ceramic samples yielded a possible *Cucurbita* starch granule (Figure 7.6). Between the two sherds, four unknown starch granules, six rondel phytoliths and one unknown pollen grain were recovered.

7.9 LOST LAKE (2-00LL)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

The four Lost Lake ceramic sherds had one sample with very thick residue, while less than 10 milligrams of residue was extracted from the other three sherds (Table 5, Appendix 7). Only one *Zizania* sp. phytolith was recovered, and between the four samples, seven other rondel phytoliths were identified. A possible *Phaseolus vulgaris* starch granule was identified on a Laurel sherd. Unknown starch was present in three samples, with the highest count at 16. One sample contained 62 diatoms, while the other three samples had an average of two recovered diatoms (Figure 7.7).

7.10 NO BEARD (05-264)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

A single Laurel sherd was analyzed from the No Beard site (Appendix 7). Although there was little residue, 152 microfossils were recovered (Figure 7.7). 150

starch granules were identified from clusters located on several areas of the microscopic slide.

Phytolith and Starch Content of Non-Carbonized Food Residue (Figures 7.8 and 7.9)

Four different samples were extracted from the No Beard grinding stone, one sample was sonicated from the working edge, while another was sonicated from the rest of the stone tool (Figures 7.2 and 7.3). The last two samples were obtained through wet-brushing and dry-brushing the tool. Diagnostic *Z.mays* ssp. *mays*. rondel phytoliths were identified from the sonicated and wet brushed samples (Figures 7.8 and 7.9). A *Zizania* sp. rondel phytolith was recovered from the sonicated sample. Some samples produced large quantities of other rondel phytoliths, with counts as low as seven and as high as 33. *Z.mays* ssp. *mays*. starch was identified on three of the four samples (Figures 7.10 and 7.13). There was a significant amount of unknown starch ranging from 25 to 50 granules (Figure 7.9). Diatoms were located on two samples, in addition to one unknown pollen grain (Appendix 5).

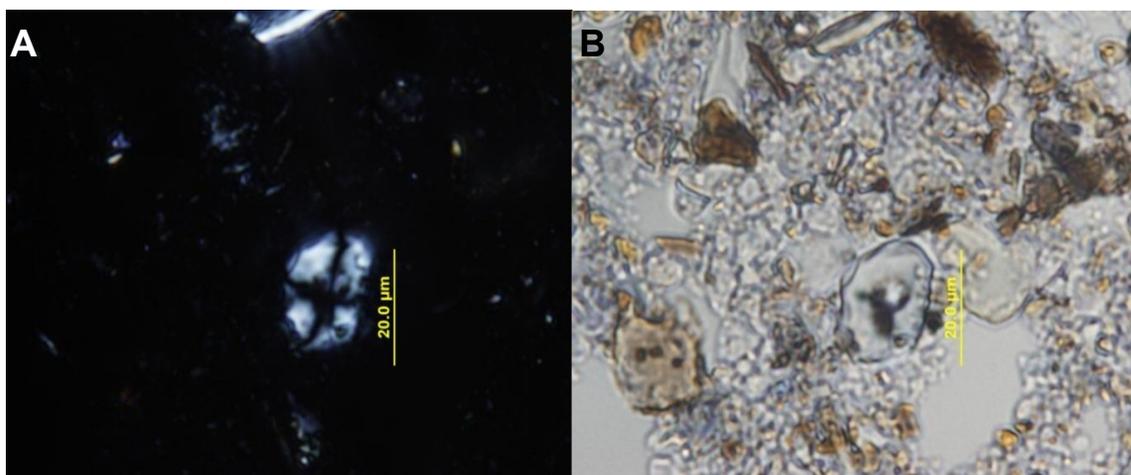


Figure 7.10: Damaged starch granule, recovered on a grinding stone from the No Beard site, (A) XPL, (B) PPL.

7.11 KYLELEEN'S BENT PINE (THIRD RIVER)

Phytolith and Starch Content of Carbonized Food Residue (Figures 7.6 and 7.7)

Out of the three samples from the Kyleleen's Bent Pine site, one yielded significantly high quantities of starch with a count of 68 (Figure 7.6, Appendix 7). All three ceramic sherds produced relatively low microfossil counts with no identifiable types. The lack of microfossils produced by cultivated or other identifiable plants may be due to low sample weight obtained from the ceramics or, alternatively, their absence at the site.

The following images (Figures 7.11 to 7.16) illustrate examples of different plant microfossils and macrofossils such as maize phytoliths and/or starch, wild rice phytoliths, possible squash and bean phytoliths, and plant seeds recovered during data analysis and excavation.

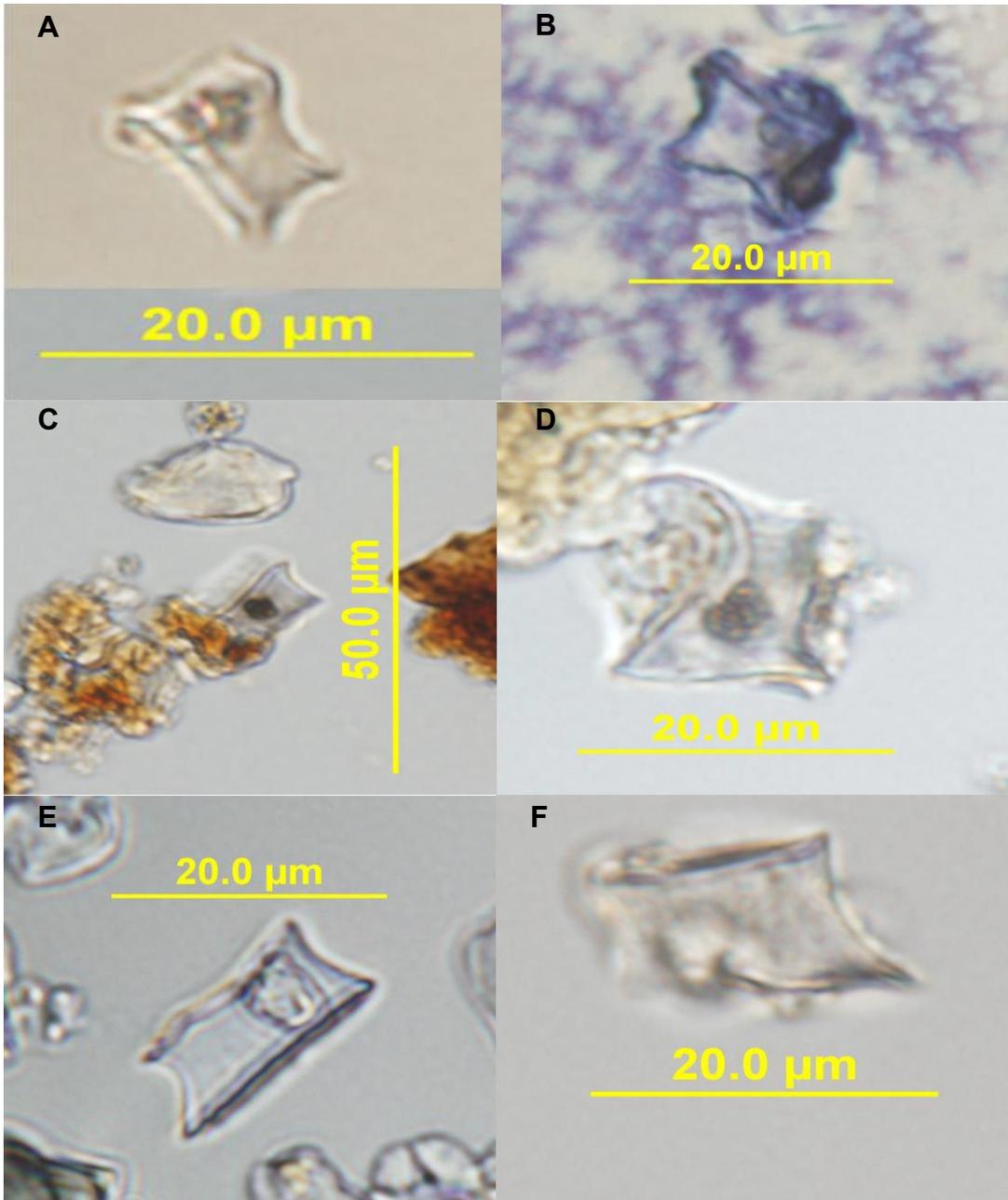


Figure 7.11: Microfossil photos of *Z.mays* ssp. *mays*. observed in carbonized food residue, soil and stone tools (A) Third River Borrow Pit site. (B) Big Rice site. (C, D, E) Windy Bead site. (F) No Beard site.

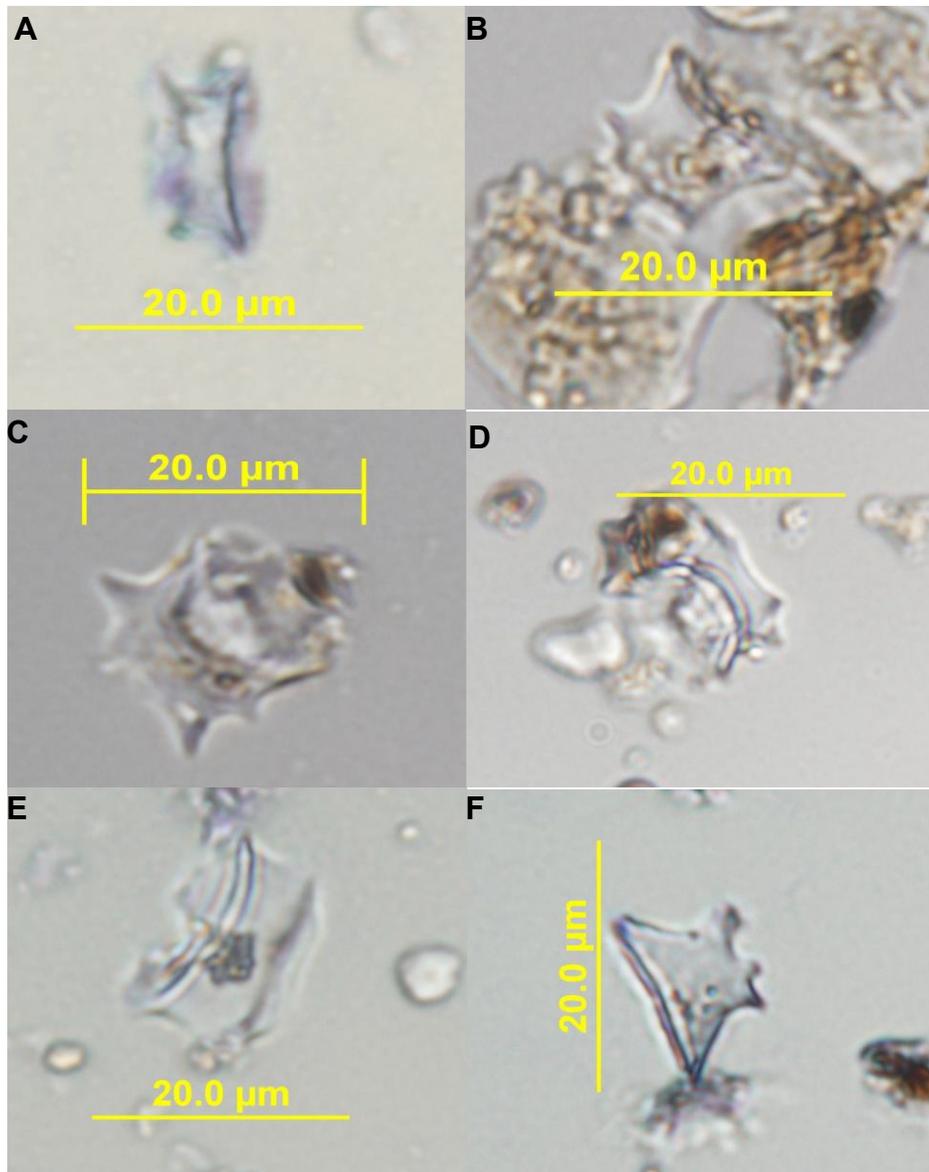


Figure 7.12: Microfossil photos of *Zizania* sp. observed in carbonized food residue, soil and stone tools (A, C, D, E, and F) Big Rice site. (B) Windy Bead site.

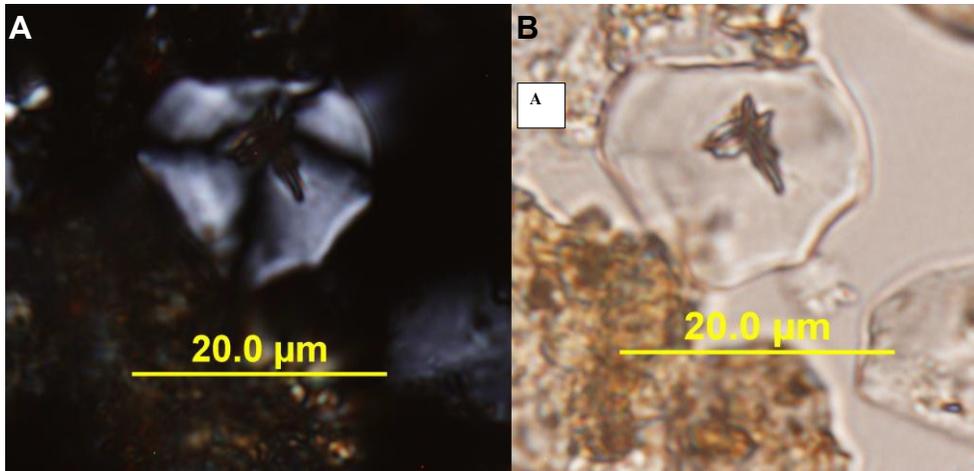


Figure 7.13: *Z.mays* ssp. *mays*. starch granules observed in carbonized food residue, soil and stone tools photographed under XPL and PPL light. (A, B) Windy Bead site.

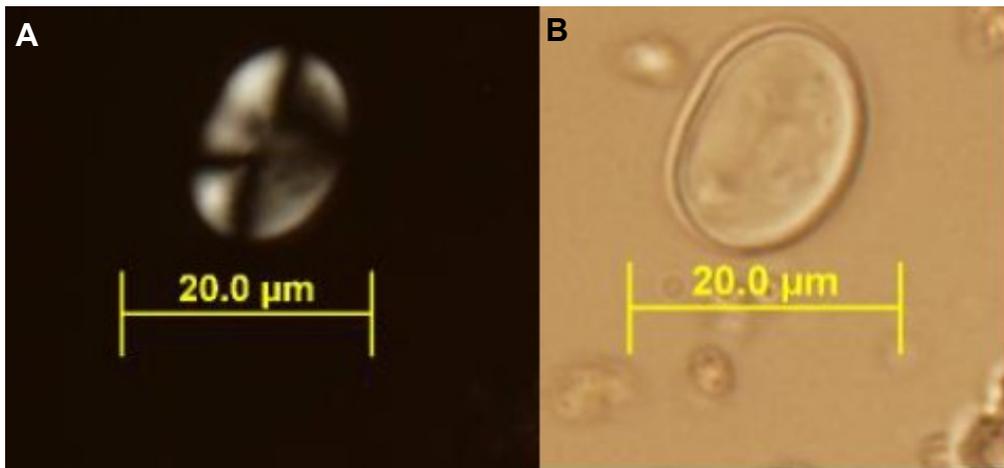


Figure 7.14: Possible *Phaseolus vulgaris* starch granule from a Big Rice soil sample. (A) XPL light, (B) PPL light.

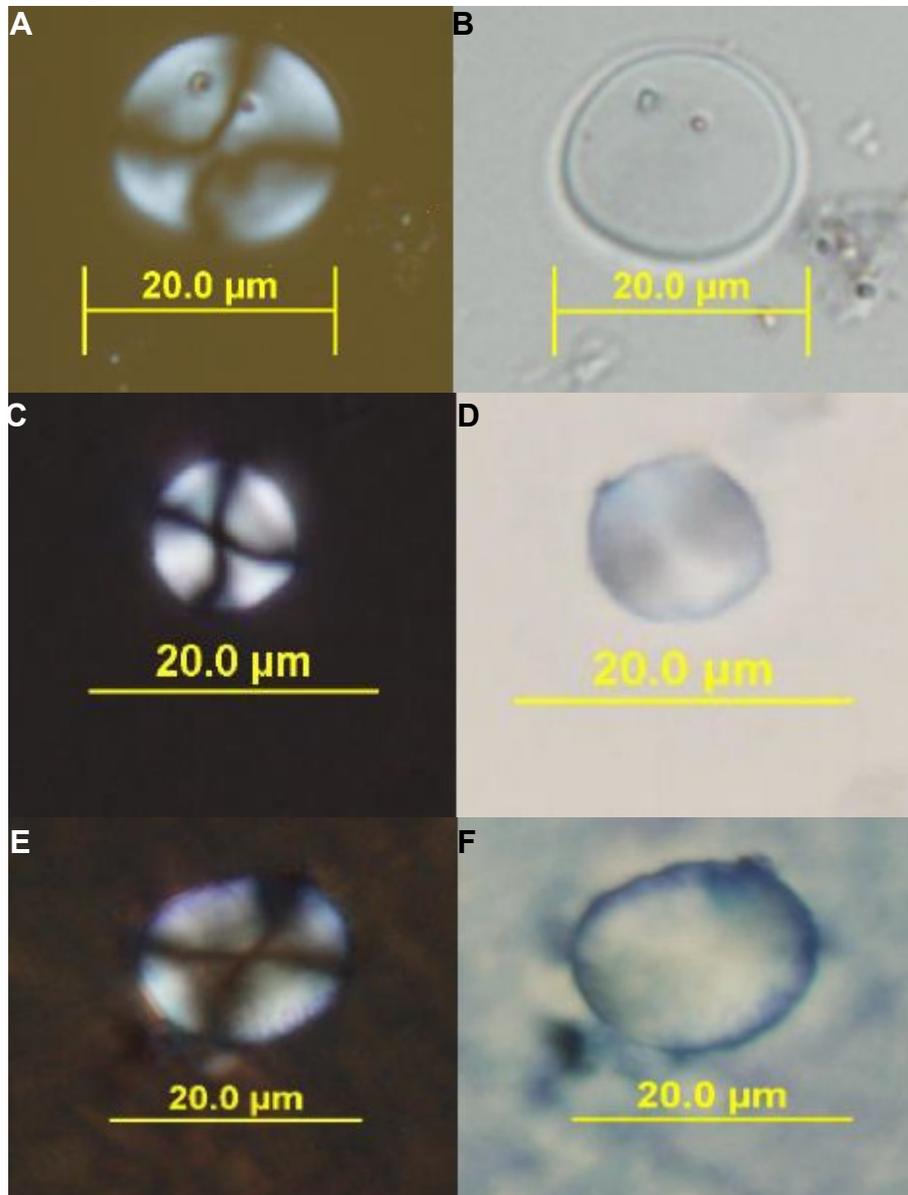


Figure 7.15: Possible *Cucurbita* sp. starch granules taken under XPL and PL light. (A, B) XPL and PL light photos taken from a Big Rice site soil sample. (C, D) Starch granules are from carbonized food residue originating from the Saga Island site. (E, F) Starch identified in carbonized food residue from the Windy Bead site.



Figure 7.16: (A) Squash seed collected during excavation at the Big Rice site (Peter and Motivans 1985). (B) Wild rice seed portion collected during excavation of the Big Rice site.

7.12 GRASS PHYTOLITHS

A large percentage of recovered plant microfossils were comprised of C3 and C4 grass species. It is difficult to interpret C3 and C4 plant presences from soil samples because of possible contamination depending on how far below the surface depth the samples were collected. The probability of cross-contamination is lower with lithics because residue deposited during milling becomes encased in micro-

fissures on grinding stones (Torrence and Barton 2006). However, contamination does occur with lithic residue, and any contamination can be assessed by comparing the lithic dry brush, wet brush and sonication samples. The phytolith distribution for the No Beard grinding stone is characterized by high amounts of Poid types, much smaller amounts of Chloridoid and low counts of Panicoid phytoliths (Figure 7.9). The sonicated samples contain lower amounts of grass phytoliths than the dry and wet brush overall, although the sonicated sample from the working edge has an even lower percentage of grass phytoliths than the other sonicated sample. Both sonicated samples contain a higher percentage of diatoms than the dry and wet brush. Similarly, the grinding stone from the Windy Bead site had a lower count of recovered grass phytoliths, and large quantities of unknown starch (Figure 7.9). Carbonized food residue provides an even less likely chance of cross-contamination because exterior residue becomes encrusted on ceramics, protecting underlying residue layers. Overall, the carbonized ceramic samples yielded higher quantities of Festucoid or Poid phytoliths, although Chloridoid phytoliths were present, as well as Panicoid phytoliths in very low amounts.

The extracted residue from all nine sites varied in size and resulting microfossils. The ceramics had the lowest samples sizes, while the sediment had the highest sample size. Many unknown phytoliths and starch granules were recovered, suggesting future work to develop extensive comparative keys. Diagnostic rondel phytoliths, and starch granules of *Zea mays* ssp. *mays* were identified, along with *Zizania* rondel phytoliths and possible *Phaseolus vulgaris* and possible *Cucurbita* starch.

8.0 INTERPRETATIONS AND DISCUSSION

8.1 INTRODUCTION

This chapter is divided into two sections. The first section discusses domesticated plant evidence recovered from the archaeological samples, and this is applied to the broader context of archaeobotanical literature. The second section reviews lines of evidence indicating whether trade, and/or local horticultural production of domesticated plants offer the most viable explanation for the microfossils found in Brainerd and Laurel components analyzed for this thesis. Interpretations and re-assessments of the floral component at archaeological sites in Northern Minnesota and peripheral locations tie together these two sections. Phytolith and starch content from all nine sites demonstrates a reliance on various floral species from the Northern Minnesota area, specifically maize, wild rice, and possibly beans, and squash. Extensive research on comparative material from the region, which is beyond the scope of this project, would allow specific species of wild plants to be better identified.

One of the objectives of this study is to reinterpret floral aspects of paleodiet at the nine sites in Northern Minnesota. Based on just the microfossils, there is no way to determine the relative importance of specific plants identified in my samples, as this would stretch the data. The literature suggests that over the course of the Middle Woodland and into the Late Woodland, the reliance on cultivated plants may have increased (Fritz 2011; Scarry and Scarry 2005; Syms et al. 2013). This increase could have been caused by expanding populations and group networks, which may have resulted in the trade of domesticated plants.

It is unlikely that the recovered microfossils are due to cross-contamination for a number of reasons. With ceramic samples, only the outside residue layer is exposed to surrounding sediment. The sediment is unlikely to have any modern contamination because starch does not move through soil at a great distance and some samples are located quite far below surface level (Haslam 2006). A ceramic sherd from the Saga Island site is in Level four, 20-25 centimetres below surface level. Groundstones contain microfissures that can trap plant remains and preserve them (Barton 2007; Zarrillo and Kooyman 2006). With the three different types of lithic extractions, wet-brush, dry-brush and sonication, it is unlikely that all three would yield modern contamination. Contamination can occur in the field from handling the artifacts after being in contact with modern food residue. However, it is improbable that cross-contamination from modern food residue affected all 33 ceramic and lithic samples used in this study. In addition, maize is the most likely source of modern contamination (Crowther 2014). In this study, two lines of evidence maize starch granules and phytoliths were recovered, greatly decreasing any possibility of modern contamination. The two lines of evidence decrease contamination risks, because in most cases modern contamination is recovered as either an abundance of maize starch, or maize phytoliths, but not both.

As discussed in Chapter 4, section 4.3.1, Brainerd ware dates are contested because of the early dates returned from samples obtained throughout Minnesota. Determining whether or not some of these dates are correct is not for the purposes of this thesis. For this study, the few dates obtained at the Northern Minnesota sites will not be used for interpretation of the cultigens recovered from plant microfossils.

Instead, the conventional Middle Woodland period dates of 100 BC to 500 AD will be used to interpret the timing of domesticated and native cultigen use.

8.2 MAIZE

Both carbonized and non-carbonized food residue from ceramics, lithics and soil samples yielded maize rondel phytoliths and starch granules (Figure 7.4, 7.6, 7.8). The Third River Borrow Pit, Big Rice, Windy Bead, Winnie Cottages, Saga Island and No Beard sites had samples that tested positive for *Z. mays* ssp. *mays* rondel phytoliths, and/or starch granules. It is worth noting that the sites testing negative for *Z. mays* ssp. *mays* (Kyleleen's Bent Pine, Kyleleen's Tall Pine, and Lost Lake) had samples with very thin carbonized residue and low sample weights. Therefore, it is possible that the absence of maize remains in these samples was an effect of small sample size. With the exception of three sites, all sites tested positive for maize indicating widespread consumption across the study area. While important, it is difficult to assess the importance of this plant to Laurel and Brainerd diet based on residue data alone.

The archaeological literature suggests that by the Late Woodland Period, maize began to play an increasingly large dietary role across the Upper Great Lakes and elsewhere (Boyd and Surette 2010; Lovis et al. 2001; Mt. Pleasant 2006; Scarry 2005). Isotope studies of human skeletal remains in the Eastern Woodlands by Vogel and Van der Merwe (1977) and Katzenberg et al. (1995) show an increase of maize consumption during the Woodland Period. Gibbon and Hohman-Caine (1980) argue that during the Middle to Late Woodland transition in Eastern Minnesota, populations switched from diffuse to local subsistence patterns. This

means that populations began to settle in areas for longer periods of time and narrow their subsistence base to include plant and animal species close to the area where they chose to settle. No previous micro-botanical evidence of cultigens has been recovered from Middle Woodland sites in eastern Minnesota, indicating that at this earlier time the subsistence reflected a “diffuse hunting-gathering strategy” (Gibbon and Caine 1980). This is the basis of the assumption that Aboriginal populations in Minnesota did not farm maize until Mississippian settlements moved into southern portions of the State around 800 AD to 1200 AD, well outside of the Middle Woodland time range (Gibbon and Caine 1980). However, a lack of evidence for maize cultivation during the Early to Middle Woodland does not necessarily mean that cultigens were not consumed. Indeed, as this study and others (Boyd and Surette 2010; Hart et al. 2003; Katzenberg et al. 1995) show, cultigens were widely consumed during the Middle Woodland period, from New York State to Northwestern Ontario.

There is some uncertainty about relying on macrobotanical remains to confirm the presence/absence of maize; however, both the macrobotanicals and microfossils provide important data about the timing and dispersal of maize. Occasional recoveries of maize and other plant macroremains in Early and Middle Woodland components in the Midwest have been interpreted by some as the result of postdepositional intrusion of later plant remains into these earlier contexts (Hart et al. 2003). This has caused some uncertainty in the timing of maize consumption based on macroremains. Macrobotanical remains deteriorate over time at a faster rate than plant microfossils. This leads to further uncertainty in the timing and

emergence of maize cultivation because the older the site, the less likely plant remains will be recovered (Hart et al. 2003). In addition, an excavation methodology that doesn't include the routine use of flotation will most likely not lead to the recovery of macrobotanicals. Archaeological components dating before the Late Woodland period generally do not have well preserved identifiable macroremains. This has formed the idea that maize cultivation doesn't appear until the Late Woodland (Crawford 2001; Lovis et al. 2001), and several authors have suggested that it may have been used non-intensively before this time (Adovasio and Johnson 1981; Crawford et al. 1997). The Meadowcroft Rockshelter in Pennsylvania contained maize cob fragments associated with charcoal deposits dating to 522 BC and 473 BC (Adovasio and Johnson 1981; Hart 2008). The Grand Banks site in Southern Ontario contained maize fragments directly dated to 1861-1416 BP 363 AD and 362 AD (Crawford et al. 1997; Hart 2008). The earliest maize macrobotanical evidence in New York State dates from AD 119 to AD 718–880 (Hart et al. 2007). Maize began to increase in importance in Southern Ontario during the Late Woodland, which is evident with Princess Point archaeobotanical remains (Crawford 2011). The dates obtained from macrobotanical remains suggest that maize was widespread in the Upper Midwest and Northeastern North America, and towards the Late Woodland, there is an increase of maize reliance and dispersal (Adovasio and Johnson 1981; Crawford et al. 1997; Crawford 2011; Hart et al. 2007; Hart 2008).

Microfossil analysis is changing past interpretations of geographic and temporal ranges of maize cultivation and its dietary importance to Woodland

populations. Microfossil data is also affecting the known ranges of the Three Sisters (maize, common bean and squash) when utilized together. Boyd and Surette (2010) used microfossil analysis to date maize consumption in Northwestern Ontario to the Middle Woodland (ca. 500 AD). A multi-proxy approach using AMS dating, phytolith and starch analysis and stable carbon isotope analysis dated maize to the seventh century AD in New York State (Hart et al. 2003). In addition, results from this study confirm the presence, processing, and cooking of maize during the Middle Woodland period in Northern Minnesota. This challenges the previous assumption of a sole reliance on native flora in northern regions of Minnesota during the Middle to early Late Woodland periods (Gibbon and Hohman-Caine 1980; Mason 2001).

8.3 WILD RICE

The combination of plant microfossils, macrobotanicals and ethnographic accounts suggest that wild rice was an important resource for populations in the Great Lakes-St. Lawrence area. Wild rice rondel phytoliths were recovered from the Big Rice, Saga Island, Lost Lake, No Beard and Windy Bead sites (Figures 7.4, 7.6, and 7.8). The sites where wild rice tested negative are the Third River Borrow Pit, Kyleleen's Bent Pine, Kyleleen's Tall Pine and Winnie Cottages sites. The results may be a product of microfossil analysis limitations, as wild rice rondel phytoliths can be morphologically varied, however; for this study, only four-spiked rondels with indented bases were used for positive identification of wild rice. The lack of support for wild rice in samples from Northern Minnesota is surprising considering a wide range of evidence suggesting intensive wild rice harvesting periods.

This wide range of evidence includes macrobotanical remains and

ethnographic records. Wild rice macrobotanical remains were recovered from the Big Rice site by other analysts (Valppu and Rapp 2000). A number of studies have also demonstrated the antiquity of wild rice in Minnesota lakes (Drewes 2008; McAndrews 1969; Vennum 1998; Yost and Blinnikov 2011). Wild rice was an important food source for Aboriginal people in this region as summarized in Chapter four, section 4.5. Some scholars have observed, furthermore, that wild rice and maize are complementary as both plants are high in carbohydrates, protein, iron, and B vitamins (Hart et al. 2003; Keane 1997; Vennum 1998). Another link between maize and wild rice consumption is the spiritual importance of both crops to Aboriginal populations (Wilson 1917; Vennum 1998). Using microfossil evidence, Thompson et al. (1994), and Valpuu and Rapp (2000) identified wild rice in Minnesota samples dating to 2,000 years. Vennum (1998) also provides ethnographic accounts of wild rice being harvested and consumed by Ojibway peoples in Northern Minnesota.

Wild rice, or *manoomin*, meaning 'good berry' or 'good seed' in Ojibway, was used ceremonially, as well as non-ceremonially. Historical and ethnographic accounts supplied by Vennum (1998) place wild rice in Aitkin County Minnesota, Big Rice Lake in the Mille Lacs area, Mud Lake in Northern Minnesota and Neds Lake in Anoka County, although it was probably present in many of Minnesota's shallow lakes and rivers. Wild rice has also been documented in Wisconsin, Michigan, Southern Ontario and Iowa. The Oneota in Wisconsin and the Huron in Southern Ontario harvested wild rice. Over 12 provinces and states report carbonized wild rice remains and prehistoric wild rice harvests are evident in South Dakota,

Tennessee, Alabama, Kentucky, Ohio, Pennsylvania, Ontario, and Illinois (Vennum 1998). In the Northeast United States, wild rice harvests may have begun around 600 BC and the productivity of wild rice stands would have fluctuated with climate change (Crawford 2011). Yost and Blinnikov (2011) recovered wild rice (*Zizania palustris* sp.) in Northern Minnesota bordering the Laurentian Mixed Forest and the Eastern Broadleaf Forest ecosystem (Arrigada 2006). In addition to microfossil studies and ethnographies, Drewes' (2008) summary of ecological reports states that Minnesota has 907 lakes with wild rice, which are located all over the state but tend to concentrate in Northern Minnesota around the northern portion of the Eastern Broadleaf Forest. Laurel populations also consumed wild rice in the Boreal Forests of Northwestern Ontario (Boyd et al. 2010; Surette 2008). The presence of wild rice in Northern Minnesota and adjacent Northwestern Ontario, suggests that wild rice was widespread and of great dietary importance to Northern Minnesotan populations during the Middle Woodland.

8.4 SQUASH AND COMMON BEAN

Possible squash (*Cucurbita* sp.) and common bean (*Phaseolus vulgaris*) were recovered in low amounts from four sites. Squash is difficult to identify due to the native plant confusers, so for the purposes of this study squash is only a possibility. Common bean is also only a possibility because, although the starch meets most of the diagnostic characteristics, it is not of the right size proportions for bean. The Saga Island, No Beard, Windy Bead and the Big Rice sites contain evidence of possible squash starch granules, and the Big Rice site has one squash seed originating from collected macrobotanical remains (Peters and Motivans 1983). The

Big Rice, No Beard and Lost Lake sites also have samples with recovered possible *Phaseolus vulgaris* starch granules.

As discussed above, *Cucurbita* sp. starch is similar to starch from a variety of wild plants making it difficult to discern; therefore, the starch granules found were identified as 'possible *Cucurbita* sp.' Squash phytoliths were not present in any of the ceramic, soil, or lithic samples. Squash phytoliths are only produced in the rind and stem, which are inedible plant portions, so it is unlikely that they would have been found in carbonized residue (Bozarth 1987). If the possible squash starch is actually squash, this may signify trade as opposed to small-scale agriculture because phytolith evidence is expected if squash was being cultivated. Although the squash seed at the Big Rice site supports small-scale agriculture, the minimal stratigraphic separation between occupations makes it impossible to place the squash seed temporally in the Middle Woodland Period. Squash seeds were also recovered from Late Archaic, 580 BC, deposits in Southeastern Minnesota and trade has been suggested with groups along the Upper Mississippi River Valley to obtain domesticated squash (Perki 1998). In the central Mississippi River Valley, some of the earliest squash macrobotanical remains date from AD 434–613 to 681–889 (Hart 2007a). The earliest evidence for squash in the eastern United States is from seeds in Illinois and Tennessee dating around 5050 BC (Hart 2008; Smith 1992). In Maine, macrobotanical remains of a squash rind dated around 4767-4345 BC (Hart 2008; Petersen and Asch Sidell 1996). Squash rinds from the Plains Nebo Hill site were AMS dated to the Late Archaic (2169 BC and 2200 BC) (Adair and Drass 2011). *Cucurbita pepo* rinds and seeds have been recovered from more Late

Archaic than Early Woodland contexts in the Eastern Woodlands (Adair and Drass 2011). Archaeological evidence suggest a hiatus in which Archaic populations intensely cultivated cucurbits. This activity may have lessened towards the Early Woodland and resumed during the Middle Woodland (Pauketat 2004). *Cucurbita pepo* may be one of the oldest plants cultivated in the Eastern Woodlands (Smith 2011), and towards the Late Woodland Period, the significance of this plant may have increased with development of the Three Sisters cultivation system.

Possible evidence of common bean (*Phaseolus vulgaris*) was present at the Big Rice site, where maize and possibly squash was also identified from various forms of microfossil evidence. The lack of bean phytoliths in food residue is not surprising because bean phytoliths are only produced in bean pods and only the seeds may have been present at sites (Lints 2012). Based on these lines of evidence, it is possible that the Three Sisters crop system was in place by the Middle Woodland Period; however, this view is speculative until further analysis connects the three major economic crops at Northern Minnesota sites.

The archaeological literature suggests that beans did not arrive until the Late Woodland in the Midwest (Fritz 2011; Hart and Scarry 1999). Reasons why it may have been the last of the Three Sisters to arrive could have been the result of traditional trade networks and/or a conscious choice. Beans are also more susceptible to spring frost and require a longer growing season, making them less viable in more northerly settings (Boyd et al. 2014). Despite the limitations for bean cultivation and consumption in more northerly locations, results in this thesis and those collected by Lints (2012) show that beans predate the Late Woodland in some

locations. Beans are difficult to identify at sites because they are not charred as much as other cultigens, affecting how they preserve compared to other plant remains. The poor preservation of beans at locations where organic remains already have a low survival rate may be affecting the perceived antiquity of bean in the Midwest. Beans have been dated to 1250 to 1300 AD in the central Mississippi Valley (Fritz 2011) and 1200 AD in the Northeastern Woodlands (Hart et al. 2002). In addition, macrobotanical evidence for bean consumption has been recorded at the Round Top site in New York dating to 1273-1400 AD (Hart 2008). Over 24 sites with 35 *Phaseolus vulgaris* remains have been dated to pre-1300 AD in the Northeast United States. In the eastern Central Plains bean macroremains were AMS dated to around 1100 AD (Adair n.d). Common bean appears to arrive last to regions with the Three Sisters agricultural system. They were consumed earlier in the Eastern Woodlands, and Central Plains, and are less utilized less in the Mississippi Valley, where macroremains yield younger dates.

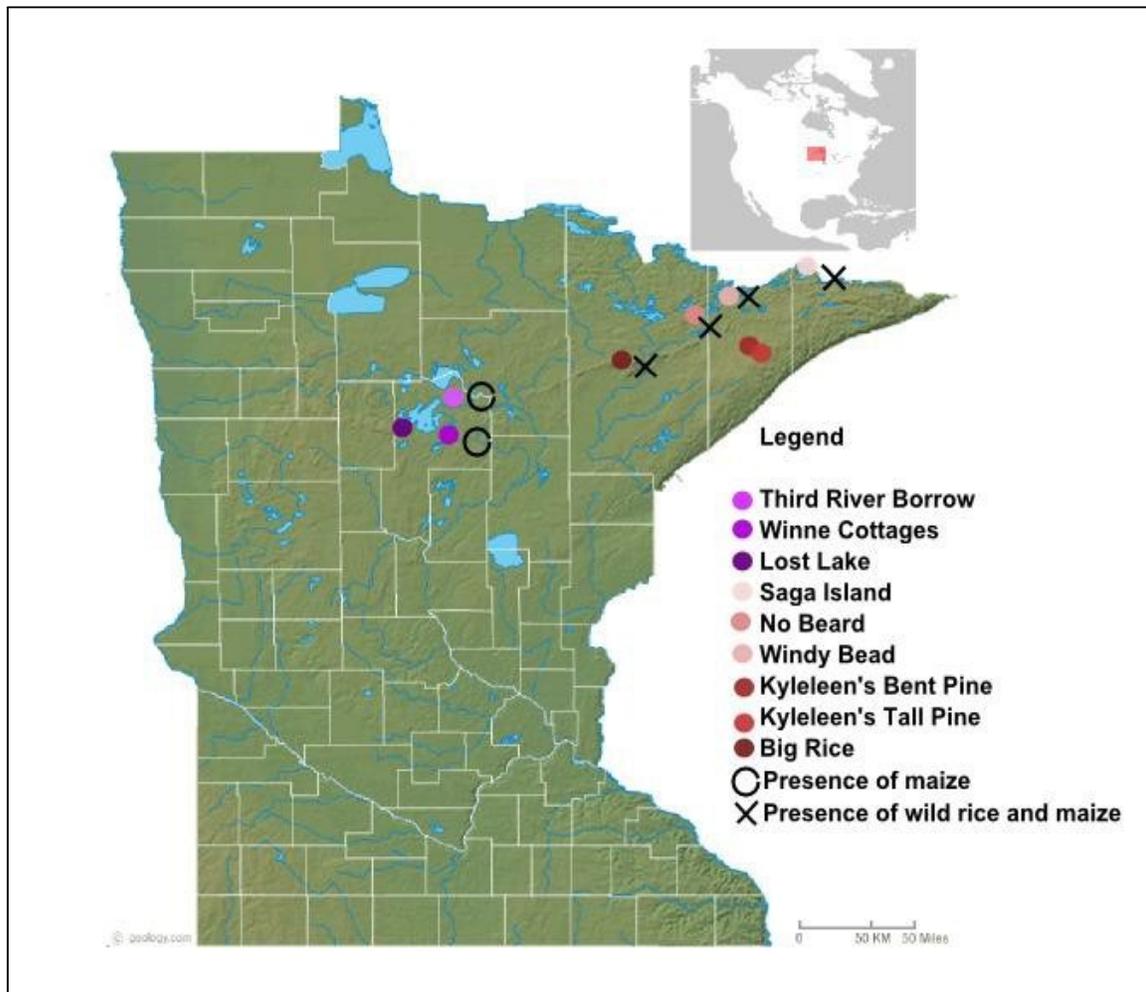


Figure 8.1: Areas of positive plant identification based on microfossil data collected from Middle Woodland occupations in Northern Minnesota sites.

From the microfossil results obtained in this study, it is clear that Brainerd and Laurel populations consumed a wide array of plant species, both cultivated and wild. Greaves and Kramer (2014) outline mixed economies and the role of cultivated and native plants in the hunter-gatherer diet. Their research has shown that cultivated plants offer similar nutritional and foraging values to wild plants, and the reliance on both could be a sign of diversified diets with fall back strategies. Greaves and Kramer (2014) use the term fall back strategies to describe foods that may be used

as back-up in unpredicted times of food scarcity when the main sources of nutrition are missing. The authors comment that cultivated foods with no nutritional, or taste advantage, may be used as fall-back strategies. In addition, cultigens were around thousands of years prior to the advent of agriculture in some areas. The replacement of wild foods by cultivated ones varies, and this is determined by environments with the possibility for agriculture (Greaves and Kramer 2014). The populations inhabiting Northern Minnesota may have used mixed economic strategies such as the ones explained by Greaves and Kramer (2014). Wild rice was a possible main food source that was supplemented by fall-back cultigens such as maize, beans, and squash. The results from this study may be another classic example of archaeological data indicating a mix of food production and foraging economies, with low-level use of cultigens and foraging (Greaves and Kramer 2014).

8.5 CULTIGEN ACQUISITION

Determining cultigen acquisition is complex and involves looking at the archaeological record in terms of trade versus farming. Based on my results there are no conventional signs of farming at the Minnesota sites. Due to a lack of evidence for farming, this section will present a series of scenarios supporting trade with surrounding horticultural groups. The first scenario describes possible trade with groups in Southern Minnesota. Scenario two discusses trade during the Middle Woodland period with the rise of Hopewellian exchange networks in the Central Mississippi Valley (Crawford 1997; Fritz 2000). The third scenario touches on

Oneota connections with groups in Southern Minnesota and evidence of macrobotanical remains from Oneota sites. The last scenario covers possible trade connections with groups in Northwestern Ontario and the Northeastern Plains.

Conventional signs of farming can include agricultural tools, macrobotanicals, and microfossil evidence. One of the clear indicators of maize farming is pollen, which was not recovered in any of the nine sites. Pollen from *Z. mays* ssp. *mays* is extremely rare, preserves in lake and wetland environments and does not travel far due to its relatively large size and high specific density (Fearn and Liu 1995). Since maize pollen is extremely rare in cores and food residue contexts, the case for maize agriculture is difficult to make; however, the rarity of maize pollen might suggest that although no evidence was collected, that does not mean it was not there. The relative infancy of micro-botanical studies means that further work may build sample sizes and the recovery rate of maize pollen. Despite the rarity of maize pollen, it does not travel far from the original source. Therefore, the absence of maize pollen opposes any argument of small-scale maize agriculture during the Middle Woodland period in Northern Minnesota.

Maize starch granules and wavy-top rondel phytoliths were identified from residue adhering to two grinding stones. These stone tools were used specifically for grinding, with one tool having a visibly worked edge (Figure 7.2; Figure 7.3). The presence of maize starch granules on both tools from the Windy Beard and No Beard sites, and a rondel phytolith from the No Beard site, may suggest maize processing at both locations. Although maize processing is a possibility, it is difficult to interpret whether the maize was obtained through trade or locally grown. In either situation,

the maize is processed in a similar way. Whether maize is obtained locally or through trade, the kernels would still need to be milled so the presence of microfossils on the stone tools does add any perspectives to the argument of trade, or small-scale agriculture.

Wilson's (1917) ethnographic account of Buffalo Bird Woman, a Hidatsa agriculturalist, provides insight into how maize was produced and prepared for storage and trade. When the corn ripened in the fields it was husked by the entire community, a process that lasted about ten days. Corn was strung together and dried on drying stages, and often they were braided to prevent the wind from shelling out the dry kernels. After the corn had dried, the grain was removed from the cob by threshing. Historically there were many goods flowing throughout the Upper Great Lakes, one example is trade connections between the Sioux and Hidatsa. The Sioux and others sought out the agricultural goods of the Hidatsa villages and were known to trade one tanned buffalo robe for a string of braided corn (Wilson 1917). Evidently, corn kernels were removed from the cob prior to trade and storage, a practise that would have decreased the number of rondel phytoliths adhering to the final product. Transporting corn kernels is much easier than transporting the entire cob so it is likely that *Z. mays ssp. mays* microfossil counts would be much lower at locations where populations are receiving agricultural goods, rather than producing them. This strengthens the case for trade with external groups, although local agriculture should not be ruled out based on the plant microfossils recovered in this thesis.

The *Cucurbita* sp. seed found at the Big Rice site is consistent with the

identification of the squash starch, although the seed dates are uncertain. Phytoliths produced in the squash rind are typically found at locations where production is taking place (Bozarth 1987). The lack of *Cucurbita* sp. phytoliths in the samples, and other indicators of local cultivation may support trade up the Mississippi corridor, as opposed to small-scale cultivation (Perkl 1998).

The Headwater Lakes Region, which is where a few of the nine study sites are located, is heavily forested with numerous lacustrine sources (Gibbon 1994). Gibbon (1994) argued that this environment would have been unsuitable for maize horticulture, and instead locals relied on the extensive wild rice stands. The environment is unsuited for maize agriculture because of the relief and heavily forested area. Wild rice parching pits were excavated at the Big Rice site and numerous wild rice macrobotanical remains were recovered (Valppu and Rapp 2000). The topography is rocky at most sites and some of the modern vegetation includes young balsam poplar, willow, spruce, jack pine and a variety of berry species. The Big Rice, Third River Borrow Pit, Windy Bead and No Beard are some of the larger sites considered in this study. Most of the sites are described as semi-permanent occupations, where populations would settle to take advantage of seasonal resources like fish, or wild rice. Although the nine sites in this study are not in areas well suited for agriculture, small-scale seasonal cultivation should not be ruled out completely. Instead, conventional archaeological evidence recovered in the future will pin point when agricultural procurement of the Three Sisters began during the Woodland Period in Northern Minnesota.

The described scenarios in this section outline connections from surrounding

cultural groups to Northern Minnesota, which may explain cultigen acquisition in small, northerly sites. There are a number of cultural connections evident from morphologically similar technologies and burial practises throughout the Midwest United States. Another aspect of these interactions includes the trade of domesticated crops such as the Three Sisters. The first scenario outlined in this section describes the trade of cultivated plant species from Southern to Northern Minnesota using the river systems of the Upper Mississippi River Valley (Perkl 1998; Crawford 1997). The Upper Mississippi Valley is located between the headwaters of the Mississippi River in Lake Itasca and the junction of the Mississippi and Iowa Rivers (Gibbon 1994). An imaginary line separates the wild rice harvesters of Northern Minnesota and the gardeners of Southern Minnesota and Iowa (Gibbon 1994). Southern Minnesota has a milder climate than Northern Minnesota and during the Middle Woodland gardening was fully implemented in Southern Minnesota (Gibbon 2012). Towards the Late Woodland, agricultural procurement began to increase, as seen in the recovery of carbonized maize from Plains Village sites such as Oakwood Lakes, southwestern Minnesota (Anfinson 1997). The next two scenarios describe the possible exchange of domesticated cultigens from the Mississippi Valley and the Midwest United States to populations in southern Minnesota.

Trade or cultural diffusion was thought to have occurred from Hopewellian centers, several of which are located in the Mississippi Valley (Mason 1970). This would have made trade with Northern groups in the Upper Mississippi Valley feasible through the lake and river systems of Minnesota. By 550 BC, the Three

Sisters were established in the Mississippi Valley. *Zea mays* ssp. *mays*, *Phaseolus vulgaris*, and *Cucurbita* sp. were brought in from the Southwest United States where cultivation began by 2000 or 1500 BC. The Mississippi Valley domesticates later diffused into the Northeastern Woodlands (Lockard 2008). A Middle Woodland period Hopewellian center was located in northwestern Missouri and this is considered the most westerly example of Hopewellian influence in North America. Large villages were situated along Missouri River tributaries and radiocarbon dates suggest the establishment of Kansa City Hopewell sites around AD 1, lasting until AD 500 (Johnson and Johnson 1998). Maize and squash were confirmed at these Hopewellian sites around AD 250 (Adair 1988). Maize cob fragments, cupules and kernels were recovered from Middle Woodland Kansa City Hopewell sites and Adair and Drass (2011) comment that this may indicate the northward spread of maize from the Central Plains. *Cucurbita pepo* has been directly AMS dated from Hopewellian occupations during the Middle Woodland (Adair and Drass 2011). Interaction with eastern Hopewellian centers in the Illinois River Valley is suggested by similarities in projectile-point and ceramic morphology (Johnson 1998). The large amount of macrobotanical evidence from Hopewellian sites confirms how widespread maize cultivation was in the Mississippi Valley, and how easily exchanged it was with northern groups.

Oneota components are present at a number of Late Woodland sites in Southwestern Minnesota, and horticulture was widespread in Oneota and related Midwestern cultures (Anfinson 1997). Oneota is referred to as a culture that links the East with the West and is located throughout the Prairie Peninsula. Oneota

peoples are defined by maize cultivation primarily, although there is also evidence of squash, sunflower, beans and native plants at Oneota sites (Egan-Bruhy 2013; Henning 1998). During the Late Woodland period, the Blue Earth Region in Southern Minnesota reveals evidence of Oneota burial practises (Henning 1998). Again, this reflects the northwards movement of plant cultigens from southern groups up the waterways of Minnesota.

Other speculation supporting how Brainerd and Laurel populations may have obtained domesticated plants includes interactions with populations on the northeastern Plains during the Middle Woodland period (Figure 8.2).



Figure 8.2: Avonlea Complex distribution (Hamilton et al. 2011; Department of Economics and Geography, Hofstra University).

Laurel and Avonlea populations may have traded for food resources, evident from cultural connections between the two groups (Meyer and Hamilton 1994).

Laurel and Avonlea groups were contemporaneous in some areas and may have had extensive trading networks between temperate and subarctic/boreal environments (Meyer and Hamilton 1994; Meyer and Walde 2009). Laurel populations are known for wild rice cultivation (Valppu and Rapp 2000) and the results from this study and Boyd and Surette (2010) demonstrate a subsistence economy reliant upon maize, wild rice and possible squash and beans. Boyd and Surette's (2010) study of Laurel food residue in northwestern Ontario proposed trade, as opposed to small-scale agriculture, as an explanation for the presence of maize in the most northerly Woodland sites. Lints (2012) study found large quantities of bean starch in most Avonlea sites tested on the Northern Plains, and it is speculated that trade might have occurred between contemporaneous Laurel and Avonlea populations. Ceramics with a mix of Avonlea and Laurel traits were also collected at the Gravel Pit site in Saskatchewan demonstrating close cultural connections between the two groups (Meyer and Walde 2009).

An important aspect of understanding cultural connections and the possible trade of cultivated plants is to acknowledge parallels between Brainerd, Laurel, and Avonlea ceramic technologies. When the production of Brainerd ware ceased, Avonlea pottery emerged in the second or third century AD, appearing in the parklands and prairie border northwest of Brainerd sites (Hohman-Caine and Goltz 1995). However, these wares may not be sequential at all and some unsurveyed areas dating to the same time may contain both wares, suggesting that Avonlea and Brainerd were contemporaneous (Hohman-Caine and Goltz 1995).

It is hypothesized that parallel-grooved and net-impressed ceramics associated

with Avonlea groups originated from southern localities, such as Manitoba and Minnesota (Norris 2007). Avonlea sites on the north-eastern Plains have higher counts of maize and beans, than Laurel sites in northwestern Ontario (Lints 2012). Wild rice may have been traded with Avonlea populations for maize and/or beans (Boyd et al. 2014) since both plants are lightweight, easily stored and transported (Lints 2012). In addition, Avonlea populations may have intercepted wild rice stands in the southern Boreal Forest at some times of the year (Boyd et al. 2014). Food residue results collected in Northern Minnesota, northwestern Ontario, and the northeastern Plains shows the widespread consumption, and in some locations small-scale agriculture of the Three Sisters, in addition to wild rice, during the Middle to Late Woodland in Northcentral North America (Boyd and Surette 2010; Lints 2012).

The results from Middle Woodland sites included in this thesis indicate a dietary reliance on native plants, possibly including the Three Sisters. However, there is lack of supporting evidence for agricultural procurement of the Three Sisters. Connections with southern groups along the Mississippi Corridor and less direct contact with Avonlea populations on the Northern Plains would make trade feasible for obtaining crops that were not locally grown, such as maize, beans, and squash. Wild rice was locally grown and may have been traded as a means of obtaining non-local floral species and other goods. Botanical remains discussed in site reports from the study area are limited, typically including only modern flora. Poor preservation due to acidic soils constricts the available data on plant use, but alternate food residue analysis methods such as phytolith and starch analyses have

redefined archaeobotanical knowledge of the Middle Woodland Period in the Northern Minnesota area (Figure 8.1). This redefines how we think about ancient hunter-gatherers in the context of small northerly sites, which may be subject to a misinterpretation of subsistence due to the lack of macrobotanical remains. This study has demonstrated the importance of looking for invisible botanical information, that could potentially re-define the hunter-gatherer label placed on many small, northerly sites and re-interpret site data to reveal a mixed economic strategy reliant on a wide range of domesticated and native cultigens.

9.0 CONCLUSIONS

Current research on plant-based subsistence in eastern North America is continuously pushing back the entry dates of local plants and non-native cultigens such as the Three Sisters. In addition, new data has reinvented the idea that past populations of the region were mobile hunter-gatherers during the Archaic and sedentary horticulturalists during the Woodland Period (Kuehn 1998). Recent studies in the Eastern Woodlands have pushed back the introduction of native cultigens to the Late Archaic (Crawford 2011; Yarnell 1993). These cultigens were not uniformly introduced across the entire region, and may have appeared sporadically until cultivation intensified during the Late Woodland. New dates for wild squashes, sunflower, sumpweed and chenopod show that these species were domesticated before 900 BC, and utilized during the Late Archaic (Fritz 1993; Yarnell 1993).

The introduction of the Three Sisters (maize, beans and squash) occurred at different times during the Woodland Period. It is theorized that beans arrived last, while squash and maize arrived sometime during the Middle to Late Woodland from the Southwest United States. Current research has also readdressed these models and pushed back the entry of domesticated cultigens in the Boreal Forest, Northern Great Plains, and Great Lakes (Boyd et al. 2014; Mulholland 1993; Perki 1998). Ethnographic accounts after European contact record intense agricultural activity in relation to these crops and extensive trade networks (Adair and Drass 2011; Wilson 1917). Evidently, the presence of the Three Sisters drastically affected the diets and subsistence base of Woodland populations, fully transforming societies from

foragers of the Early Woodland to agriculturalists of the Late Woodland (Hamilton et al. 2011; Scarry 2005).

Not much research on early subsistence strategies had been completed in Northern Minnesota, due to small site sizes, poor organic preservation, and other factors. Soils in Northern Minnesota prevent the preservation of macrobotanicals and other organic remains, causing a low recovery rate of plant remains and fauna. Phytolith and starch analysis has confirmed the consumption of these cultigens in some areas of Northern Minnesota. The microfossil counts and diagnostic types found on 31 ceramic samples, two grinding stones and five soil samples from nine sites dispersed across Northern Minnesota indicate widespread plant use.

The presence of maize phytoliths at half of the sites, along with starch granules indicates that it was consumed in Northern Minnesota. The earliest evidence of maize came from the Third River Borrow Pit site on a horizontally-corded Brainerd sherd dating to 390 BC. Maize was also confirmed on Laurel sherds at the Big Rice and Saga Island sites, pushing back the entry date for maize to 280 AD. This gives an accurate representation of when maize cultigens may have been exchanged with external populations, and predates maize consumption by groups in northwestern Ontario and the northeastern Plains (Boyd et al. 2014).

The presence of possible squash (*Cucurbita* sp.) and domesticated bean (*Phaseolus vulgaris*) on Laurel material may indicate trade. Squash was thought to have been carried up the Mississippi Corridor to Southeastern Minnesota during the Archaic (Perki 1998). Microfossils identified in the form of phytoliths confirms that squash was present in Northern Minnesota prior to 500 AD, so it was likely traded

with Southern Minnesotan groups who established it during the Late Archaic, or even earlier in time (Perkl 1998).

Interpretations made with bean starch granules will be considered speculative until more evidence is found; however, this puts the estimated date for the introduction of bean to 500 AD from the prior date of 1300 AD (Hart et al. 2002). Beans are still considered the last of the Three Sister crops to significantly influence the diets of Woodland populations. It is clear from evidence presented in this study and others, that beans could have been utilized across much of the subarctic, Canadian Plains and Northeastern Woodlands prior to AD 500 (Hart et al. 2002; Lints 2012).

A wide array of native plants and wild rice were present in Brainerd and Laurel contexts, as shown with this study. Wild rice has already been confirmed in Northern Minnesota and around the Lake Superior Basin; evidence of wild rice from this study readdresses the dietary importance of wild rice to Middle Woodland populations (Boyd and Surette 2010; Valppu and Rapp 2000; Wilcox 2007; Yost et al. 2013). The development of local comparative keys from Northern Minnesota would greatly aid the interpretation and species identification of some of these wild plants. Ethnographic accounts and macrobotanical remains suggest the reliance on a wide variety of berries, nuts, wild fruits and vegetables (Marles et al. 2000; Simon 2009).

Previous research describes Brainerd and Laurel populations as hunter-gatherer/foragers generally subsisting on wild rice, local plants and a wide variety of mammals. Seasonal rounds would have been made to exploit these resources, and

wild rice would often be stored for winter months (Shafer 2003; Wilson 1917). Food residues analyzed in this study supports this subsistence model and in addition shows a wider variety of plant consumption than previously assumed. Wild rice has been present in Northern Minnesota for the last 10,000 years, although the presence of wild rice would have fluctuated with climate. Recovered *Zizania* phytoliths and charred remains indicate local harvesting. Similar to maize, domesticated squash was possibly traded; evidence includes starch granules and a seed found at the Big Rice site. Bean evidence in the form of starch granules suggests that they were likely traded as no other microfossils were recovered. Based on the comparison of microfossils from all nine sites investigated in this study, not all populations subsisted on the same plant species or engaged in their trade. More research using microfossil analysis should be carried through to aid in interpreting and defining the extent of trade versus local agriculture at other Northern Minnesota sites. Wild rice was possibly a key asset for these Middle Woodland populations to obtain non-native resources such as the Three Sisters.

Brainerd and Laurel populations inhabited Northern Minnesota from roughly 100 BC to 500 AD, representing a time when both domesticated cultigens and wild rice were paired in a mixed economic approach. The presence of maize and possibly squash and beans throughout the nine sites in Northern Minnesota has altered the archaeological discourse in Northern Minnesota by identifying when and where the Three Sisters began to emerge through trade. In addition, the resulting interpretations have confirmed the widespread use of wild rice and native plants that would have been of economic importance before the spread of agriculture during the

Late Woodland Period. This study extends evidence of known plant use in Northwestern Ontario, the Canadian Plains, north-eastern Plains, and the Eastern Woodlands by identifying another northerly location of early use of the Three Sisters paired with wild rice. These data are refined because in most locations, microfossil analysis has never been completed and a limited knowledge of plant use before European contact was common. Future research should aim to reconstruct notions of paleodiet with a multi-proxy approach at sites pre-dating the Woodland Period.

REFERENCES

- Adair, J. M.
n.d. *Defining Central Plains Agriculture: The Arrival of the Common Bean (Phaseolus vulgaris)*. Museum of Anthropology, University of Kansas.
- Adair, J. M.
1988. Prehistoric Agriculture in the Central Plains. Publications in *Anthropology* 16, University of Kansas, Lawrence, Kan.
- Adair, M. and Drass, R.
2011. Patterns of Plant Use in the Prehistoric Central Plains and Southern Plains. In B. Smith. ed. *The Subsistence Economies of Indigenous North American Societies*. Washington: Smithsonian Institute Scholarly Press, 330-352.
- Adovasio, J. M. and Johnson, W. C.
1981. The appearance of cultigens in the upper Ohio Valley: A view from Meadowcroft Rockshelter. *Pennsylvania Archaeologist* 51(1-2), 63-80.
- Ahlegren, F. I. and Ahlegren, E. C.
1965. Effects of Prescribed Burning on Soil Microorganisms in a Minnesota Jack Pine Forest. *Ecology* 46(3), 304-310.
- Anderson, Y. R., Bradbury, P. J. and Dean, E. W.
1993. Elk Lake in Perspective. In *Elk Lake, Minnesota: Evidence for Rapid Climate Change in the North-Central United States*, ed. Bradbury, Platt. J and Dean, E. Walter, 1-6. The Geology Society of America, Inc, Boulder, Colorado.
- Anfinson, F. S.
1979. *A Handbook of Minnesota Prehistoric Ceramics*. Occasional Publications in Minnesota Anthropology No. 5. Fort Snelling: Minnesota Archaeological Society.
1997. *Southwestern Minnesota Archaeology: 12,000 Years in the Prairie Lake Region*. Minnesota Historical Society Press.
- Archibold, O. W., Weichel, J. B. and Fitzgibbon, E. J.
1985. Factors in the Ecology of Wild Rice in Northern Saskatchewan. *The Canadian Geographer* 29(2), 100-112.
- Arnott, J. H. and Webb, A. M.
2000. Twinned Raphides of Calcium Oxalate in Grape (*Vitis*): Implications for Crystal Stability and Function. *International Journal of Plant Sciences* 131(1), 133-142.

- Arrigada, J. E.
2006. Plant Communities of Lake Ogechie, Mille Lacs Co., MN. Unpublished Report. Department of Biology. Saint Cloud State University, St. Cloud, MN. 56301.
- Arzigian, C.
2008. *Minnesota Statewide Multiple Property Documentation Form for the Woodland Tradition*. University of Wisconsin-La Crosse: Minnesota Department of Transportation, Mississippi Valley Archaeology Center.
- Babot M. del. P.
2003. Starch Grain Damage as an Indicator of Food Processing. In *Phytolith and Starch Research in the Australian-Pacific-Asian Regions: The State of the Art*. Papers from a conference held at The Australian National University, August 2001, Cranberry, Australia.
- Bartlein, J. P., and Watts A. W.
1993. Paleoclimatic Interpretation of the Elk Lake Pollen Record. In Bradbury, Platt, J. and Dean, E. Walter. eds. *Elk Lake, Minnesota: Evidence for Rapid Climate Change in the North-Central United States*. Boulder, Colorado: The Geology Society of America Inc, 275-294.
- Barton, H.
2007. Starch residues on museum artefacts: implications for determining tool use. *Journal of Archaeological Science* 34, 1752-1762.
- Barton, H. and Fullagar, R.
2006. Microscopy. In Torrence, R. and Barton, H. eds. *Ancient Starch Research*. Walnut Creek: Left Coast Press Inc, 47-52.
- Benz F. Bruce.
2006. Maize in the Americas. In John E. Staller, Robert H. Tykot, Bruce F. Benz. eds. *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Biogeography, Domestication and Evolution of Maize*. San Diego and New York: Elsevier Academic Press, 9-18.
- Berman, J. M. and Pearsall, M. D.
2008. A the Crossroads: Starch Grain and Phytolith Analyses in Lucayan Prehistory. *Latin American Antiquity* 19(2),181-203.
- Bernal, R. G., Tlusty, B. Estevez de Jensen, C. van Berkum, P. Graham, P. H.
2004. Charactersitics of Rhizobia Nodulating Beans in the Central Region of Minnesota. *Canadian Journal of Microbiology* 50(12), 1023-1031.

- Birks, B. J. H.
1976. Late-Wisconsinan Vegetational History at Wolf Creek, Central Minnesota. *Ecological Monographs* 46, 395-429.
- Bishop, E. H.
2007. *Lake Superior: The Ultimate Guide to the Region*. Duluth, Minnesota: Lake Superior Port Cities, Inc.
- Blake, M.
2006. Dating the Initial Spread of *Zea mays*. In John E. Staller, Robert H. Tykot, Bruce F. Benz. eds. *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Biogeography, Domestication and Evolution of Maize*. San Diego and New York: Elsevier Academic Press, 55-72.
- Blitz, J. H.
1988. Adoption of the Bow in Prehistoric North America. *North American Archaeologist* 9(2), 123-145.
- Boyd, M., Running, IV. G. and Havlom, K.
2003. Paleoecology and Geochronology of Glacial Lake Hind During the Pleistocene- Holocene Transition: A Context for Folsom Surface Finds on the Canadian Prairies. *Geoarchaeology: An International Journal* 18(6), 583-607.
- Boyd, M.
2005. Phytoliths as Paleoenvironmental Indicators in a Dune Field on the Northern Great Plains. *Journal of Arid Environments* 61, 357-375.
- Boyd, M., Surette, C. and Nicholson, B. A.
2006. Archaeobotanical Evidence of Prehistoric Maize (*Zea mays*) Consumption at the Northern Edge of the Great Plains. *Journal of Archaeological Science* 33, 1129-1140.
- Boyd, M., Varney, T. Surette, C. and Surette, J.
2008. Reassessing the northern limit of maize consumption in North America: stable isotope, plant microfossil, and trace element content of carbonized food residue. *Journal of Archaeological Science* 35, 2545-2556.
- Boyd, M. and Surette, C.
2010. Northernmost Precontact Maize in North America. *American Antiquity* 75(1), 117-133.

- Boyd, M., Lints, A. Surette, C. and Hamilton, S.
2014. Wild rice (*Zizania* spp.), the Three Sisters, and the Woodland Tradition in Western and Central Canada. In Maria E. Raviele and William A. Lovis. eds. *Reassessing the Timing, Rate and Adoption Trajectories of Domesticated Use in the Midwest and Great Lakes*. Special Paper No. 8. Midwest Archaeological Conference, Inc.
- Bozarth, R. S.
1987. Diagnostic Opal Phytoliths from Rinds of Selected Cucurbita Species. *American Antiquity* 52(3), 607-615.

1990. Diagnostic Opal Phytoliths from Pods of Selected Varieties of Common Beans (*Phaseolus vulgaris*). *American Antiquity* 55(1), 98-104.

1992. Classification of opal phytoliths formed in selected dicotyledons native to the Great Plains. *Phytolith Systematics Advances in Archaeological and Museum Science* 1, 193-214.

1993. Maize (*Zea mays*) Cob Phytoliths from a Central Kansas Great Bend Aspect Archaeological Site. *Plains Anthropologist* 38(146), 279-286.
- Brad C.
2013. www.Geology.com. "Minnesota Physical Map." *Geoscience News and Information Geology.com* N.p., Web. June 17, 2014
- Bradury, P. J., Dean, E. W. and Anderson, R. Y.
1993. Holocene Climatic and Limnologic History of the North-Central United States as Recorded in the Varved Sediments of Elk Lake, Minnesota: A Synthesis. In Bradbury Platt, J. and Dean E. Walter (eds) *Elk Lake Minnesota, Evidence for Rapid Climate Change in the North-Central States*. Special Paper 276. The Geological Society of America, Inc, 309-329.
- Brandzin-Low, V.
1997. *The distribution and characteristics of Laurel ceramics from northern Manitoba: a comparative study*. MA Thesis, University of Saskatchewan Department of Anthropology and Archaeology.
- Brown, A. Dwight.
1984. Prospects and Limits of a Phytolith Key for Grasses in the Central United States. *Journal of Archaeological Science* 11, 345-368.
- Buckler, E. S. and Stevens, N. M.
2005. Maize origins, domestication, and selection. In Motley, T. J., Zerega, N. and Cross, H. eds. *Darwin's Harvest*. New York: Columbia University Press, 67-90.

- Bunzel, M., Allerdings, E. Sinwell, V. Ralph, J. and Steinhart, H.
2002. Cell Wall Hydroxycinnamates in Wild Rice (*Zizania aquatica* L.) Insoluble dietary fibre. *European Food Research and Technology* 214, 484-488.
- Chandler-Ezell, K. and Pearsall, M. D.
2003. Piggyback microfossil processing: joint starch and phytolith sampling from stone tools. *The Phytolitharien* 15, 2-8.
- Crawford, W. G., Smith, G. D. and Bowyer, E. V.
1997. Dating the Entry of Corn (*Zea mays*) into the Lower Great Lakes Region. *American Antiquity* 62(1), 112-119.
- Crawford, W. G.
2011. People and Plant Interactions in the Northeast. In Bruce D. Smith. ed. *The Subsistence Economies of Indigenous North American Societies*. Washington, D.C: Smithsonian Institution Scholarly Press, 503-516.
- Crowther, A.
2012. The Differential Survival of Native Starch during Cooking and Implications for Archaeological Analyses: A Review. *Archaeological Anthropological Science* 4, 221-235.
- Crowther, A., Haslam, M. Oakden, N. Walde, D. and Mercader, J.
2014. Documenting Contamination in Ancient Starch Laboratories. *Journal of Archaeological Science* 49, 90-104.
- Cummings, S. L.
2007. *Manual for Pollen, Phytolith, Starch, FTIR, AMS Radiocarbon, and Macrofloral Sampling*. Golden, Colorado: Paleo Research Institute.
- Dawson, K. C. A.
1981. The Wabinoash River Site and the Laurel Tradition in Northwestern Ontario. *Ontario Archaeology* 36, 3-46.
1987. Northern Ontario and the Early Contact Period: The Northern Ojibwa 1615 - 1715. *Canadian Journal of Archaeology* 11, 143-187.
- Dean, E. W. and Megard, O. R.
1993. The Varve Chronometer in Elk Lake: Record of Climatic Variability and Evidence for Solar Geomagnetic ¹⁴C Climatic Connection. In: Bradbury Platt, J. and Dean E. Walter (eds) *Elk Lake Minnesota, Evidence for Rapid Climate Change in the North-Central States*. Special Paper 276. The Geological Society of America, Inc, 45-68.

- Doebley, J.
1984. Maize introgression into teosinte: a reappraisal. *Annals of the Missouri Botanical Garden* 71, 1100–1113.
- Donaldson, S. W. and Wortner, S.
1995. The Hind Site and the Glacial Kame Burial Complex in Ontario. *Ontario Archaeology* 59, 5-95.
- Drewes, A. L. D.
2008. *Sustaining a Ricing Culture: An Integrated Landscape Approach to Understanding Harvest, Distribution and Management of Wild Rice (Zizania Palustris) Across the Upper Great Lakes Region*. ProQuest.
- Duncan, N. A., Pearsall, D. M. and Benfer, R. A.
2009. Gourd and squash artifacts yield starch grains of feasting foods from preceramic Peru. *Proceedings of the National Academy of Sciences* 106(32), 13202-13206.
- Egan-Bruhy, C. K.
2013. *Ethnicity as Evidenced in Subsistence Patterns of Late Prehistoric, Upper Great Lakes Populations*. Commonwealth Cultural Resources Group, Inc.
- Fearn, M. and Lui, K.
1995. Maize Pollen of 3500 B.P. from Southern Alabama. *American Antiquity* 60(1), 109-117.
- Ferris, N.
1999. Telling tales: Interpretive trends in southern Ontario Late Woodland archaeology. *Ontario Archaeology* 68,1-62.
- Fiedel, J. S.
2001. What Happened in the Early Woodland? *Archaeology of Eastern North America* 29, 101-142.
- Fischer, A. and Heinenmeier, J.
2003. Freshwater Reservoir Effect in ¹⁴C Dates of Food Residue on Pottery. *Radiocarbon* 45(3), 449-466.
- Fitting, E. J.
1969. Settlement Analysis in the Great Lakes Region. *Southwestern Journal of Anthropology*. 25(4): 360-377.

- Fritz, G.
1993. Early and Middle Woodland Paleoethnobotany. In C. Margaret Scarry. ed. *Foraging and Farming in the Eastern Woodland*. University Press of Florida, 39-56.
2011. The Role of "Tropical" Crops in Early North America. In Bruce D. Smith. ed. *The Subsistence Economies of Indigenous North American Societies*. Washington, D.C: Smithsonian Institution Scholarly Press, 503-516.
- Gibbon, E. G. and Hohman-Caine, A. C.
1980. The Middle to Late Woodland Transition in Eastern Minnesota. *Midcontinental Journal of Archaeology*. 5(1), 57-72.
- Gibbon, E. G.
1994. Cultures of the Upper Mississippi River Valley and Adjacent Prairies in Iowa and Minnesota. In Karl H. Schlesier. ed. *Plains Indians, A.D. 500-1500: The Archaeology of Past Historic Groups*. University of Oklahoma Press: Norman and London, 128-148.
- 2012a. Upper Rice Lake (21CE04): A Multiple Component Woodland Site in Clear-water County, Minnesota. *The Minnesota Archaeologist* 71: 74-88.
- 2012b. *Archaeology of Minnesota: The Prehistory of the Upper Mississippi River Region*. University of Minnesota Press.
- Gott, B., Barton, H. Samuel, D. and Torrence, R.
2006. Biology of Starch. In R. Torrence. and H. Barton. eds. *Ancient Starch Research*. Walnut Creek: Left Coast Press, 35-47.
- Greaves, D. R. and Kramer, L. Karen.
2014. Hunter-gatherer use of Wild Plants and Domesticates: Archaeological Implications for Mixed Economies before Agricultural Intensification. *Journal of Archaeological Science* 41, 263-271.
- Haas, J., Creamer, W. Mesía, H. L. Goldstein, D. Reinhard, K. and Rodriguez, V. C.
2013. Evidence for maize (*Zea mays*) in the Late Archaic (3000–1800 BC) in the Norte Chico region of Peru. *Proceedings of the National Academy of Sciences* 110(13), 4945-4949.
- Hamilton, S. and Nicholson, B. A.
2006. Aboriginal Seasonal Subsistence and Land Use on the Northeastern Plains: Insight from Ethnohistoric Sources. *Plains Anthropologist* 51(199), 253-280.

- Hamilton, S., Taylor-Hollings, J. and Norris, D.
2011. Human Ecology of the Canadian Prairie Ecozone ca. 1500 BP: Diffusion, Migration and Technological Innovation. In B. A. Nicholson. ed. *Human Ecology of the Canadian Prairie Ecozone*. Regina: Canada Plains Research Center, 99-152.
- Hardy, K., Blakeney, T. Copeland, L. Kirkham, J. Wrangham, R. Collins, M.
2009. Starch granules, dental calculus and new perspectives on ancient diet. *Journal of Archaeological Science* 36(2), 248-255.
- Hart, C. T.
2011. Evaluating the Usefulness of Phytoliths and Starch Granules found on Surface Artifacts. *Journal of Archaeological Science* 38, 3244-3253.
- Hart, P. J. and Scarry, C. M.
1999. The Age of Common Beans (*Phaseolus vulgaris*) in the Northeastern United States. *American Antiquity* 64(4), 653-658.
- Hart, J., Asch, D. Scarry, C. and Crawford, G.
2002. The Age of Common Bean in the North Eastern Woodlands. *American Antiquity* 76, 377-385.
- Hart, J., Thompson, R. and Brumbach, H.
2003. Phytolith Evidence for Early Maize (*Zea Mays*) in 2003 the Northern Finger Lakes Region of New York. *American Antiquity* 68(4), 619-640.
- Hart, J. P., Brumbach, H. J., & Lusteck, R.
2007. Extending the phytolith evidence for early maize (*Zea mays* ssp. *mays*) and squash (*Cucurbita* sp.) in central New York. *American Antiquity*, 72(3), 563.
- Hart, J. P., & Lovis, W. A.
2007a. A multi-regional analysis of AMS and radiometric dates from carbonized food residues. *Midcontinental Journal of Archaeology* 32(2), 201-261.

2007b. The freshwater reservoir and radiocarbon dates on cooking residues: Old apparent ages or a single outlier? Comments on Fischer and Heinemeier (2003). *Radiocarbon* 49(3), 1403-1410.

2014. A Re-Evaluation of the Reliability of AMS Dates on Pottery Food Residues from the Late Prehistoric Central Plains of North America: Comment on Roper (2013). *Radiocarbon* 56(1), 341-353.

- Hart, J. P.
2008. Evolving the three sisters: The changing histories of maize, bean, and squash in New York and the greater Northeast. *Current Northeast Paleoethnobotany II* 512, 87-99.
- Hart, J. P., Lovis, W. A. Urquhart, G. R. and Reber, E. A.
2013. Modeling Freshwater Reservoir Offsets on Radiocarbon-Dated Charred Cooking Residues. *American Antiquity* 78(3), 536-552.
- Haslam, M.
2004. The decomposition of starch grains in soils: implications for archaeological residue analyses. *Journal of Archaeological Science* 31(12), 1715-1734.

2006. Potential misidentification of in situ archaeological tool-residues: starch and conidia. *Journal of Archaeological Science* 33(1), 114-121.
- Henning, R. D.
1998. The Oneota Tradition. In W. Raymond Wood. ed. *Archaeology on the Great Plains*. University Press of Kansas, 345-415.
- Henry, A. G., Hudson, H. F. and Piperno, D. R.
2009. Changes in starch grain morphologies from cooking. *Journal of Archaeological Science* 36(3), 915-922.
- Henry, A. G., & Piperno, D. R.
2008. Using plant microfossils from dental calculus to recover human diet: a case study from Tell al-Raqā'i, Syria. *Journal of Archaeological Science*, 35(7), 1943-1950.
- Henry, A. G., Brooks, A. S. and Piperno, D. R.
2014. Plant foods and the dietary ecology of Neanderthals and early modern humans. *Journal of human evolution* 69, 44-54.
- Hill, L. C. and James, K. H.
1996. Geo-ecological Dynamics in the Glacial Lakes Duluth-Agassiz Region (Northern Minnesota) During the Late Pleistocene and Early Holocene. *Current Research in the Pleistocene* 13, 119-121.
- Hohman-Caine, A. C. and Goltz, E. G.
1995. Brainerd Ware and the Early Woodland Dilemma. *The Minnesota Archaeologist* 59, 109-129.
- Hohman-Caine, A. C., Syms, E. Lee. and Goltz, E. Grant.
2012. *The Age of Brainerd Ceramics*. Minnesota State Historical Society Contract No. 4107232, Hackensack, Minnesota: Soils Consulting.

- Holst, Irene., Moreno, J. E. and Piperno, R. D.
2007. Identification of teosinte, maize, and *Tripsacum* in Mesoamerica by using pollen, starch grains, and phytoliths. *Proceedings of the National Academy of Sciences* 104(45), 17608-17613.
- Hoover, H.
1963. *The Long-Shadowed Forest*. London: Souvenir Press.
- Horrocks, M.
2005. A combined procedure for recovering phytoliths and starch residues from soils, sedimentary deposits and similar materials. *Journal of archaeological science*. 32(8), 1169-1175.
- Hsieh, H. M., Swanson, B. G. and Lumpkin, T. A.
2000. Abrasion, Grinding, Cooking and the Composition and Physical Characteristics of *Azuki koshi an*. *Journal of food processing and preservation* 24(2), 87-106.
- Janzen, D. E.
1968. The Naomikong Point Site and the Dimensions of Laurel in the Lake Superior Region. *Anthropological Papers: Museum of Anthropology*, University of Michigan No. 36.
- Jenks, A.
1903. *The Wild Rice Gatherers of the Upper Great Lakes: A Study in American Primitive Economics*. *Man* 3, 124-126.
- Jenkins, E.
2009. Phytolith taphonomy: a comparison of dry ashing and acid extraction on the breakdown of conjoined phytoliths formed in *Triticum durum*. *Journal of Archaeological Science* 39(10), 2402-2407.
- Johannessen, S.
1993. Food, Dishes, and Society in the Mississippi Valley. In Scarry, M. ed. *Foraging and Farming in the Eastern Woodlands*. University Press of Florida, 182-205.
- Johnson, M. A. and Johnson, E. A.
1998. The Plains Woodland. In W. Raymond Wood. ed. *Archaeology on the Great Plains*. University Press of Kansas, 201-235.
- Johnson M. C.
1998. The Coalescent Tradition. In W. Raymond Wood. ed. *Archaeology on the Great Plains*. University Press of Kansas, 308-345.

- Kato, T. A.
1984. Chromosome morphology and the origin of maize and its races. *Evolutionary Biology* 17, 219–253.
- Katzenberg, M. A., Schwarcz, H. P, Knyf, M. and Melbye, F. J.
1995. Stable Isotope Evidence for Maize Horticulture and Paleodiet in Southern Ontario, Canada. *American Antiquity* 60, 335-350.
- Keane, K.
1997. *Wild Rice (Zizania L. spp.)*. Root Woman and Dave.
- Klimko, O.
1985. *Nipawin Reservoir Study, Volume 7 The Gravel Pit and Eastcott Flat Sites*. Saskatchewan Power Corporation, Saskatchewan.
- Knee, M.
N.d. Plants Cells. Ohio State University.
<http://www.hcs.ohiostate.edu/hcs300/cell1.htm>.
- Kuehn, S. R.
1998. Evidence for Late Paleoindian-Early Archaic Subsistence Behaviour in the Western Great Lakes. *American Antiquity* 63(3), 457-476.
- Lakela, O.
1965. *A Flora of Northeastern Minnesota*. Minneapolis: University of Minnesota Press.
- Lamb, J. and Loy, T.
2005. Seeing red: the use of Congo Red dye to identify cooked and damaged starch grains in archaeological residues. *Journal of Archaeological Science* 32(10), 1433-1440.
- Landals, A.
1995. The Miniota and Broadview Sites: Two Avonlea Loci on the Northeastern Plains. *Manitoba Archaeological Journal* 5(1), 1-27.
- Lee E. T.
1954. The First Sheguiandah Expedition, Manitoulin Island, Ontario. *American Antiquity* 20(2): 101-111.
- Lints, A.
2012. *Evidence of Domesticates From Early Ceramics of the Northern Plains: An Analysis of Avonlea Cultural Materials (AD 300-1000)*. MA Thesis, Lakehead University, Department of Anthropology.

- Liu, L., Field, J. Fullagar, R. Zhao, C. Chen, X. and Yu, J.
2010. A Functional Analysis of Grinding Stones from an Early Holocene Site at Donghulin, North China. *Journal of Archaeological Science* 37(10), 2630-2639.
- Liu, L., Bestel, S. Shi, J. Song, Y. and Chen, X.
2013. Paleolithic human exploitation of plant foods during the last glacial maximum in North China. *Proceedings of the National Academy of Sciences*, 110(14), 5380-5385.
- Lockard, A. C.
2008. *Societies, Networks, and Transitions: A Global History*. Houghton Mifflin Company.
- Lovis, A. W., Egan-Bruhy, C. K. Beverly, A. S. and Monaghan, G. W.
2001. Wetlands and Emergent Horticultural Economies on the Upper Great Lakes: A New Perspective from the Schultz Site. *American Antiquity* 66(4), 615-632.
- Loy, T., Spriggs, M. and Wickler, S.
1992. Direct evidence for human use of plants 28,000 years ago: starch residues on stone artefacts from the northern Solomon Islands. *Antiquity* 66(253), 898-912.
- Loy, T.
1994. Methods in the analysis of starch residues on prehistoric stone tools. *Tropical archaeobotany: Applications and new developments*, 86-114.
- Lu, H. Y., Wu, N. Q. Yang, X. D. Jiang, H. Liu, K. B. and Liu, T. S.
2006. Phytoliths as quantitative indicators for the reconstruction of past environmental conditions in China I: phytolith-based transfer functions. *Quaternary Science Reviews* 25(9), 945-959.
- Lugenbeal, E. N.
1976. *The Archaeology of the Smith Site: A Study of the Ceramics and Culture History of Minnesota Laurel and Blackduck*. PhD Thesis, University of Wisconsin, Department of Anthropology.
- Madella, M., Lancelotti, C. and García-Granero, J.
2013. Millet microremains—an alternative approach to understand cultivation and use of critical crops in Prehistory. *Archaeological and Anthropological Sciences*, 1-12.
- Mallard Club Wild Rice
2014. "The Mallard Club Wild Rice." *The Mallard Club Wild Rice, Minnesota*. www.mallardclubwildrice.com. N.p. Web June 17, 2014.

Mason, R.

1970. Hopewell, Middle Woodland, and the Laurel Culture: A Problem in Archaeological Classification. *American Anthropologist* 72(4), 802-815.

1981. *Great Lakes Archaeology*. The Blackburn Press.

Maple Hill Park.

2013. "Glacial Geology and Soils of Maple Hill." *Friends of Maple Hill Park*. www.maplehillpark.org. N.p. Web June 17, 2014.

Marschner, J. Francis.

1974. *The Original Vegetation of Minnesota*. Compiled from U.S. General Land Office Survey Office Notes. Office of Agricultural Economics. U.S. Department of Agriculture.

Marles J. R., Clavelle, C. Monteleone, L. Tays, N. and Burns, D.

2000. *Aboriginal Plant Use in Canada's Northwest Boreal Forest*. Natural Resources Canada, Canada Forest Services.

Matsuoka, Y., Vigouroux, Y. Goodman, M. M. Sanchez, J. Buckler, E. and Doebley, J.

2001. A single domestication for maize shown by multilocus microsatellite genotyping. *Proceedings of the National Academy of Sciences* 99(9), 6080-6084.

McAndrews, J. H.

1969. Paleobotany of a wild rice lake in Minnesota. *Canadian Journal of Botany* 47(11), 1671-1679.

1999. Wild Rice and Upland Vegetation History near Lake Mille Lacs, Minnesota. In Mather, D. and Abel, E. eds. *The Lake Onamia- Trunk Highway 169 Data Recovery Project, Mille Lacs County, Minnesota*. Maple Grove: Loucks and Associates, Inc.

Meyer, D. and Hamilton, S.

1994. Neighbours to the North: Peoples of the Boreal Forest.

In K. H. Schlesier. ed. *Plains Indians A.D. 500 – 1500*. University of Oklahoma Press, 96–127.

Meyer, D. and Walde, D.

2009. Rethinking Avonlea: Pottery Wares and Cultural Phase. *Plains Anthropologist* 54(209), 49-73.

Morgan, Grace R.

1979. An Ecological Study of the Northern Plains as Seen Through the Garrett Site. University of Regina, *Occasional Papers in Anthropology*, No.1.

Mt. Pleasant, J.

2006. The Science behind the Three Sisters Mound System: An Agronomic Assessment of an Indigenous Agricultural System in the Northeast. In John E. Staller., Robert H. Tykot, and Bruce F. Benz. ed. *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize*. New York: Academic Press, 529-535.

Mulholland, C. S.

1986. Identification of Plants in a Sediment. In Rovner, Irwin. ed. *Plant Opal Phytolith Analysis in Archaeology and Paleoecology*. Occasional Papers 1 of *The Phytolitharien* N.C. State University, 123-128.

1993. A Test of Phytolith Analyses at Big Hidatsa, North Dakota. In Pearsall, D. M. and Piperno, D. R. eds. *Current Approaches in Phytolith Analysis: Applications in Archaeology*. *Journal of Archaeological Research* 21, 175-216.

Mulholland, C. S., Mulholland, L. S, Shafer, R. J. Valppu, H. S. and Rapp, Jr. G.

1996. *Evaluation of Two Sites on the Dixon Lake Road/Third River, Blackduck District, Chippewa National Forest, Itasca County, Minnesota*. University of Minnesota, Duluth: Archaeometry Laboratory.

1997. *Mitigation of the Third River Borrow Pit Site (21-IC-0176, 09-03-01-0355), Blackduck District, Chippewa National Forest, Itasca County, Minnesota*. University of Minnesota, Duluth: Archaeometry Laboratory.

Norris, D.

2007. *Presence of Net-impressed and Horizontally Corded Ware in Southern Manitoba: The Relationship between Rock Lake and Brainerd Ware*. MA Thesis, University of Saskatchewan, Department of Archaeology.

Ollendorf, A.L., Mulholland, C. S., and Rapp, G. Jr.

1988. Phytolith Analysis as a Means of Plant Identification: *Arundo donax* and *Phragmites communis*. *Annals of Botany* 61, 209-214.

Olympus Microscopy Resource Center.

2012. <http://www.olympusmicro.com/> Olympus America Inc.

Ojakangas. J. R. and Charles L. M.

1982. *Minnesota's Geology*. Minneapolis: University of Minnesota Press.

Pauketat R. T.

2004. *Ancient Cahokia and the Mississippians*. Cambridge University Press.

- Pearsall, M. D.
1982. Phytoliths: Application of a New Phytolith Technique in Archaeology. *American Anthropologist* 84(4), 860-871.
- Pearsall, D. M., Chandler-Ezell, K., & Chandler-Ezell, A.
2003. Identifying maize in neotropical sediments and soils using cob phytoliths. *Journal of Archaeological Science*, 30(5), 611-627.
- Pearsall, D. M., Chandler-Ezell, K. and Zeidler, J. A.
2004a. Maize in Ancient Ecuador: Results of Residue Analysis of Stone Tools from the Real Alto site. *Journal of Archaeological Science* 31(4), 423-442.
- Pearsall, D. M., Chandler-Ezell, K. and Chandler-Ezell, A.
2004b. Maize can still be Identified Using Phytoliths: Response to Rovner. *Journal of Archaeological Science* 3: 1029: 1038.
- Perkl, E. B.
1998. Cucurbita pepo from King Coulee, Southeastern Minnesota. *American Antiquity* 63(2), 279-288.
2009. The Late-Archaic-Early Woodland Transition in Southeastern Minnesota. PhD Thesis, University of Minnesota, Department of Archaeology,
- Peters, R. G. and Motivans, A. K.
1983. Evaluation: The Big Rice Site (F.S. #09-09-034). *Cultural Resource Management on the Superior National Forest 1983 Annual Report: Duluth, MN, USDA Forest Service, edited by G.R. Peters, 280-317*
- Peterson, J. B. and Asch Sidell, N.
1996. Mid-Holocene Evidence of Cucurbita Sp. from Central Maine. *American Antiquity* 61, 685-698.
- Peterson, A. L.
1977. *A Field Guide to Edible Wild Plants Eastern and Central North America*. New York, New York: Houghton Mifflin Company.
- Piperno, D. R.
1988. *Phytolith analysis: an archaeological and geological perspective*. San Diego: Academic Press.
2006. *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. Lanham, MD: Rowman AltaMira Press.

2009. Identifying Crop Plants with Phytoliths (and Starch Grains) in Central and South America: A Review and an Update of the Evidence. *Quaternary International* 193, 146-159.
- Piperno, D. R., Weiss, E. Holst, I. and Nadel, D.
2004. Processing of wild cereal grains in the Upper Palaeolithic revealed by starch grain analysis. *Nature* 430(7000), 670-673.
- Piperno, R. D. and Tom, D. D.
2008. Starch Grains on Human Teeth Reveal Early Broad Crop Diet in Northern Peru. *Proceedings of the National Academy of Sciences of the United States* 105(50), 19622-19627.
- Piperno, R. D., Ranere, J. A. Holst, I. Iriarte, Jose. and Dickau, R.
2009. Starch Grain and Phytolith Analysis from Early Ninth Millennium B.P. Maize from Central Balsas River Valley, Mexico. *Proceedings of the National Academy of Sciences of the United States of America* 106(13), 5019-5024.
- Piperno, R. D.
2011. The Origins of Plant Cultivation and Domestication in the New World Tropics. *Current Anthropology* 52(S4), S453-S470.
- Piperno, R. D. and Flannery, V. K.
2011. The Earliest Archaeological Maize (*Zea mays* L.) from Highland Mexico: New Accelerator Mass Spectrometry Dates and their Implications. *Proceedings of the National Academy of Sciences of the United States of America* 98(4), 2101-2103.
- Phillips, B. and Hill, C.
2004. Deglaciation History and Geomorphological Character of the Region between the Agassiz and Superior Basins, Associated with the 'Interlakes Composite' of Minnesota and Ontario. In *The Late Paleo-Indian Great Lakes: Geological and Archaeological Investigations of Late Pleistocene and Early Holocene Environments*, eds. L. J. Jackson and A. Hinshelwood, 275-301. Mercury Series Archaeology Paper 165. Quebec: Canadian Museum of Civilization,
- Powers, H. Alix.
1992. Great Expectations: A Short Historical Review of European Phytolith Systematics. In Rapp, Jr. George and Susan C. Mulholland. eds. *Phytolith Systematics: Emerging Issues*, 15-36.
- Rapp, Jr. G. and Mulholland, C. S.
1982. Phytolith Systematics: An Introduction. *Phytolith Systematics: Emerging Issues*, 1-15.

- Reid, C. S. and Rajnovich, G.
1985. Laurel Architecture: Five Case Studies. *The Minnesota Archaeologist* 44(2), 5–30.
1991. Laurel: A Re- evaluation of the Spatial, Social and Temporal Paradigms. *Canadian Journal of Archaeology* 15:193–234.
- Rocha, T. D. S., Carneiro, A. P. D. A. and Franco, C. M. L.
2010. Effect of enzymatic hydrolysis on some physicochemical properties of root and tuber granular starches. *Food Science and Technology (Campinas)* 30(2), 544-551.
- Roper, C. D.
2013. Evaluating the Reliability of AMS Dates on Food Residue on Pottery from Late Prehistoric Central Plains of North America. *Radiocarbon* 55(1), 151-162.
2014. A Response to Hart and Lovis. *Radiocarbon* 56 (1), 355-359.
- Rosenswig, R. M., Pearsall, D. M. Masson, M. A. Culleton, B. J. and Kennett, D. J.
2014. Archaic period settlement and subsistence in the Maya lowlands: new starch grain and lithic data from Freshwater Creek, Belize. *Journal of Archaeological Science* 41, 308-321.
- Rovner, I.
1971. Potential of opal phytoliths for use in paleoecological reconstruction. *Quaternary Research* 1(3), 343-359.
- Scarry, M. C.
2003. Patterns of Wild Plant Utilization in the Prehistoric Eastern Woodlands. In Paul E. Minnis. ed. *People and Plants: in Ancient Eastern North America*. Smithsonian Institution, 50-105.
- Scarry, C. M. and Scarry, F. J.
2005. Native American 'Garden Agriculture' in Southeastern North America. *World Archaeology* 37(2), 259-274.
- Scarry, C. M. and Yarnell, A. R.
2011. Native American Domestication and Husbandry of Plants in Eastern North America. In Smith D. Bruce. ed. *The Subsistence Economies of Ingenuous North American Societies*. Washington D.C.: Smithsonian Institution Scholarly Press, 483-503.

- Shafer, R. J.
2003. *A Seriation of Ceramics from the Big Rice Site (21SL163, FS 09-09-034), St. Louis County, Minnesota*. MA Thesis, University of Minnesota, Faculty of Graduate School.
- Shillito, L.
2011. Grains of Truth or Transparent Blindfolds? A Review of Current Debates in Archaeological Phytolith Analysis. *Vegetational History Archaeobotany* 22, 71-82.
- Silbernagel, J., Martin, R. S. Gale, R. M. and Chen, J.
1997. Prehistoric, historic, and present settlement patterns related to ecological hierarchy in the Eastern Upper Peninsula of Michigan, USA. *Landscape Ecology* 12(4), 223-240.
- Simon, L. M.
2009. A Regional and Chronological Synthesis of Archaic Period Plant Use in the Midcontinent. In Thomas E. Emerson., Dale L. MacElrath, and Andrew C. eds. *Archaic Societies: Diversity and Complexity across the Midcontinent*. Fortier: State University of New York, 81-114.
- Simon, M. L.
2011. Evidence for variability among squash seeds from the Hoxie site (11CK4), Illinois. *Journal of Archaeological Science* 38(9), 2079-2093.
- Skibo, M. J.
2013. *Understanding Pottery Function (Manuals in Archaeological Method, Theory and Technique)*. New York: Springer Science and Business Media.
- Smith, D. B.
1989. *Origins of agriculture in eastern North America*. American Association for the Advancement of Science.
1992. *Rivers of Change: Essays on Early Agriculture in Eastern North America*. Alabama: The University of Alabama Press.
2006. Eastern North America as an Independent Center of Plant Domestication. *Proceedings of the National Academy of Sciences* 103(33), 12223-12228.
2011. ed. *The Subsistence Economies of Indigenous North American Societies: A Handbook*. Washington D.C.: Smithsonian Institute Scholarly Press.

- Staller, E. J.
2010. *Maize Cobs and Cultures: History of Zea mays L.* Heidelberg Dordrecht London New York: Springer.
- Staller, J., Tykot, R. and Benz, B.
2006. *Histories of Maize: Multidisciplinary Approaches to the Prehistory, Linguistics, Biogeography, Domestication, and Evolution of Maize.* United States: Elsevier Academic Press.
- Stoltman, James B.
1973. The Laurel Culture in Minnesota. *Minnesota Prehistoric Archaeology Series*, no. 8. Minnesota Historical Society. St. Paul.
- Struever, S.
1965. Middle Woodland Culture History in the Great Lakes Riverine Area *American Antiquity* 31(2), 211-223.
- Surette, L. J. C.
2008. *The Potential of Microfossil Use in Paleodiet and Paleoenvironmental Analysis in Northwestern Ontario.* MA Thesis, Lakehead University, Department of Geology.
- Syms, E. L., Speirs, K. and Durawa, H.
2013. *Aboriginal Peoples as the First Cultivators Centuries of Plant Cultivation before the Europeans* (Rev). Draft
- Thomas, M. M. and Mather, D. eds.
1996. *The McKinstry Site (21KC2): Final Report of Phase III Investigations for Mn/DOT S.P. 360-44, Replacement of T.H. 11 Bridge 5178 over the Little Fork River, Koochiching County, Minnesota.* Loucks Project Report 93512, prepared for the Minnesota Department of Transportation. Maple Grove: Loucks & Associates, Inc.
- Thomas, Matthew.
1996. Ceramic Analysis. In M. M. Thomas and D. Mather (eds.), *The McKinstry Site (21KC2): Final Report of Phase III Investigations for Mn/DOT S.P. 360-44, Replacement of T.H. 11 Bridge 5178 Over the Little Fork River, Koochiching County, Minnesota.* Loucks Project Report 93512, prepared for the Minnesota Department of Transportation. Maple Grove: Loucks & Associates, Inc.
- Thompson, G. R., Kluth. R. A. and Kluth. D. W.
1994. Tracing the Use of Brainerd Ware through Opal Phytolith Analysis of Food Residue. *The Minnesota Archaeologist* 53: 86-95.

1995. Ceramic Artifacts. In Justin, Michael. ed. *Archaeological Data Recovery at the Roosevelt Lake Narrows Site, Cass County, Minnesota*. Woodward-Clyde Report 93e209, prepared for Minnesota Department of Transportation. St. Paul, Minnesota: State Historic Preservation Office.
- Torrence, R.
2006. *Ancient Starch Research*. Walnut Creek, CA: Left Coast Press Inc
- Torrence, R. and Barton, H. eds.
2006. *Ancient Starch Research*. Walnut Creek, California: Left Coast Press.
- Twiss, P. C., Suess, E. and Smith, R. M.
1969. Morphological classification of grass phytoliths. *Soil Science Society of America Journal* 33(1), 109-115.
- Twiss, P. C.
1992. Predicted world distribution of C3 and C4 grass phytoliths. *Phytolith systematics* 113-128.
- University of Minnesota
Bell Museum of Natural History Minneapolis, Minnesota.
<http://www.bellmuseum.umn.edu>. N.p. Web June 17, 2014.
- Valppu, S. and Rapp, G.
2000. Paleoethnobotanical Context and Dating of the Laurel Use of Wild Rice: The Big Rice Site. *The Minnesota Archaeologist* 59:81–87.
- Vennum, T. Jr.
1988. *Wild Rice and the Ojibway People*. St. Paul, Minnesota: Historical Society Press.
- Vogel, J. C. and Van der Merwe, N. J.
1977. Isotopic evidence for early maize cultivation in New York State. *American Antiquity* 42, 238–242.
- Wilcox, L.
2007. Going with the Grain: on Minnesota Lakes, Native Americans Satisfy a Growing Hunger for 'Slow Food' by Harvesting Authentically Wild Rice the Old-Fashioned Way. *Smithsonian* 38(6), 94.
- Wilson, J., Hardy, K. A. R. Copeland, L. Wrangham, R. and Collins, M.
2010. Automated classification of starch granules using supervised pattern recognition of morphological properties. *Journal of Archaeological Science* 37(3), 594-604.

- Wilson, G. L.
1917. *Agriculture of the Hidatsa Indians: An Indian Interpretation*. University of Minnesota, Studies in the Social Sciences, No. 9.
- Winham, P. R. and Calabrese, A. F.
1998. The Middle Missouri Tradition. In W. Raymond, Wood. ed. *Archaeology on the Great Plains*. University Press of Kansas, 269-308.
- Wright, Jr. E. H.
1993. History of the Landscape in the Itasca Region. In Bradbury, Platt. J. and Dean, E. Walter. eds. *Elk Lake, Minnesota: Evidence for Rapid Climate Change in the North-Central United States*. The Geology Society of America, Inc, Boulder, Colorado, 7-18.
- Yarnell, R. A.
1964. *Aboriginal Relationships between Culture and Plant Life in the Upper Great Lakes Region*. Anthropological Papers 23. Museum of Anthropology, University of Michigan.

1993. The Importance of Native Crops during the Late Archaic and Woodland Periods. In C. Margaret, Scarry. ed. *Foraging and Farming in the Eastern Woodland*. University Press of Florida, 39-56.
- Yerkes, W. R.
1988. The Woodland and Mississippian Traditions in the Prehistory of Midwestern North America. *Journal of World Prehistory* 2(3), 307-357.
- Yoneda, M., Tanaka, A. Shibata, Y. Morita, M. Uzawa, K. Hirota. M. and Uchida, M.
2002. Radiocarbon marine reservoir effect in human remains from the Kitakogane site, Hokkaido, Japan. *Journal of archaeological science* 29(5), 529-536.
- Yost, L. C.
2007. *Phytolith Evidence for the Presence and Abundance of Wild Rice (Zizania spp.) from Central Minnesota Lake Sediments*. MS Thesis, St. Cloud State University, Minnesota. Department of Geography.
- Yost, C. L., and Blinnikov, M. S.
2011. Locally diagnostic phytoliths of wild rice (*Zizania palustris* L.) from Minnesota, USA: comparison to other wetland grasses and usefulness for archaeobotany and paleoecological reconstructions. *Journal of Archaeological Science* 38(8), 1977-1991.

- Yost, L. C., Blinnikov, S. M. and Julius L. M.
2013. Detecting Ancient Wild Rice (*Zizania* ssp. L.) Using Phytoliths: A Taxonomic Study of Modern Wild Rice in Minnesota (USA) Sediments. *Journal of Paleolimnology* 49(2), 221-236.
- Zarrillo, S. and Kooyman B.
2006. Evidence of Berry and Maize Processing on the Canadian Plains from Starch Grain Analysis. *American Antiquity* 71(3), 473-499.
- Zarrillo, Sonia., Deborah M. Pearsall. Scott J. Raymond. Mary Ann Tisdale. and Dugane J. Quon.
2008. Directly Dated Starch Residues Document Early Formative Maize (*Zea mays* L.) in Tropical Ecuador. *Proceedings of the National Academy of Sciences* 105(13), 5006-5011.
- Zellie, C.
1988. *Upper Mississippi River Headwaters Reservoirs Damsites Cultural Resources Investigation*. Lake Winnibigoshish, Leech Lake, Pokegama Lake, Sandy Lake, Pine River and Gull Lake. St. Paul, Minnesota: Landscape Research.

APPENDIX

Archaeological Site	Flora	Fauna
Big Rice	<i>Zizania</i> spp. (Wild Rice)	<i>Odocoileus virginiana</i> (Deer)
	Tubers	<i>C. Canadensis</i> (Beaver)
	Hog-nut	<i>Bison bison</i> (Bison)
	Fruits	Testudines (Turtle)
	Nuts	Chordate (Fish)
	<i>Z. mays</i> (Corn)	Gastropoda (Land Snail)
	<i>Cucurbita</i> (Squash)	<i>Bivalvia</i> (Mussels)
	<i>Cyanococcus</i> (Blueberry)	<i>A. alces</i> (Moose)
	<i>Rubus idaeus</i> (Wild Red Raspberry)	<i>O. zibethicus</i> (Muskrat)
	<i>Sambucus</i> (Red-berried Elder)	<i>Erethizontidae</i> (Porcupine)
	<i>Prunus pensylvanica</i> (Pincherry)	<i>Lepus</i> (Hare)
	<i>Abies</i> (Fir)	<i>Aves</i> (Variety of Birds)
	<i>Populus tremuloides</i> (Aspen)	
	<i>Acer</i> (Maple)	
	<i>Crataegus</i> (Thornapple)	
	<i>Betula</i> (Birch)	
	<i>Tilia Americana</i> (Basswood)	
Schultz	<i>Zizania</i> ssp. (Wild Rice)	
	Nuts	
Upper Rice Lake		<i>C. Canadensis</i> (Beaver)
		<i>O. zibethicus</i> (Muskrat)
		<i>C. Lupus</i> (Dog)
		<i>U. americanus</i> (Black Bear)
		<i>Aves</i> (Bird)
		<i>Chordate</i> (Fish)
		<i>Anura</i> (Frog)
		<i>Bivalvia</i> (Mussels)
		<i>Bison bison</i> (Bison)
		<i>A. alces</i> (Moose)
		<i>Cervus canadensis</i> (Elk)
		<i>O. virginianus</i> (White-tailed Deer)
		<i>Mephitidae</i> (Skunk)
		<i>Mustelinae</i> (Mink)
		<i>Lynx lynx</i> (Lynx)

		<i>Spermophilus</i> (Gopher)
Third River Borrow Pit	<i>Picea</i> (Spruce)	<i>Canis lupus</i> (Wolf)
	<i>Pinus strobus</i> (White Pine)	<i>Ursidae</i> (Bear)
	<i>Pinus resinosa</i> (Red Pine)	<i>O. zibethicus</i> (Muskrat)
	<i>Pinus banksiana</i> (Jack Pine)	<i>C. Canadensis</i> (Beaver)
		<i>Mustela</i> (Mink)
		<i>Lutrinae</i> (Otter)
		<i>M. pennanti</i> (Fisher)
		<i>Leporidae</i> (Rabbit)
		<i>Anseriformes</i> (Waterfowl)
		<i>Chordate</i> (Fish)
		<i>A. alces</i> (Moose)
		<i>Rangifer tarandus caribou</i> (Woodland Caribou)
		<i>Bison bison</i> (Bison)
		<i>Cervus canadensis</i> (Elk)
		<i>Cervidae</i> (Deer)
McKinstry (21KC2)	<i>Chenopodium sp.</i>	<i>Acipenser fulvescens</i> (Lake Sturgeon)
	<i>Viola canadensis</i>	<i>Alces alces</i> (Moose)
	<i>Rubus idaeus</i>	<i>Marmota monax</i> (Woodchuck)
	<i>Sambucus spp.</i>	<i>Castor canadensis</i> (Beaver)
	<i>Rumex sp.</i>	<i>Moxostoma</i> (sucker)
	<i>Pinus sp.</i>	
	<i>Picea sp.</i>	
	<i>Abies balsamea</i>	
	<i>Zizania Aquatica</i>	

Appendix 1: Floral and faunal remains recovered from a few northern Minnesota Woodland sites, representing some species in the Great Lakes-St. Lawrence Forest (Bishop 2007; Gibbon 2012a; Hoover 1963; Mulholland et al. 1996; Peter and Motivans 1983; Shafer 2003).

Sample and Laboratory Number	Association	Material	Date with Standard Deviation
N/a	Feature with pit and wild rice	Charcoal	1670 + 45 BP

Appendix 2: Radiocarbon date from a sample at the Big Rice site (Shafer 2003).

			Radiocarbon Age (BP)		Calibrated Age		
Sample and Laboratory Number	Association	Material	Date with Standard Deviation	Conventional Age	Intercept	1 Sigma	2 Sigma
C1-A Beta 94420	Top of Feature 1 Brainerd	Charcoal Birch (cf <i>Betula papyrifera</i>)	1700+70	1700+70	AD380	AD250-425	AD 210-535
C2-A Beta 101863	Base of Feature 1 Brainerd	Charcoal	1850+50	1860+50	AD145	AD100-235	AD 65-260
C3-A Beta 101864	Through-out Feature 1 Brainerd	Charcoal	1590+50	1620+50	AD430	AD405-530	AD 350-560
Crust 1	Brainerd Horizontally Corded Sherd in Feature 1	Organic Residue	2460+60	2320+60	BC390	BC405-320	BC 505-330 BC 330-205

Appendix 3: Radiocarbon dates from charcoal and organic residue samples at the Third River Borrow Pit Site (Mulholland et al. 1996).

Feature	Sample	Conventional 14C Age (B.P.)	1 Max Cal Age (Intercepts) Min Cal Age	2 Max Cal Age (Intercepts) Min Cal Age
11	(BA 94091)	1910 +/-100	B.C. 35 (A.D.81) A.D. 229	B.C. 156 (A.D. 81) A.D. 339
22	(BA 94092)	2040 +/- 100	B.C. 172 (44.5.5) A.D. 66	B.C. 358 (44.5.5) A.D. 133
33	(BA 94093)	2020 +/- 90	B.C. 160 (39.29.22.10.1) A.D. 72	B.C. 349 (39. 22. 10.1) A.D. 133
36	(BA 94094)	1060 +/- 80	A.D 894 (989) 1024	A.D. 780(989) 1159
36	(Beta-75859)	600 +/- 60	A.D. 1299 (1327, 1346, 1393) 1410	A.D. 1283 (1327. 1346. 1393. 1435)

Appendix 4: AMS dates from Area A of *Zizania aquatica* seeds (Valppu and Rapp 2000).

	Site Name					
Microfossils	No Beard(1)	Windy Bead (1)	Windy Bead (2)	No Beard (2)	No Beard (3)	No Beard (4)
Elongate Plates (Gramineae)	6	4	2	9	5	3
Elongate Plates (Smooth)	1	1	0	0	0	0
Elongate Plates (other)	2	1	0	4	3	0
Short Plates	1	0	0	0	0	0
Trichomes	22	18	7	15	20	3
Double Outlines	7	14	1	22	10	2
Saddles	22	20	7	30	18	3
Long Sinuous Trapezoids	33	51	7	29	24	8
Short Sinuous Trapezoids	44	37	18	28	18	2
Long Non Sinuous Trapezoids	30	29	8	11	21	9
Short Non Sinuous Trapezoids	43	45	9	14	38	3
Bilobates	4	7	0	12	9	0
Polylobates	0	1	1	3	0	0
Crosses	0	0	1	0	3	0
Rondel (Zea mays)	0	0	0	1	1	0
Rondel (Zizania)	0	0	1	0	1	0
Other Rondel	8	1	3	33	31	7
Zea mays starch	0	1	1	10	4	1
Possible Cucurbita starch	0	0	0	0	1	0
Possible Phaseolus vulgaris starch	0	0	0	0	0	1
Starch Unknown	30	20	95	47	50	25
Diatoms	0	0	0	0	1	1
Pollen	0	0	0	0	1	0

Appendix 5: Microfossils recovered from lithic samples.

	Site Name				
Microfossils	Big Rice (1)	Big Rice (2)	Windy Bead (1)	Windy Bead (2)	Windy Bead (3)
Elongate Plates Gramineae	7	18	15	11	22
Elongate Plates Smooth	0	2	6	9	8
Elongate Plates Other	3	6	12	11	18
Short Plates	5	0	0	13	0
Trichomes	15	13	24	15	18
Double Outlines	10	16	7	11	23
Saddles	34	17	18	31	34
Long Sinuous Trapezoids	41	38	62	34	26
Short Sinuous Trapezoids	17	31	18	23	17
Long Non Sinuous Trapezoids	10	17	23	29	22
Short Non Sinuous Trapezoids	18	16	29	20	11
Bilobates	3	1	3	9	25
Polylobates	1	0	2	6	4
Crosses	0	0	1	0	1
Bulliforms	0	2	0	2	3
Rondel <i>Zea mays</i>	1	2	2	1	1
Rondel cf <i>Zea mays</i>	0	0	0	0	0
Rondel <i>Zizania</i> sp	10	5	0	5	2
Rondel cf <i>Zizania</i> sp	0	0	0	0	0
Rondel Other	90	50	24	139	104
Unclassified Phytoliths	3	0	4	2	3
<i>Zea mays</i> starch	4	0	0	0	0
Possible <i>Cucurbita</i> starch	1	0	0	0	1
Possible <i>Phaseolus vulgaris</i> starch	1	0	0	0	0
Unknown Starch	19	1	6	5	15
Diatoms	4	6	1	1	0
Pollen	0	0	0	1	1

Appendix 8: Microfossils recovered from sediment samples.

	Rondel Type		
Site Name			
Windy Bead Unit 4	<i>Zea mays</i>	<i>Zizania</i>	<i>Hesperostipa comata</i>
Big Rice 09-034 2754g	<i>Zizania</i>	<i>Hesperostipa comata</i>	
Big Rice #3	<i>Zizania</i>	<i>Danthonia spicata</i>	
Saga Island AB45	<i>Zizania</i>		

Appendix 9: Possible plants identified from rare rondel phytoliths.