Archaeobotanical and Soil Chemistry Investigation of a Woodland Site on Whitefish Lake, Northwestern Ontario

By:

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Masters of Environmental Studies

Northern Environments and Cultures

Lakehead University, Thunder Bay, Ontario

May 2017

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ABSTRACT

Whitefish Lake is a large, shallow lake abundant in wild rice (*Zizania palustris*) that lies near the transitional zone between the Boreal Forest and Great Lakes-St. Lawrence forest regions of Northwestern Ontario. The lake exhibits extensive use during the Woodland period (150 BC- AD 1600) inferred from the lithic and pottery recoveries and the presence of burial mounds at several archaeological sites. The soils here are typical of those elsewhere in the Boreal Forest, characterized by poor organic preservation and disturbed, compacted stratigraphy thus limiting knowledge of plant use at many sites. On-going research from Whitefish Lake, particulary the Martin-Bird site (DbJm-5), is revealing aspects of paleoecology and human paleodiet in the absence of conventional lines of evidence through the analysis of plant microfossils, like starch and phytoliths. The objectives of this thesis are to further understand aspects of paleoecology and precontact land-use at the Martin-Bird site and to assess the utility of subtle lines of evidence at sites exhibiting poor organic preservation. A multi-proxy approach, combining the analysis of plant microfossils (starch, phytoliths, and charcoal) and soil chemistry (phosphorus) on soils from the site, is used to address these objectives. My thesis explores the information and land-use patterns that can be obtained from plant microfossils and soil chemistry analyses in the absence of organic lines of evidence, while providing a greater understanding of the Woodland period of the Eastern Woodlands culture history.

ACKNOWLEDGEMENTS

I'm very grateful to have attended Lakehead University and to have a university with such high-quality research opportunities in my home-town of Thunder Bay, Ontario. Although I never had to leave the comforts of home to complete my undergrad and Masters, I have experienced invaluable personal growth throughout my university education, most notably throughout my Masters. The path was a challenging one and there are many individuals who deserve acknowledgement for their role in helping me pursue this academic endeavor.

First of all, I'd like to thank my advisor, Dr. Matthew Boyd who was intergral to this thesis. Matt carefully read over many drafts and provided invaluable feedback and sat at the microscope with me a number of times. He directed me to many useful references and was available to meet regularly to keep the research and writing on track. Matt also provided continuous encouragement and his patient and kind demeanor was greatly appreciated throughout the process.

The work in this thesis would not have been possible without Roy Macgillivray and family granting access to Macgillivray Island where the Martin-Bird site is located. Thank you to Drs. Matt Boyd and Scott Hamilton, Clarence Surette, Kayleigh Speirs and Kelsey Pennanen for their help in the field collecting soil samples, brushcutting and digging stratigraphy pits at the Martin-Bird site and for their general knowledge.

Many thanks to Clarence Surette who trained me on laboratory equipment and walked me through the methodology for processing plant microfossils. Thank you also to the Lakehead University Environmental Laboratory who helped me with total phosphorus testing.

I want to thank my committee members, Drs. Scott Hamilton and Florin Pendea for their insight and helpful feedback on draft versions of my thesis and to Dr. William Lovis, my external reviewer. I am also thankful for Jennifer McKee who promptly responded to all of my administrative related questions, scheduled my thesis defence and ensured all required documents were compiled and sent to the Faculty of Graduate Studies.

Additional support came from Lakehead University's Department of Anthropology for offering me a graduate assistantship and the Social Sciences and Humanities Research Council (SSHRC) of Canada for awarding me an amazing grant. I am so grateful that I did not have to worry about finding additional work to sustain me financially throughout my Masters.

As someone who struggles with mental health issues, the focus and motivation required to complete my studies often evaded me. My undergrad had already been a difficult period in my life and my Masters was even more taxing. Completing my Masters was a frustrating experience because I had all the financial and intellectual capacity to successfully complete a Masters degree yet it seemed like an impossible task. There had been many occasions where I felt like quitting as I believed that the rigours of grad school were too much to endure mentally, even though I did not truly want to give up. I suffered such intense self-criticism and experienced long periods of depression and anxiety to a point when the interstices of wellbeing almost entirely ceased and I was left with all-consuming dark thoughts. It was indescribably scary, overwhelming and incapacitating. Most importantly, I want to thank my loved ones for helping to lift me out of such dark places and for all of the confidence they had in me. There is nothing I value more than the relationships and people in my life. I am so thankful for the endless love and support that surrounds me. I also wish to thank the excellent doctors and counsellors at the Student Health and Counselling Centre who graciously helped me handle my many existential crises and smaller dilemmas too. For anyone else battling mental illness throughout their studies, please reach out when you need to. There is no shame. You are stronger, braver, and more resilient and capable than you believe.

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CHAPTER 1: INTRODUCTION

Whitefish Lake (Figure 1.1), a large, shallow basin abundant in wild rice, lies within the transitional zone between the Boreal Forest and the Great Lakes-St. Lawrence forest regions, and has been the subject of much archaeological inquiry and excavation. Numerous sites associated with the Woodland period (~150 B.C.-A.D. 1650; Arzigian 2008; Syms 1977) have been identified around the modern shore of Whitefish Lake as well as on islands within the lake. One such site, Martin-Bird (DbJm-5) located on Macgillivray Island in the western end of the lake, was first investigated in the 1970s (Dawson 1970) and has been the subject of recent re-investigation. Subsequent research involved the analysis of plant microfossils (starch and phytoliths) from carbonized and non-carbonized food residues adhering to pottery and other artifacts from the site (Boyd & Surette 2010; Boyd et al. 2014; Boyd et al. 2015). The findings indicate the presence of maize and other domesticated plants on the island.

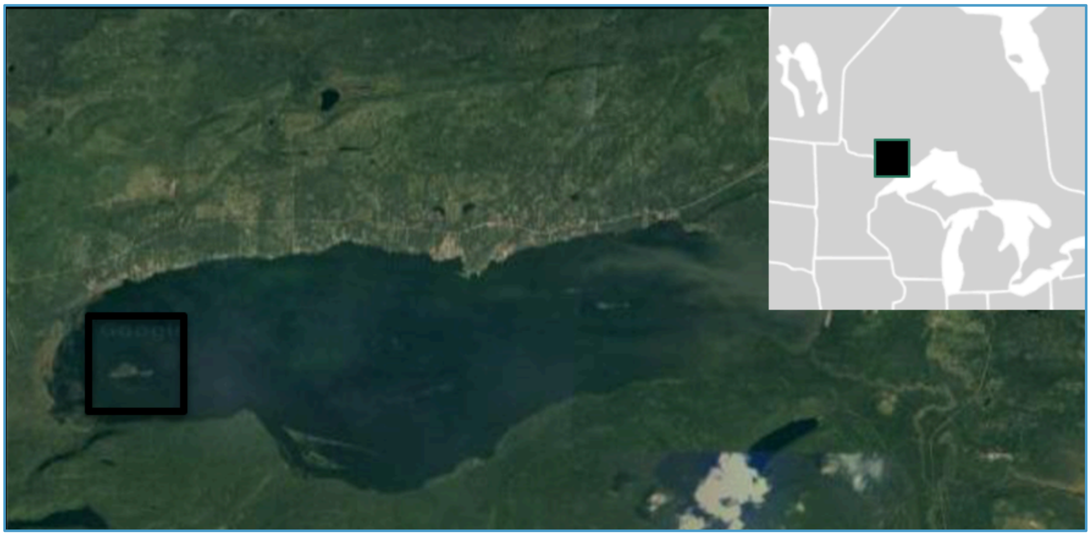


Figure 1.1. Map situating Whitefish Lake and Macgillivray Island of the study area.

The recovery of plant microfossils from maize, common bean, and squash, from archaeological residues at this site raises the possibility that some Woodland societies in the southern Boreal Forest engaged in horticulture—something that archaeologists have not previously documented in the region. Due to poor organic preservation, and thin and disturbed soils, however, conventional archaeobotanical methods such as macrobotanical analysis cannot be employed to develop a fuller picture of subsistence practices in the Woodland period. Indeed, in many ways, Martin-Bird and other Boreal sites represent a ‘worst case scenario’ with respect to the reconstruction of ancient diet. This is particularly so when addressing domesticated plant foods due to their (suspected) small contribution to the diet of ancient Subarctic peoples.

The major goal of this thesis is to explore the utility of plant microfossils in soil, as well as soil chemistry (specifically P content), for the identification of economic plants and food processing areas in northern archaeological sites. In other words, in the absence of organic macroremains and other perishable lines of evidence, do plant microfossil assemblages and soil P values provide information on the importance and spatial dimensions of domesticated plant use in small, disturbed, hunter-gatherer sites?

My specific research questions are as follows:

1. Do economic plant microfossils in soil, and soil P values, at the Martin-Bird site allow for the identification of food processing or other activity areas involving plants?

2. Do plant microfossils recovered from soil differ from assemblages recovered from archaeological residues such as carbonized encrustations on pottery or residues on grinding stones?

The methodological approach taken for this thesis focuses on microanalytical and chemical proxies that include plant microfossils (starch and phytoliths), soil phosphorus content, and microscopic charcoal type and abundance. These proxies were selected for the study as they are often comparably well-preserved in a Boreal Forest setting where acidic soils are widespread and the stratigraphy is often intensely compacted (Dawson 1983a), thus limiting the recovery of organic plant remains and other conventional lines of evidence. Phytoliths are inorganic remains of plants and therefore preserve exceptionally well. Starch granules, though organic, have been recovered from both well and poorly preserved environments, in some cases from deposits dating back 2 million years (Torrence & Barton 2006). With the help of keys and comparative collections, taxonomic identification of plants based on starch and phytoliths is possible and this application reflects a growing trend in archaeological studies of this nature.

Phosphorus is the most widely used element for the chemical analysis of archaeological soils (Holliday & Gartner 2007). It is comparatively immobile in soils, relative to other elements like carbon and nitrogen, making it a well-suited indicator of past human activity as the concentrations likely represent past inputs or depletions of the element (Lauer et al. 2013; Holliday & Gartner 2007). Phosphorus also tolerates acidic soil conditions, bonding with iron and aluminum in such a pH range (Holliday & Gartner 2007).

Finally, charcoal, an indicator of past burning events, is assessed microscopically in terms of its relative abundance in the mounted archaeological samples. Higher values may represent, for example, areas of cooking features like hearths or the act of clearing a parcel of land for cultivation, though distinguishing between charcoal from natural fire events and anthropogenic burning is inherently difficult.

These proxies were recovered from soil samples collected at the Martin-Bird site as well as non-archaeological control samples collected from the northwestern and western mainland surrounding Whitefish Lake. The collective application of these proxies gives an opportunity to obtain interesting and informative patterns of plant-use and land-use for the Martin-Bird site, Whitefish Lake, and the region as a whole that would otherwise be archaeologically unknown. Conventional archaeological approaches are inadequate in the face of poor preservation conditions that severely limit the recovery of organic remains. Using subtle lines of evidence like microfossil analyses and soil chemistry, a new narrative on precontact subarctic subsistence and human-environment interactions for the region can begin to form.

CHAPTER 2: ENVIRONMENTAL SETTING AND ARCHAEOLOGICAL BACKGROUND OF THE STUDY AREA

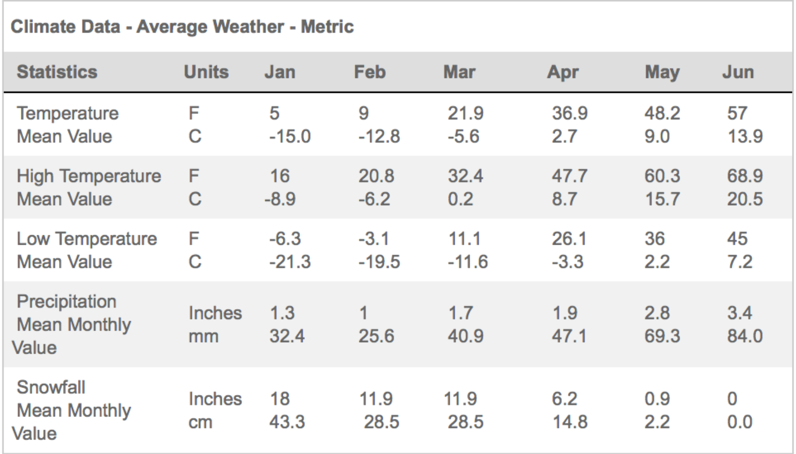
2.1. MODERN ENVIRONMENT OF NORTHWESTERN ONTARIO AND WHITEFISH LAKE

Whitefish Lake is located approximately 60 km southwest of the city of Thunder Bay in Northwestern Ontario near the transitional zone between the Boreal and Great Lakes-St. Lawrence Forests. It extends about 11 km long and is a shallow, flat-bottomed, lake with an average water depth of 2.0 metres. Because of this, the basin supports a diverse aquatic vegetation community and is particularly rich in wild rice (*Zizania palustris*). Faunal species that inhabit the region include black bear (*Ursus americana*), wolf (*Canis lupus*), fox (*Vulpes vulpes*), bobcat (*Lynx rufus*), and lynx (*Lynx canadensis*), ungulates like moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*), aquatic mammals like beaver (*Castor* sp.), muskrat (*Ondatra zibethicus*), otter (*Lutrinae* sp.), and small rodents like squirrels (*Sciuridae* sp.), chipmunks (*Tamias*), voles (*Microtus*), and mice (*Mus* sp.) (Kemp 1991).

2.1.1. Climate

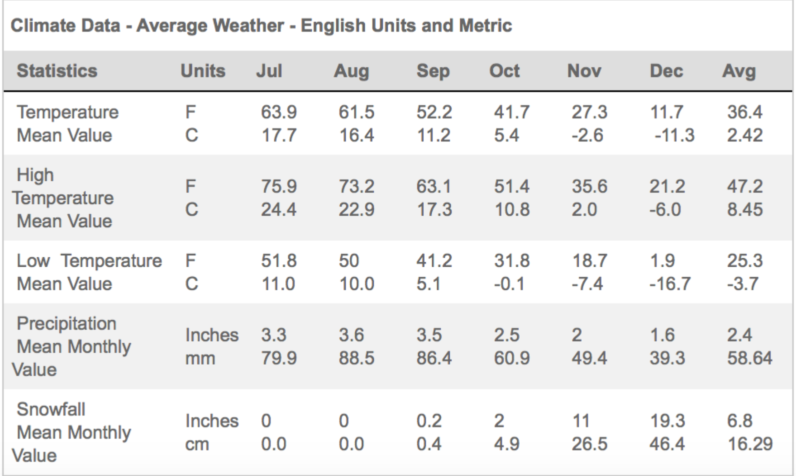
Northwestern Ontario is characterized by a subarctic climate with short, warm summers and prolonged cold winters, with snow accounting for nearly half of all annual precipitation (Nelson 2012; Kemp 1991). The area is affected by three main air masses: the Arctic air masses from the north bring cold and relatively dry, tropical air masses from the south also affect the region, bringing typically warm, moist air, and lastly Pacific air masses move into the area with mild air from the west (ibid). The Environment Canada Thunder Bay Airport weather station provides the closest climate data for Whitefish Lake (Figure 2.1).

2.1.2. Physical Geography



Climate Data - Average Weather - Metric

Statistics	Units	Jan	Feb	Mar	Apr	May	Jun
Temperature Mean Value	F C	5 -15.0	9 -12.8	21.9 -5.6	36.9 2.7	48.2 9.0	57 13.9
High Temperature Mean Value	F C	16 -8.9	20.8 -6.2	32.4 0.2	47.7 8.7	60.3 15.7	68.9 20.5
Low Temperature Mean Value	F C	-6.3 -21.3	-3.1 -19.5	11.1 -11.6	26.1 -3.3	36 2.2	45 7.2
Precipitation Mean Monthly Value	Inches mm	1.3 32.4	1 25.6	1.7 40.9	1.9 47.1	2.8 69.3	3.4 84.0
Snowfall Mean Monthly Value	Inches cm	18 43.3	11.9 28.5	11.9 28.5	6.2 14.8	0.9 2.2	0 0.0



Climate Data - Average Weather - English Units and Metric

Statistics	Units	Jul	Aug	Sep	Oct	Nov	Dec	Avg
Temperature Mean Value	F C	63.9 17.7	61.5 16.4	52.2 11.2	41.7 5.4	27.3 -2.6	11.7 -11.3	36.4 2.42
High Temperature Mean Value	F C	75.9 24.4	73.2 22.9	63.1 17.3	51.4 10.8	35.6 2.0	21.2 -6.0	47.2 8.45
Low Temperature Mean Value	F C	51.8 11.0	50 10.0	41.2 5.1	31.8 -0.1	18.7 -7.4	1.9 -16.7	25.3 -3.7
Precipitation Mean Monthly Value	Inches mm	3.3 79.9	3.6 88.5	3.5 86.4	2.5 60.9	2 49.4	1.6 39.3	2.4 58.64
Snowfall Mean Monthly Value	Inches cm	0 0.0	0 0.0	0.2 0.4	2 4.9	11 26.5	19.3 46.4	6.8 16.29

Figure 2.1. Average Weather for Thunder Bay, Ontario (City of Thunder Bay 2009)

A prevalent physiographic feature consisting of Precambrian metamorphic rocks (Liu 1990), commonly referred to as the Canadian Shield, characterizes the rugged landscape of northwestern Ontario. The Canadian Shield has an extensive distribution in Canada.

When deglaciation was occurring after the last Ice Age, glacial activity largely removed existing soil and left depressions where glacial till, sand or gravel was deposited. This resulted in a poor foundation for the development of new soil (Kemp 1991). The soils are typical for a Boreal Forest setting, being thin, acidic, and nutrient poor (Kemp 1991). Additionally, peatlands cover a considerable area of the region. Waterlogged environments with poorly drained, organic rich soils encouraged their development (Kemp 1991).

Whitefish Lake is connected to several different townships including the township of Strange. Geological surveys of Strange township reveal the following characteristics of the area: numerous bedrock ridges and areas of outwash with a peat veneer (Mollard & Mollard 1983). The soil in the area can be described as mostly fine sand and clay loam along the northern shoreline (Lakehead Region Conservation Authority 2011). A detailed description of soils from the Martin-Bird site is presented in Chapter 5.

2.1.3. Vegetation

The vegetation surrounding Whitefish Lake is characterized by the Boreal and Great Lakes-St. Lawrence forests zones, comprising a mixture of coniferous and deciduous tree species. Hardwoods like maple (*Acer*), elm (*Ulmus L.),* oak (*Quercus*), ash (*Fraxinus*), and birch (*Betula papyrifera*) grow, interspersed with white and black spruce (*Picea glauca* and *Picea mariana*), hemlock (*Tsuga canadensis*), pine (*Pinus sp*.), tamarack (*Larix laricina*), and balsam fir (*Abies balsamea*) (Kemp 1991; Liu 1990). Rich stands of wild rice (*Zizania palustris*) occur at the western end of the lake interspersed with patches of *Nuphar variegatum* (pond lily), *Nymphaea odorata* (water lily), and *Potamogeton gramineus* (pondweed) (Lee & McNaughton 2004).

The Martin-Bird Site

Current vegetation at the Martin-Bird site on Macgillivray Island reflects a high percentage of deciduous species, most notably mountain maple (*Acer spicatum),* pincherries, chokecherries (*Prunus spp*.), beaked hazel (*Corylus cornuta)*, and black ash (*Fraxinus nigra)*. Other frequently encountered plants include red baneberry (*Actaea rubra*), wild strawberry (*Fragaria virginiana*)*,* American mountain ash (*Sorbus americana*)*,* lesser round-leaved orchid (*Platanthera orbiculata*)*,* boxelder or 'Manitoba maple' (*Acer negundo*)*,* balsam fir (*Abies balsamea*)*,* red osier dogwood (*Cornus stolonifera*), and cow parsnip (*Heracleum lanatum*)*.* Lesser amounts of plants like American cranberry (*Viburnum trilobum*), grapes (*Vitis* spp.), dwarf raspberry (*Rubus pubescens*), showy mountain ash (*Sorbus decora*), paper birch (*Betula papyrifera*), yew tree (*Taxus canadensis*), and saskatoon or serviceberry (*Amelanchier alnifolia*) also grow near the site. (See Appendix 1)

The Macgillivray Site (Historical Garden Area)

Remnants of a historical-period (post-contact) garden area are still discernible near the Macgillivray site. Some areas of the garden are still maintained while others are overgrown with fireweed (*Epilobium* spp.), orange jewelweed (*Impatiens capensis*), thistle (*Cirsium* spp.), and wild mint (*Mentha arvensis)* . Healthy patches of blackberry and raspberry (*Rubus* spp.) occur near the site, as well as wild grapes (*Vitis* spp.), currants, and gooseberries (*Ribes* spp.). Crab apple (*Malus* spp.), wild plum (*Prunus* spp.), and pear (*Pyrus* spp.) orchards can also be found. Even asparagus grows on the island (pers. comm. Macgillivray family). Much caragana (*Caragana* sp.), an introduced shrub often used in shelter belts, can also be seen along the trails near the site and ferns occur in the garden area as well.

Mound Island

Mound Island, a small finger-like island located in the eastern portion of the lake, is another important archaeological site recorded by Dawson (1978). A vegetation survey was attempted but the island is intensely overgrown and therefore difficult to access. Many coniferous trees were observed such as spruce (*Picea* spp.), balsam fir (*Abies balsamea*), white cedar (*Thuja occidentalis*), and yew trees (*Taxus canadensis*). Paper birch (*Betula papyrifera*) was also identified. Near the waterline, orange jewelweed (*Impatiens capensis*) and wild mint (*Mentha arvensis*) grow. Other plants on the island include saskatoon (*Amelanchier alnifolia*) and red osier dogwood (*Cornus stolonifera*).

Northwestern Mainland of Whitefish Lake

Areas surveyed on the mainland around the northwestern shores of Whitefish Lake proved to be less diverse than Macgillivray Island but similar vegetation includes high occurrences of *Acer spicatum*, *Fraxinus nigra*, and *Abies balsamea.* Ferns, wild strawberry (*Fragaria virginiana*), purple-flowering raspberry (*Rubus parviflorus*), paper birch (*Betula papyrifera*), speckled alder (*Alnus incana*), red osier dogwood (*Cornus stolonifera*), and prickly rose (*Rosa acicularis*) are also commonly encountered. (See Appendix 1)

Overall, Macgillivray Island vegetation shows much diversity compared to other locales in the region and even the mainland around the Whitefish Lake basin. The over-story is dominated by an array of deciduous tree species, like black ash (*Fraxinus nigra*) and maple (*Acer* spp.) that are noticeably prominent on the island, while the understory contains many fruit-bearing species. The vegetation mosaic is unlike that typically observed in the Boreal Forest and the diversity is likely attributable to the favourable micro-climate of Whitefish Lake. The island's soils, composed of thick accumulations of soft sediment also promote greater diversity compared to the mainland and elsewhere in the region where soils overlay bedrock.

2.2. PALEOENVIRONMENTAL HISTORY OF NORTHWESTERN ONTARIO AND WHITEFISH LAKE

2.2.1. Post-Glacial History

During the Pleistocene, much of North America, including the study region, was covered by a large ice sheet. In particular, the Laurentide Ice Sheet (LIS), that covered a vast part of the continent, had a significant role in the development of present day topographic features. When the LIS began its retreat, glacial activity contributed to the development of the present-day the landscape.

Before ~12,300 cal B.P the Laurentide Ice Sheet (LIS) retreated northward from the Steep Rock Moraine, beginning the deglaciation of Whitefish Lake (Lowell et al., 2009). The basin was filled by the water of proglacial Lake O'Connor until ~11,000 cal B.P. when the LIS re-advanced to the Marks Moraine during the Marquettte advance (Loope 2006). Northeast of Whitefish Lake (~27km), varved sediments show uninterrupted sedimentation occurred for at least 300 years in Lake O'Connor before becoming overridden by the Superior Lobe (Loope 2006). Glacial retreat resulted in lower elevation outlets that opened along the north-western shore of Lake Superior, permitting the drainage of proglacial Lake O'Connor and others in the region (Loope 2006; Phillips & Hill 2004; Zoltai 1963).

2.2.2. Paleovegetation

Pollen records indicate that the early postglacial forest of Northwestern Ontario 10,000 BP (~9600 cal BP) was populated chiefly with white spruce (*Picea* *glauca*), interspersed deciduous species like oak (*Quercus*), elm (*Ulmus*), and poplar (*Populus*) (Liu 1990). With the onset of Holocene climatic conditions, the vegetation mosaic changed, with an invasion of characteristic Boreal Forest species including jack pine (*Pinus banksiana*), black spruce (*Picea mariana*), and tamarack (*Larix laricina*) (Liu 1990). A period of warming and drying during the middle Holocene likely promoted the spread of Great Lakes-St. Lawrence forest species into the southern portion of the region, including white pine (*Pinus strobus L.*), hemlock (*Tsuga*), and cedar (*Thuja*) (Liu 1990; Wright 1976). Pollen analyzed from lake sediment cores collected from Lake Ojibway on Isle Royale reveal a significant increase in precipitation during the Late Holocene beginning around 4,700 BP. This led to a mixed forest dominated by conifers, with pine declining slightly while birch, spruce, fir, alder and herbs increased (Flakne 2003: 1156). The region experienced a cooler, moist climate ~4,000 BP and an increase in *Abies*, *Picea*, *Betula*, and *P. banksiana* is seen, while the population of *Pinus strobus* appears to have diminished (Liu 1990). Around this time, the present mixed northern hardwoods forest was established, consisting of yellow birch, sugar maple, red oak, spruce, fir, and pine (Flakne 2003: 1156).

2.2.3. Paleoecology of Wild Rice

Wild rice (*Zizania* sp.) is a North American native plant, with a distribution from Lake Winnipeg to the Gulf of Mexico and east to the Atlantic (Keane 1997; Lorenz 1981). *Zizania* is ecologically important plant as a source of food and habitat for waterfowl and many other organisms. This annual aquatic grass favors shallow lakes and slow-flowing streams of the Great Lakes region (Archibold et al., 1985; Drewes and Silbernagel, 2004; Keane, 1997; Kuhnlein and Turner, 1991; Stickney, 1896; Quayyum et al., 1999; Steeves 1952). However, the range of wild rice in precontact times and the antiquity of natural stands in lakes are not well understood (McAndrews 1969). Whitefish Lake is rich in *Zizania palustris,* the most widespread species of wild rice in Canada (Archibold et al. 1985). Extensive stands of wild rice grow at the western end of the lake (Boyd et al. 2013; Lee & MacNaughton 2004). *Zizania palustris*, also known as northern wild rice, is similar to *Zizania aquatica*, southern wild rice, which occupies much of the same regions. Their habitats often include small bays of large lakes and seldom grow in inland lakes with no outlets (Keane 1997). These species cannot grow in anoxic soil, but thrive in nutrient rich, muddy, algal bottoms of streams, marshy lakes, and tributaries (Stickney 1896; Keane 1997) however, temperature and pollution can negatively impact their growth (Vogel 1990). Optimal growing conditions also include a 15-45 cm layer of loose silts or clays, and organic materials that provide full root growth and anchorage for the plant (Archibold et al., 1985). *Zizania palustris* grows between 0.5 to 3.0 m in height (Duvall & Biesboer 1988).

The antiquity of the colonization of *Zizania* on the Canadian Shield is unknown. Nearby in central Minnesota, however, estimates for its first appearance range from 10,600 (12,600 cal) BP (Birks 1976) to 2,000 (1,960 cal) BP (McAndrews 1969). The paleoecology of wild rice in Whitefish Lake has only recently been the subject of investigation. Lake sediment cores sampled around Macgillivray Island at the western end of the basin were analyzed for pollen, phytoliths and elemental content to provide a reconstructed chronology of the colonization of the lake by wild rice and its development (Boyd et al., 2013). The following chronology relates to the development of the lake: (1) proglacial lake phase with deeper waters and high sediment flux; (2) a shallowing of the lake with the onset of a drier climate; (3) colonization of wild rice (*Zizania sp.*) in the western basin by ~5,300 (6,100 cal) BP correlating with higher humidity and a deepening of the lake; (4) steady increase in the overall productivity of the basin beginning ~4,000 (4,500 cal) BP and continuing to recent times (Boyd et al., 2013: 372).

2.3. THE ARCHAEOLOGY OF WHITEFISH LAKE

2.3.1. Middle and Late Woodland Periods

The archaeological record of Whitefish Lake is sparse until the Woodland period. A number of Woodland sites showing extensive habitation have been identified along the modern shore or on islands within the lake (Boyd et al., 2013; Dawson, 1987) (Figure 2.5). The Woodland encompasses the period of Eastern Woodlands culture history following the Archaic, beginning around 150 B.C. (Arzigian 2008) and is generally marked by the first appearance of pottery in the archaeological record. The Woodland is typically divided into Early, Middle, and Late periods based largely on changes in pottery vessel shape and decoration. Presently, no evidence exists for an Early Woodland occupation in Northern Ontario, for the first pottery seen has been identified as Laurel, a Middle Woodland complex. The distinctions “Initial Woodland” and “Terminal Woodland” are sometimes used when addressing Northern Ontario, specifically (Dawson 1983; Wright 1981). However, Middle Woodland and Late Woodland will be used herein to comply with terminology still applicable to Northern Ontario and most commonly employed elsewhere.

In addition to pottery technology, other general trends observed across the Eastern Woodlands during the Woodland period include larger settlements, an expansion of long-distance trade networks and increase in regional interactions, and burial mound ceremonialism (Boyd et al. 2014). These trends are observed at some sites in Northern Ontario, a region occupied by various complexes throughout the Woodland distinguished mainly by their pottery decoration style, however, the culture history framework of the region remains comparatively underdeveloped. Some factors contributing to this gap in the literature include limited archaeological investigation, the paucity of securely-dated sites, and the taphonomic processes especially prevalent in the acidic soils of the Boreal Forest such as poor organic preservation and slow soil development, contributing to poor site stratigraphy (Boyd et al. 2014; Dawson 1983a).

Middle Woodland

The first pottery producing complex of the Canadian Boreal Forest is the Laurel phase (150 B.C. – A.D. 1100) during the Middle Woodland. Many sites on Whitefish Lake feature a Laurel component. The complex has a wide geographic distribution, extending from eastern Saskatchewan, through central and southeastern Manitoba and into the Lake Superior region, encompassing much of Northern Ontario and adjacent northern Minnesota (Figure 2.2) (Stoltman 1973; McMillan 1995). Laurel is cited as being the most geographically extensive Middle

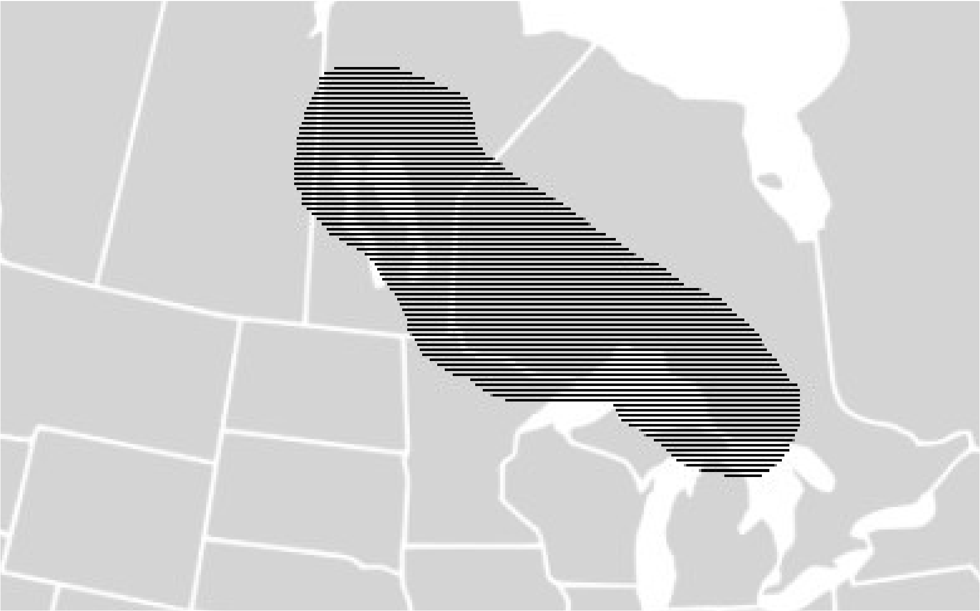


Figure 2.2 Map showing approximate distribution of the Laurel phase by 500 A.D. (Meyer & Hamilton 1994)

Woodland culture in North America (Gibbon 2012). Laurel pottery vessels are characterized by their conoidal shape, smoothed exterior surface and grit-tempered construction (Gordon 1985; Syms 1977) (Figure 2.3). Other aspects of the Laurel tool-kit include a range of lithic, bone, and some copper tools. Laurel lithic assemblages closely resemble previous Late Archaic ones (McMillan 1995; Mason 1981). Laurel stone tool assemblages show a "strikingly" large representation of scrapers (Mason 1981:285), including unifacial end scrapers and side scrapers (Gordon 1985). This trend is observed at most of the sites at Whitefish Lake with Laurel occupations. Projectile points typologies are consistent across Laurel assemblages (Syms 1977) with "small side-notched and corner-notched forms [and] occasional large lance or spear points" (Gordon 1985). Occasional copper tools such as awls, barbs, and beads are also associated with Laurel sites (McMillan 1995; Syms 1977). Recovered bone tools from Laurel sites,

Figure 2.3. Reconstructed Laurel pot, from the Department of Anthropology collection at Lakehead University, Thunder Bay, Ontario. (Meyer & Hamilton 1994)

though infrequently encountered due to preservation issues, include "socketed toggling harpoons, barbed harpoons, beaver-incisor knives, awls, and snowshoe netting needles" (Gibbon & Ames 1998: p. 451).

Another major component of the Laurel phase is the first appearance of burial mound ceremonialism in Northern Ontario and adjacent Minnesota, a practice that was widely adopted during the Woodland period in eastern North America. Several mounds appear on Whitefish Lake, like the Laurel mound at the

Macgillivray site, marking the area as one of the most northerly expressions of this trend in North America and the northernmost in the Boreal Forest (Boyd et al. 2014).

There are several aspects of the Laurel phase that reveal its potential cultural origin and diffusion, like the construction of burial mounds for example. These structures appear to have Hopewellian cultural origins and their manifestation with the Laurel phase may indicate an indirect cultural borrowing of the tradition from cultures more immediately to the south. However, beyond the adoption of burial mounds, it appears that Laurel did not engage in any significant way with the Hopewell Interaction Sphere (Wright 1999) and Laurel mound ceremonialism is restricted to the southern portion of the complex's distribution, mainly around the Boundary Waters area (Minnesota and Ontario) (Boyd et al. 2014). Laurel pottery also shows broad similarities to Lower Great Lakes pottery vessels such as those of the Saugeen and Point Peninsula complexes suggestive of some cultural diffusion (Wright 1999). Net-impressed pottery sometimes occurs within Laurel assemblages, a style shared with Avonlea ceramics in Manitoba and Saskatchewan (Meyer & Walde 2014; Hamilton et al. 2011). The same style also occurs in north and central Minnesota but is classified as 'Brainerd Ware' (Meyer & Hamilton 1994). Some Brainerd sherds have been recovered from the Martin-Bird site (Boyd et al. 2014). The dating of Brainerd ware is unclear, though Brainerd and Laurel pottery have been recovered together at several sites in Minnesota like the Dead River (Michlovic 1979), McKinstry Mound 2 (Lugenbeal 1978), and Third River Borrow Pit (Mulholland et al. 1996) sites, to name a few. To the eastern extent of its distribution, a considerable blending of traits is recognized between Laurel and pottery producing cultures of southern Ontario such as Saugeen and Point Peninsula (Mason 1981; Stoltman 1973). Generally, many scholars believe that in subarctic regions like Northern Ontario, Laurel developed from Shield Archaic antecedents as the tool kit appears relatively unchanged with the exception of pottery (Hamilton 1981; Mason 1981; McMillan 1995; Schlesier 1994; Syms 1977; Wright 1999).

Late Woodland

While the Middle Woodland period in Northern Ontario is entirely defined by the Laurel complex, the appearance of numerous other complexes primarily distinguished by their pottery styles marks the onset of the Late Woodland period. The major complexes include Blackduck-Kathio, Rainy River Late Woodland, Psinomani (Sandy Lake), and Selkirk (Boyd et al. 2014) and generally date to around A.D. 1000 though some Blackduck occupations in northern Minnesota and southern Manitoba have been dated to around A.D. 600 and 800 (Arzigian 2008; Hamilton et al. 2007; Rapp et al. 1995). At Whitefish Lake, the Late Woodland pottery assemblage is dominated by Blackduck wares. At the Martin-Bird site alone, Blackduck accounts for nearly 50 percent of the total pottery assemblage, suggesting the site was primarily occupied by the makers of Blackduck and related wares (Kathio and Duck Bay) (Boyd et al. 2014). The complex's geographical distribution extends from southern Manitoba to west-central Minnesota and into the northern Lake Superior area (Gregg 1994; McMillan 1995) (Figure 2.4). Blackduck vessels are marked by their fabric-impressed exteriors and exhibit a globular body form, with a constricted neck and out-flaring rim, often decorated with cord-wrapped stick impressions and a row of punctates (Gibbon 2012; McMillan 1995; Meyer & Hamilton 1994; Syms 1977) (Figure 2.7). The non-ceramic portion of Blackduck artifact assemblages exemplify little modification from previous Laurel ones and remain relatively static until European contact (Mason 1981). Lithic tool kits "include small end scrapers, retouched flakes, small side-notched and triangular projectile points, along with ovoid and semi-lunar bifaces" (Dawson 1974; Webster 1973; as cited in Gordon 1985: 162). Other implements recovered from sites with Blackduck components include knives, awls, fishhooks, tubular

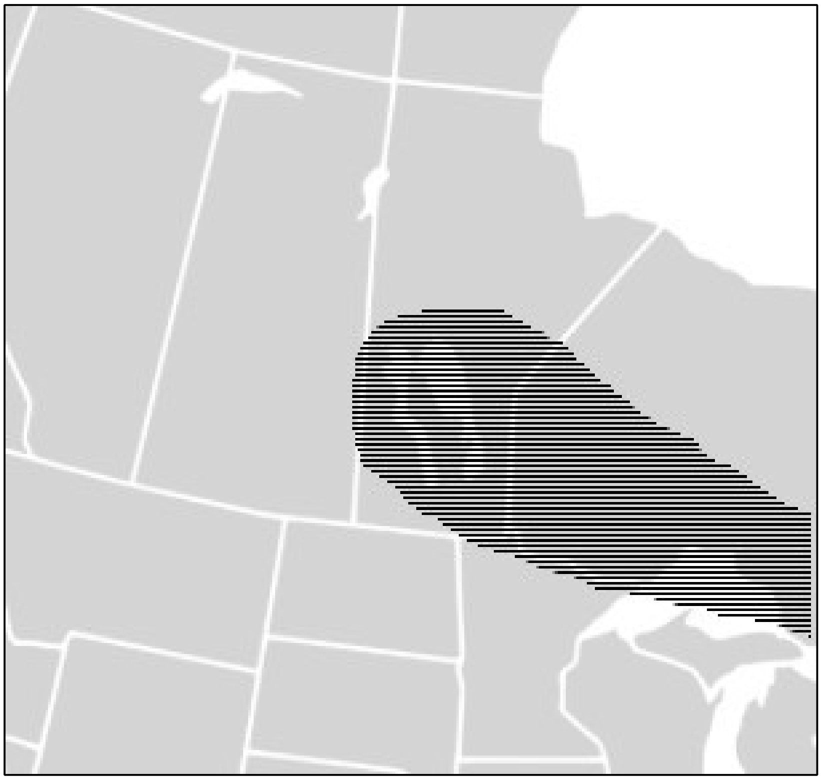


Figure 2.4. Map showing approximate distribution of the Blackduck complex (adapted from Meyer & Hamilton 1994)

pipes, bone spatulates, fleshers, and beads made of native copper (McMillan 1995; Syms 1977). The practice of burial mounds, first seen during the Laurel phase, continues into the Late Woodland. The Martin-Bird mound is associated with the Blackduck complex, detailed further in the site description. Blackduck mounds are comparatively smaller than Laurel ones (McMillan 1995), and sometimes existing Laurel mounds are used (Gibbon 2012; Boyd et al. 2014).

Extensive interaction between Blackduck and the Selkirk complex is evidenced by apparent borrowing of ceramic decorative techniques and the occurrence of both wares at many Late Woodland sites (Buchner 1979; Meyer & Hamilton 1994). Carriers of the Selkirk culture occupied some of the same regions as Blackduck (McMillan & Yellowhorn 2004) and farther still into western Saskatchewan (Meyer & Hamilton 1994). A blending of Blackduck and Selkirk decoration styles is seen on some vessels recovered from the Martin-Bird site (Boyd 2013b). Intermarriage between the two groups has been suggested as an explanation for such cases of stylistic blending (McMillan 1995). These syncretic wares may represent marriage patterns with women from distant groups marrying into another and blending both familiar and local pottery styles. They may also represent transitional styles where one is ancestral to the other. For example, several sherds from sites in the Whitefish Lake basin reveal a Laurel construction method (coiling and paste) but their exteriors are decorated with fabric-impression and punctuates typical of Late Woodland pottery (Boyd 2013a,b).

2.3.2. Diet and Subsistence

The reconstruction of Laurel and Late Woodland diet and subsistence practices is limited by the scant faunal and botanical remains at sites due to highly acidic soils of a Boreal Forest setting that tend to destroy nearly all organic material, and by the general lack of focus on the plant component of the diet by archaeologists in the region. Subsistence practices would have depended on the region though in general, Laurel and Late Woodland subsistence revolved around a mixed hunter-gatherer economy operating in a seasonal round as various resources became available throughout the year (Arzigian 2008). Fish, large and small game, and plant foods were seasonally exploited and during times of abundance, large gatherings of people likely occurred (Arzigian 2008). In Ontario and adjacent Minnesota for example, fish like pike, suckers, sturgeon and varieties of shellfish would have been available and mammalian resources such as beaver, moose, deer, muskrat, and other game typical of Boreal Forest regions (Arzigian 2008). Diet and subsistence of Woodland groups in southeastern Manitoba and adjacent northwestern Minnesota is interpreted as a seasonal movement of people from the Boreal Forest to the parklands to exploit a different set of resources, particularly bison (Meyer & Hamilton 1994). Hamilton (1981) outlines three main subsistence economies practiced by Laurel peoples:

> “1) large summer aggregates supported by the exploitation of concentrated fish resources and small winter groups relying

> upon diffuse land mammal resources. This strategy seems to be employed in the Lake-Forest regions in the vicinity of the Great Lakes (Fitting 1970:99, 129-142).
>
> 2) a strategy employing seasonally available resources that imply movements from Mixed Conifer-Hardwood and Parkland biomes in Minnesota (Syms 1977: 83)
>
> 3) a strategy represented by the scattered distribution of sites reflecting a reliance on diffuse resources in eastern and northern Manitoba and Northwestern Ontario. (Syms 1977: 83; Wiersum and Tisdale 1977:1; Meyer and Smailes 1974)." (p.21)

The first and last strategies are most applicable to Northern Ontario Laurel groups, and are likely applicable to Late Woodland groups in the region as well. During the spring and early summer months, large aggregations concentrated around major spawning runs of sturgeon and pickerel would have occurred (Hamilton 1981). Into the summer, smaller groups likely dispersed and returned in the fall to form small-scale gatherings permitted by whitefish spawning and wild rice harvesting (Meyer & Hamilton 1994). Thomas and Mather (1996) view these group-oriented seasonal exploitation strategies as giving more structure to Laurel ways of life, imposing some restriction to their mobility patterns. This may reflect a shift toward some degree of sedentary living during the Laurel phase and continuing into the Late Woodland, also inferred from "increased artifact densities at sites [and] the appearance of domestic architecture" (Thomas & Mather 1996: 5.10-

5.11) like multi-family dwellings. Features associated with Laurel are sparsely encountered in Northern Ontario (Wright 1967), likely the result of taphonomy and limited exploration of the region, or perhaps a reflection of the third strategy wherein sites would have only been occupied for short periods and by small, highly mobile groups to “exploit a large number of diffuse resources” (Hamilton 1981). Features can include hearths, refuse pits, and remnants of house structures (Gordon 1985; Wright 1967). One such example of the latter comes from the Ballynacree site in Kenora, Ontario where post moulds appear to outline three oval-shaped houses, suggesting a Laurel village of sorts occurring at the site (Reid & Rajnovich 1983). A single post mould was also uncovered at the Martin-Bird site (Dawson 1987). Late Woodland sites tend to have greater visibility due to larger populations occupying and reusing sites (Dawson, 1983b). Buckmaster (cited by Emerson et al., 2000) notes that Late Woodland sites are found “in a broader range of microenvironments” than Middle Woodland sites (p.565). The location of Whitefish Lake near the transitional zone of the Great Lakes-St. Lawrence and Boreal Forest ecozones is an example of such, as the area supports an affluent and diverse resource base.

Wild Rice and Domesticated Plant Foods

Carriers of Laurel and Late Woodland pottery undoubtedly exploited wild plant resources and possibly domesticates, but the lack of macro-botanical remains limits knowledge of this aspect of diet and subsistence (Arzigian 2008). The relative importance of wild rice to precontact peoples of the Upper Great Lakes is not well known but archaeologists have generally assumed that a strong connection existed (Boyd et al. 2014). For example, another theory relating to the origin of the Laurel phase suggests that carriers of Laurel pottery represent an intrusive population entering the Upper Great Lakes area from the south and east. Migrating peoples would have followed the northward expansion of wild rice into the area (O'Brien, 1979). One way in which this theory is supported is the apparent overlapping distribution of both Laurel and Late Woodland sites and the range of wild rice in the area (Buchner 1979; Stoltman 1973; Rajnovich 1984; Wright 1999). With increasing populations during the Woodland, wild rice would have been particularly important as the plant provided much food security (LaDuke 1999; Emerson et al. 2000). The plant was easily harvested and transported and required little to no effort to prepare for the following season (Stickney 1896).

Occasionally, macro-botanical remains of wild rice have been recovered like at the McKinstry site (21KC2) along the Rainy River in Minnesota (Valppu 1996), where several wild rice grains were collected. Wild rice processing features containing various pottery wares have also been identified from the Big Rice site in Minnesota (Valppu & Rapp 2000). A portion of a wild rice seed as well as a squash seed were also recovered during excavations of the Big Rice site (Peter and Motivans 1985). Recent microfossil analyses have been furthering knowledge on this aspect of diet and subsistence, such as Surette (2008) who identified diagnostic wild rice phytoliths from carbonized food residues in Laurel and Late Woodland vessels from several sites in Northwestern Ontario. The abundance of wild rice seen at Whitefish Lake would undoubtedly have been observed by Laurel and Late Woodland groups and may explain, in part, the relatively high density of large Woodland sites in this locale. Carbonized food residue analyses of 63 pottery sherds of Laurel and various Late Woodland affiliations from Whitefish Lake revealed wild rice phytoliths in nearly half of all samples (Boyd et al. 2014). In food residues, furthermore, wild rice will probably be under-represented because it produces low amounts of starch and the starch grains lack identifiable morphotypes, while the diagnostic phytoliths are produced in the “chaff” (glumes) portion of the plant that would not likely be consumed (Surette 2008; Boyd et al. 2014). Analyzing soil samples for diagnostic wild rice phytoliths has the potential to fill this gap in the data.

In addition to important wild economic plants like wild rice, evidence is now emerging that Laurel and Late Woodland groups also consumed domesticated plants, particularly maize. Microfossil analyses by Burchill (2014) of Laurel material from nine sites across Northern Minnesota found maize phytoliths and starch from nearly half of the sites and found the presence of possible squash and bean microfossils. Boyd & Surette (2010) identified maize in carbonized food residues from Laurel and Late Woodland pottery samples representing nine different sites, including the Macgillivray site and the Martin-Bird site in the Whitefish Lake basin. The aforementioned Boyd et al. (2014) study also identified common bean and squash microfossils from Laurel and Late Woodland ceramics around Whitefish Lake but found an apparently strong relationship between wild rice and maize, as microfossils of the two were positively identified together from 57% of the Laurel and Late Woodland ceramics analyzed, suggesting they were frequently consumed together.

In the 'Three Sisters' agricultural system (Mt. Pleasant 2006; Scarry & Scarry 2005), widely used by indigenous groups across North America, domesticates like maize, bean, and squash were intercropped. Microfossil recoveries for bean were sparse despite the legume being very starch-rich, although it is less hardy in more northerly climates as it is more susceptible to spring frost (Mt. Pleasant 2006; Boyd et al. 2014). In the Three Sisters system, bean is complementary to maize in the diet as it provides protein and missing amino acids from maize. However, it may be that bean was relatively unimportant for the diet of Whitefish Lake groups as wild rice is nutritionally similar to *Phaseolus* and hunting would provide ample animal-derived protein (Mt. Pleasant 2006; Boyd et al. 2014). In the Boreal Forest, Laurel and Late Woodland groups likely acquired domesticates primarily through trade although non-intensive horticulture may have been practiced in the southern Boreal Forest in areas with favourable micro-climates like Whitefish Lake for example.

2.3.3. Archaeological Sites in the Whitefish Lake Basin

Mound Island (DbJl-2)

The Mound Island site is located on a small island at the eastern end of Whitefish Lake (Dawson 1978) (Figure 2.5). This multicomponent Woodland site includes an occupation by Middle Woodland Laurel culture and a subsequent short occupation by a Late Woodland Algonkian culture (Dawson 1978). Classifications of recovered pottery sherds suggest styles associated with Laurel, Blackduck and possibly Mackinac wares (Dawson 1978). The lithic assemblage consists of ~85% debitage but finished tools include scrapers and a biface. Overall, refuse from the site was sparse and its lack of European trade goods suggests a seasonal occupation of the site prior to the Historic period (Dawson 1978).

McCluskey Site (DbJm-2)

The McCluskey site, interpreted as a Blackduck encampment site, is located on the northwestern shore in the western basin of the lake, adjacent to Macgillivray Island (Figure 2.5). It is the most severely disturbed site, with 20th century occupation resulting in buildings, roadways, and garden plots throughout some parts of the site (Dawson 1974). Several features were identified including a pottery concentration, two small possible hearths, a roasting pit, and a mound (Dawson 1974). The mound is currently situated around ten feet inland from the shore bank, with dimensions of roughly ten feet wide and one foot high, extending in length to fifty-five feet giving the mound an overall elliptical shape (Dawson

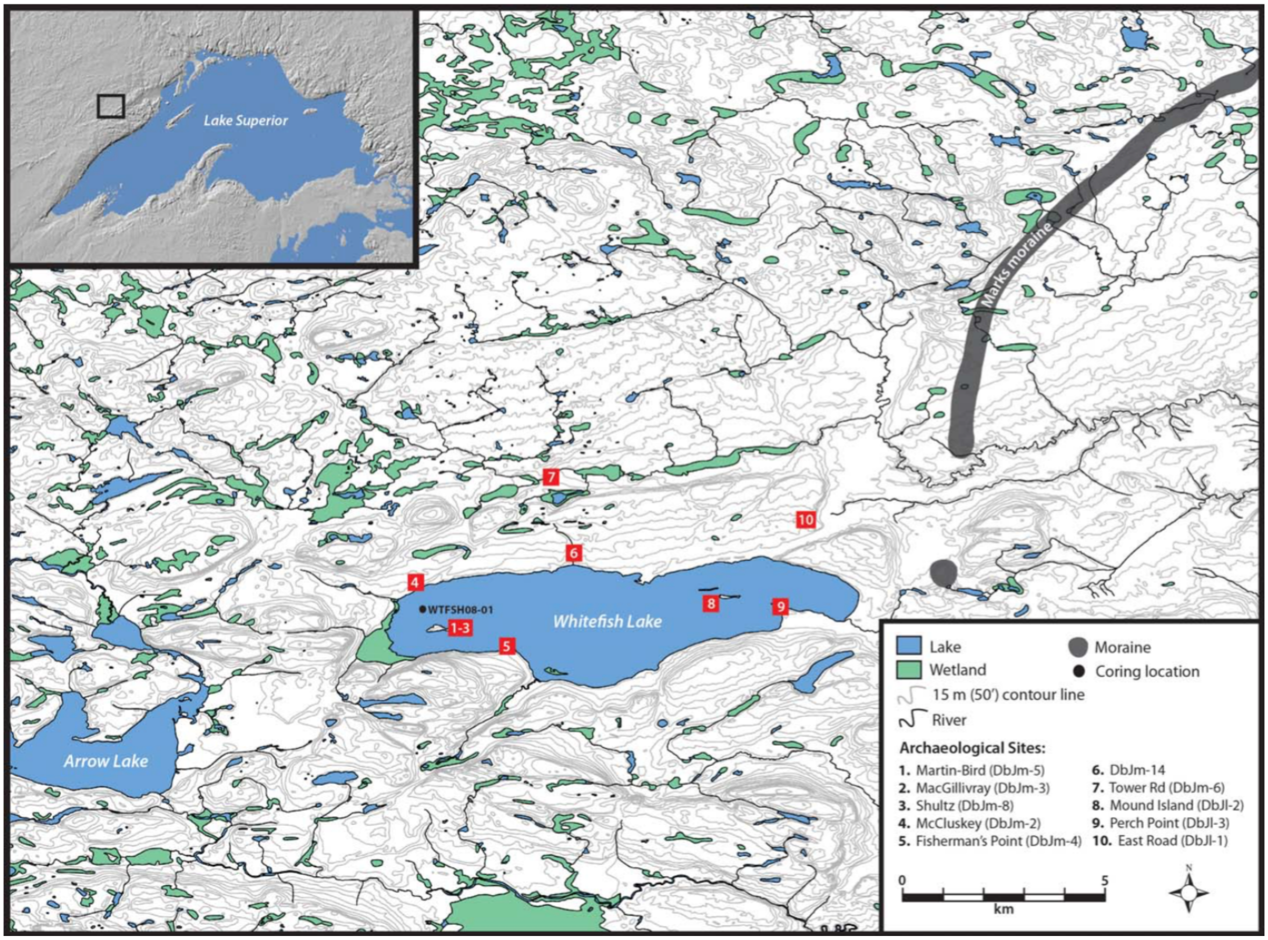


Figure 2.5. Whitefish Lake archaeological site distribution (Boyd et al. 2014)

1974). Human remains were recovered from the mound and multiple mortuary vessels were unearthed in adjacent excavation units (Dawson 1974). The pottery assemblage (nearly 6000 sherds) is mostly of Blackduck affiliation. The lithic assemblage includes thirty-three projectile points, exhibiting unnotched triangular, triangular side-notched, and stemmed varieties, and many scrapers, consisting of end, side and expedient scrapers made from flakes (Dawson 1974).

Macgillivray Site (DbJm-3)

The Macgillivray site is located on Macgillivray Island in the western portion of the Whitefish Lake basin and is identified primarily as a Laurel habitation site (Dawson 1980). The majority of the site is thought to date to ca. A.D. 700 to A.D. 900, but a mound at the site has been tentatively dated to 200 B.C. to A.D. 300 (Dawson 1980). However, radiocarbon dates obtained from the original (1960s) excavation should be approached with considerable caution due to uncertain association between the dated material (usually charcoal recovered from the site matrix) and archaeological remains (See Appendix 2). The mound is circular in shape with a diameter of around 15 metres and is one metre in height (Dawson 1980). There are clear signs of past excavation or possibly looting, prior to partial excavation by Dawson (1980). Immediately south of the mound is visibly depressed land interpreted as the borrow area used to construct the mound (Dawson 1980). A central burial pit in the mound was secured by logs and boulders placed on top (Dawson 1980). Skeletal remains from both adults and children were recovered from the pit (Dawson 1980). Other site features included multiple hearths. Historic cairns are also present in the vicinity of the site (Dawson 1980), undoubtedly the result of post-contact cultivation efforts (Boyd 2010a). Artifact recoveries reported by Dawson (1980) included over 1000 pottery sherds, 9 projectile points, 51 scrapers, 4 copper awls, and a polished slate pendant (Dawson 1980).

Martin-Bird Site (DbJm-5)

The Martin-Bird site is located at the southwestern tip of Macgillivray Island. Although evidence of looting and other modern forms of disturbances can be seen, the Martin-Bird site appears to be the least disturbed (Dawson 1987). The site was recorded by Ken Dawson and colleagues in 1964, surveyed in 1966 and first excavated in 1970 (Dawson 1970). Three areas of the site were isolated and chosen for excavation by Dawson (Figure 2.6). A Late Woodland burial mound of Blackduck affiliation marks one area, Area C. The burial mound lies within a knoll that separates the two encampment zones (Area A and B). This low, south-facing, mound contained a secondary bundle burial apparently once enclosed in a birch bark container and an intact Blackduck mortuary vessel (Figure 2.7) with accompanying clam shell “spoon” (Dawson 1987). Other features from the site include six hearths with signs of repeated use, six refuse pits and a copper cache in Area B (Dawson 1987). Dawson’s excavations also revealed Blackduck artifacts and European goods in direct association with each other (Dawson 1987), though recent excavation did not reveal any association (Hamilton 2011; Boyd 2013a,b). The earlier findings may have represented localized intrusions.

The Martin-Bird site was revisited in 2009 and 2010 by Drs. Matt Boyd and Scott Hamilton of Lakehead University. The site was “selected for further study because the Dawson excavations yielded significant amounts of pottery, some of which contains micro-botanical evidence of maize” (Hamilton 2011: 5-6). The

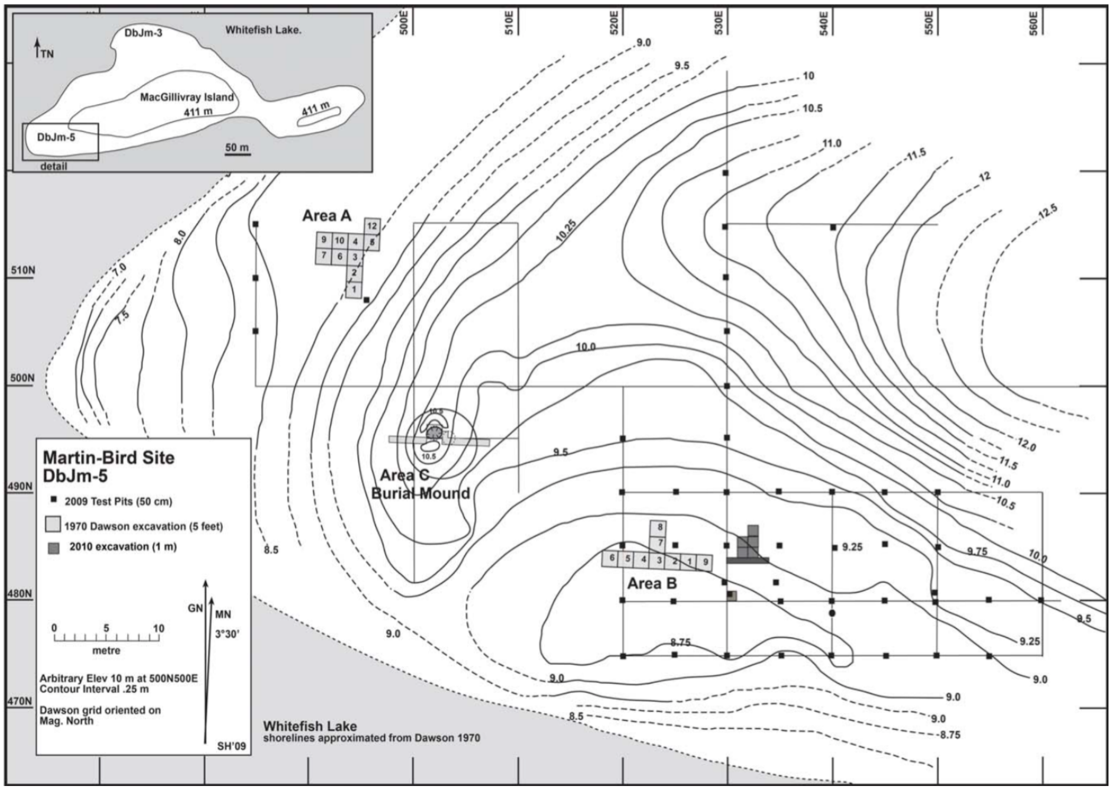


Figure 2.6. Topographic Map of the Martin-Bird Site showing areas of Dawson's excavations and test pitting and excavation by Boyd and Hamilton (Hamilton 2011)

Figure 2.7. Reconstructed Blackduck mortuary vessel recovered from the burial mound at the Martin-Bird Site (Boyd et al. N.D.) The diameter of the vessel orifice is approximately 13 cm.

abundance of wild rice near the site was also of great interest (Hamilton 2011). During the 2009 field season, Dawson's three areas of excavation were reassessed. A series of test pits, some in Area A but most in Area B, were undertaken (Hamilton 2011). Test pits were not excavated in Area C given the burial mound feature (Hamilton 2011). A dense quantity of FCR (fire-cracked rock) was encountered throughout Area B (Hamilton 2011). Geophysical survey was also conducted in Areas B and C using a magnetic gradiometer, and GPR (ground-penetrating radar) data were also collected from Area B by Dr. Terry Gibson (Hamilton 2011). The area with the most intense magnetic gradient within Area C contained large cobbles and boulders at the surface, interpreted as being deliberately placed to enhance the terrace platform where the burial mound is located (Hamilton 2011). Within Area B, many large magnetic fields were encountered. One such anomaly was explored using a 50 cm wide and 4 m long test trench and the exposure revealed "the edge of a dense pavement of fire broken rock" (Hamilton 2011: 24). This feature was investigated further in 2010 through a block excavation (Figure 2.8), exposing what has been interpreted as a roasting or drying feature. This interpretation is based on the following observations that many rocks seemed to be platy and were placed in a way that had some semblance of structure and organization and the underlying matrix was oxidized, perhaps revealing the application of fire to the area. The feature was potentially used to dry or roast maize, a claim supported by the identification of many maize starch grains, mostly from around the periphery of the feature which may be because starch does not survive well in areas of intense heat, like the centre of such a feature (Boyd 2013b).

Figure 2.8. Composite photo of block excavation and possible FCR roasting feature from Area B (Boyd 2013b). Excavation units are 1 metre squares.

The Whitefish Lake basin offers a unique locale to explore the Middle and Late Woodland periods in Northern Ontario. The importance of the lake during the Woodland period can be seen with the number of extensive occupations on the islands within the lake and along the shores. Many of the general trends of the Woodland period observed throughout the Eastern Woodlands can be inferred from the archaeological record at multiple sites within the lake basin. The practice of mound ceremonialism is apparent with several mounds occurring at both the Martin-Bird and Macgillivray site on Macgillivray Island and at the adjacent McCluskey site along the northwest

shore. Increased sedentism and residence sizes is suggested from denser artifact assemblages and in some case, post moulds and the presence of various pottery styles as well as syncretic wares suggest a greater emphasis on regional interaction and trade. Lastly, evidence of consumption of wild rice and domesticated plant foods reveals
an expansion of dietary breadth and possible horticulture being practiced in the Whitefish Lake basin.

CHAPTER 3: METHODOLOGY

3.1. INTRODUCTION

This thesis is based on a multi-proxy approach to understanding aspects of paleoecology and land-use at an archaeological site in the absence of conventional lines of evidence such as macro-botanical remains. Specifically, my research combines the analysis of starch and phytolith microfossils, microscopic charcoal, and soil chemistry. This chapter discusses each proxy, their limitations, and their relevant applications in archaeology. The study area provides significant challenges to understanding past environments and plant use because the surrounding lake is large and shallow, there are no wetlands on the island, and there is poor organic preservation in the soil. The proxies used in this thesis emphasize the contribution of subtle lines of evidence for archaeologists to understand aspects of land-use. Site activities and plant use that would otherwise be unknown given the aforementioned taphonomy issues can be inferred using these proxies.

3.2. STARCH

3.2.1. Formation and Composition

Starch grains are energy storage components of plants but they can also be found in fungi, algae, and other organisms (Gott et al. 2006; Haslam 2004). They are formed in various parts of the plant and exist in two forms. Transient starch, found primarily in plant leaves, is a temporary form of carbohydrate storage acting as a continual source of energy for the plant (Haslam 2004). This type of starch is produced in the chloroplasts when the plant is undergoing photosynthesis (Haslam 2004; Zarrillo 2008). Photosynthesis prompts the production of glucose within the plant and the compound provides the necessary building blocks for protein, fat, cellulose, and starch that the plant requires (Gott et al. 2006). Some glucose is transported from the chloroplasts to amyloplasts where the second form of starch is produced. Reserve or storage starch is produced in granules within amyloplasts located in multiple parts of the plant including the seeds, roots, tubers, corms, rhizomes, and fruits (Haslam 2004; Gott et al. 2006). This type of starch serves to provide the plant with a long-term source of nutrients that supports the plant during unfavourable conditions and also provides carbon during germination (Haslam 2004). When plants use storage starch, it is converted back into sugar and transported to the parts of the plant where it is required (Gott et al. 2006).

It is important to know the locations of transient and storage starch to understand how the grains may have entered the archaeological record. Storage starch is often concentrated in storage organs, which include tubers, roots, fruits, and seeds while transient starch grains are found in the leaves of the plant (Zarillo 2008). Starch grains from non-edible parts of a plant may also appear in the archaeological record, on tools or in fibers used for rope for example.

Starch is composed mainly of glucose molecules and trace amounts of lipids, proteins, and phosphorus (Haslam 2004; Gott et al. 2006). Each starch granule begins to form at the hilum, a central growth point of the grain that may or may not be the exact physical centre (Haslam 2004; Gott et al. 2006). Additional layers are laid down successively in a concentric fashion (Gott et al. 2006; Haslam

2004). The typical growth rate is a layer a day (Tester 1997). The layering consists of alternating crystalline and amorphous shells, each measuring around 120 to 400 nm thick (Haslam 2004; Gott et al. 2006). Amylose, an un-branched glucose chain, and amylopectin, a highly branched glucose chain, are the foundation of starch granules (Gott et al. 2006). They form a ring of six carbon atoms and amylose has a 1-4 bond while amylopectin has a 1-4 bond as well as a 1-6 bond (Gott et al. 2006). Amylose chains are composed of 1500 glucose units and amylopectin, one of the largest known biomolecules, is composed of 600,000 glucose units (Gott et al. 2006). The amylose-amylopectin ratios in plants are controlled by genetic and environmental factors. Starch grains tend to have less amylose than amylopectin, with around 20 to 30 percent amylose content in most economic plants (Gott et al. 2006).

3.2.2. Birefringence

Perhaps the most diagnostic feature of starch grains is their appearance under cross-polarized light (XPL). Starch grains will appear to be illuminated against a black background of other microfossils, a characteristic known as birefringence (Barton & Fullagar 2006; Gott et al. 2006). Birefringence in starch granules is due to their highly ordered molecular structure (Banks & Greenwood 1975). An extinction cross can also be seen in starch grains viewed under XPL, often appearing as a dark, cross pattern with its centre originating from the hilum of the granule (Gott et al. 2006) (Figure 3.2).

3.2.3. Morphology, Size, and Shape

Starch grain morphology is chiefly determined by the genetic composition of the plant (Gott et al. 2006). No two starch grains are exactly alike, each with varying characteristics discussed below. Some starch grains are highly diagnostic while others occur in multiple plants, making taxonomic identification to a single species difficult (Lentfer 2006). Some plant species may also contain several diagnostic forms of starch (Gott et al. 2006). Starch grains have multiple properties that distinguish them from other plant microfossils. Firstly, the hilum is usually the central growth point of the granule and can be located in the exact physical centre (centric) as mentioned, like in maize starch granules but it can be located closer to either end of the granule (eccentric), like in potato starch grains, for example (Gott et al. 2006) (Figure 3.1). Fissures originating from the hilum can sometimes aid in identifying starch granules to species. Larger starch granules may have visible lamellae, or growth layers (Gott et al. 2006). Other distinguishable features may include striations, ridges, pores, and equatorial grooves, as seen in larger granules of wheat, rye, and barley (Gott et al. 2006).

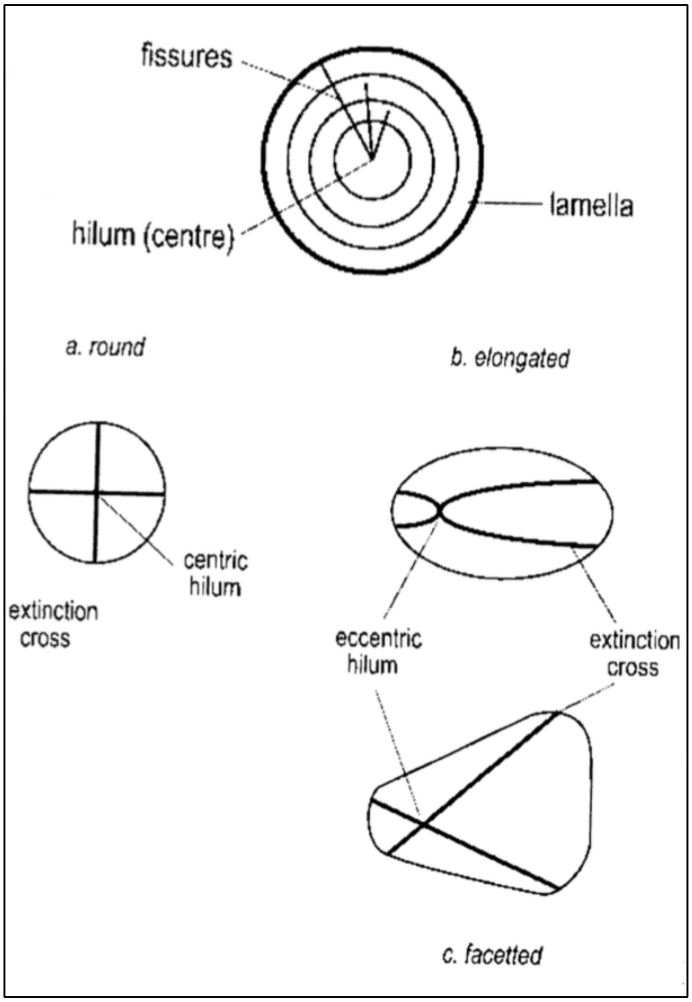


Figure 3.1. Hilum positions in starch grains (Gott et al. 2006)

Starch grains can be further classified according to their type, which may be simple, compound, or semi-compound. The form is determined by how the granules form in the amyloplast (Gott et al. 2006). Simple starch grains are characterized by a single component in the amyloplast, an example being maize (Figure 3.2) whereas compound starch grains have multiple separate parts called subgranules that have formed simultaneously within a single amyloplast (Banks & Greenwood 1975; Gott et al. 2006) like white pond lily (*Nymphaea odorata* ssp. *tuberosa*) (Figure 3.2). Individual extinction crosses are still visible in compound starch granules despite being clustered together (Gott et al. 2006). Food preparation such as milling can cause compound granules to break apart into individual subgranules (Gott et al. 2006). Lastly, semi-compound starch granules start out as compound granules but become fused together as layer of amorphous starch, resulting in one exterior surface but several hila (French 1984; Gott et al. 2006).

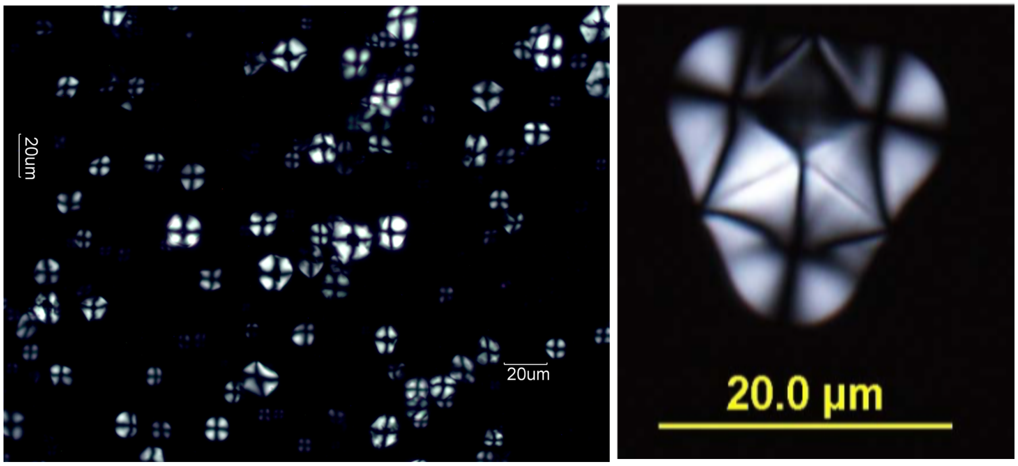


Figure 3.2. Example of simple starch (*Zea mays*, left) (Crutcher 2007) and compound starch (*Nymphaea odorata* ssp. *tuberosa*, right) (Lints 2012)

Starch grains also vary by size and shape. Firstly, a significant distinction in size between the aforementioned storage and transient starch is typically seen, with storage starch exhibiting considerably larger granules than transient starch. Transient starch grains tend to range from 1-5µm in size while most other starch grains range from 1 to about 100µm in size with a few exceptions exceeding the upper limit (Haslam 2004; Gott et al. 2006). Diagnostic *Zea mays* starch grains for example measure 20µm or more in diameter while potato starch grains can be 40µm or more. There are a myriad of variables than can influence the size of any given starch grain. Some include, swelling due to water, storage site, maturity, plant taxa, nutritional status, and growing conditions (Gott et al. 2006).

Spherical, rounded, oval, faceted, kidney-shaped, irregular, disc, elongated, and polyhedral are all possible shapes to describe starch grains (Gott et al. 2006). The same plant can produce more than one shape of starch grains such as in the cereal grasses in the tribe Triticeae (wheat, barley, and rye) that exhibit small spherical ones and large disc-shaped or lenticular ones (Shannon & Garwood 1984; Jane et al. 1994; Gott et al. 2006). The location of the granules in the plant can also impact the shape. For example, starch from the centre of the *Dieffenbachia* stem are elongated while starch from the periphery of the stem are small and rounded (Gott et al. 2006). Their composition can also affect shape. In general, starch granules with higher amylose content tend to be elongated and irregular (Buléon et al. 1998).

3.2.4. Staining

Biochemical staining is often successful at isolating starch grains on a microscope slide as well as identifying which have been affected by past food processing. Iodine-potassium-iodide will stain starch grains differently depending on their amylose-amylopectin ratio (Lamb & Loy 2005). Grains with higher concentrations of amylose will stain a deep-blue while those with more amylopectin will produce a reddish colour with the iodine stain (Gott et al. 2006; Haslam 2004). Damaged and gelatinzed starch grains can be the product of natural events but can also indicate past processing of the plant through milling or roasting for example (Babot 2003). These grains can be isolated using a Congo Red stain which will produce a red-pink colour in damaged or gelatinized starch though they still remain difficult to identify to species level (Haslam 2004; Zarillo 2008).

3.3. PHYTOLITHS

3.3.1 Formation and Function

The word “phytolith” in Greek translates to “plant stone” and is the most common term used to refer to the microscopic inorganic silica molds that form in and between plant cells and tissues (Piperno 2006; Mulholland & Rapp Jr. 1992; Hart 2015) (Figure 3.3). In contrast to starch grains that provide plants with energy, phytoliths are waste products of plants (Piperno 2006: 10). Not all plants produce phytoliths and their function is not well known. Arguments in support of phytoliths conferring benefits to the plants they are found come from an evolutionary perspective, involving the thinking that plants would not expend energy to absorb silica from the soil for no purpose (Piperno 2006). Ultimately, phytoliths seem to serve “structural, physiological, and protective” functions (Sangster et al. 2001). Structural functions refer to those that support the plant’s rigidity and in the process, increase the plant’s exposure to sunlight, thus increasing its ability to manufacture energy (Piperno 2006). Physiological functions refer to the role of silica in certain processes in the plant’s development or within its growing environment (Piperno 2006). Experimental studies have shown that silicon dioxide acts as a detoxifier in the plant, lessening the damaging effects of heavy metals that plants (i.e. aluminum and manganese) consume (Sangster & Hodson 2001; Piperno 2006). Lastly, protective functions phytoliths confer to the plant include resistance to pathogenic fungi as well as a mechanical defence against herbivory

(Piperno 2006). Phytoliths protect against defoliation by creating less penetrable leaves for insects and larger grazers alike, making the food harder to digest and even wearing down the grazer's teeth over time (Coley & Barone 1996).

There are several locations where phytoliths are commonly deposited in the plant in which they are found. Examples include the epidermis of numerous trees and herbs (Bozarth 1992), the subepidermal tissue of palm and orchid leaves, and the epidermis of glumes, lemmas, and paleas surrounding grass seeds (Mulholland 1993; Rosen 1992).

The degree to which phytoliths develop in plants is affected by multiple factors including climatic conditions, soil characteristics, maturity of the plant, and most importantly, the plant taxa (Piperno 2006). The following are two methods used by plants in the uptake of silica from the surrounding matrix to form phytoliths: (1) "active transport of monosilicic acid by metabolic processes under strict control of the plant"; (2) "passive, nonselective flow of monosilicic acid along with other elements from groundwater through the transpiration stream" (Pipermo 2006: 9). The first mechanism involves the plant expending energy metabolically to absorb the silica while in the second it does not. The process of phytolith formation begins once monosilicic acid (H_4SiO_4), or soluble silica is drawn up through the roots and enters the plant's vascular system where some is then transformed into solid silicon dioxide (SiO_2) laid down in cell walls, cell interiors, and intercellular spaces (Piperno 2006). Phytoliths are composed of mainly noncrystalline silicon dioxide

(**a**) globular echinate; (**b**) globular granulate; (**c**) cross-shaped; (**d**) bilobate short cell; (**e**) *Stipa*-bilobate short cell; (**f**) palylobate; (**g**) rondel; (**h**) square saddle; (**i**) oblong concave saddle 2; (**j**) oblong concave saddle 1; (**k**) one-horned tower; (**l**) two-horned tower; (**m,n**) sedge-type; (**o**) cuneiform bulliform cell-rice; (**p**) cuneiform bulliform cell-bamboo; (**q**) cuneiform bulliform cell; (**r,s**) trapeziform; (**t**) hair cell; (**u**) parallepipedal bulliform cell 1; (**v**) parallepipedal bulliform cell 2; (**w**) gymnosperm-type; (**x**) abbreviated stellate; (**y**) elongate echinate; (**z**) elongate smooth; (**aa**) cylindrical sclereid; (**ab**) pteridophyte.

Figure 3.3. Example of phytolith type diversity (An et al. 2015)

(SiO_2) and 4-9% water content (Piperno 2006). Trace amounts of Mn, P, Fe, Cu, Al, organic C, Mg, and N can also occur in phytoliths (Bartoli & Wilding 1980; Wilding et al. 1967).

When the plant dies, its phytoliths are released through decay and deposited into the A horizon of the surrounding soil (Piperno 2006). Phytoliths can also enter the soil through animal droppings, wind, and fire (Piperno 2006). Archaeological middens tend to reveal clusters of phytoliths from economic plants discarded by past people after their use (Piperno 2006). A small percentage of phytoliths encountered at an archaeological site may represent incidental deposition and do not necessarily reflect actual use of certain parts of the plant by past peoples. An example of this is remaining foliage on firewood carried in from the margins of a site
(Piperno 2006). Overall, phytoliths do not move much once deposited into the soil and, paired with their ability to preserve well given their inorganic nature, phytoliths make for very valuable proxies in paleodietary and paleoenivronmental studies.

3.3.2. Identification

When viewed microscopically under transmitted light, phytoliths may appear transparent or light brown to opaque (Jones & Beavers 1963). Transparent phytoliths sometimes allow for three-dimensional shapes to be ascertained without moving them in the mounting medium (Piperno 2006). Darker phytoliths are likely the result of plant burning and their charred surfaces give them their dark appearance (Piperno 2006) though recent studies have also found that weathering can produce the same effects (Opfergelt et al. 2010; Yao et al. 2012) . Phytoliths are optically isotropic and have a refractive index of 1.41 to 1.47, although the range varies between organic and burnt phytoliths (Piperno 2006).

Phytolith identification and classification research are comparatively underdeveloped but it has been established that taxonomic identification is possible (Rovner 1971). Plants of the same genera, species, and family produce phytoliths of similar shapes. Their shape is determined by two factors: the type of cell accumulating silica and its location in the plant, the latter involving incomplete silicification of part of the lumen resulting in shapes that do not conform to the cell (Piperno 2006). There is much variation in phytolith shape as seen in Figure 3.3. In addition to shape, other phytolith characteristics used for identification include size, orientation, and thickness and ornamentation of the cell walls (Rovner 1971; Brown 1964).

3.4. MICROSCOPIC CHARCOAL

Charcoal encompasses the charred remains of organic matter from either natural or anthropogenic burning. Charcoal is a commonly used proxy in paleoclimatology studies to reconstruct fire histories either locally or regionally as well as in archaeological studies investigating past human behaviours. It generally preserves well but may be subject to breakage (Patterson III et al. 1987). Charcoal, an amorphous inorganic compound (Patterson III et al. 1987), is created when fire incompletely combusts organic material (Whitlock & Larsen 2001). It can be found in lake sediments or terrestrially, in the soil. Fire size, intensity, and severity are the main factors that affect charcoal production as well as aerial transport of the charcoal (Whitlock & Larsen 2001). Typically, it is divided by size into macroscopic and microscopic charcoal prior to investigation. Macroscopic charcoal is usually >125 microns (µm) in size and tends to reflect local fire regimes whereas microscopic charcoal (<125 µm) is more easily transported, sometimes travelling great distances by factors discussed below and therefore tends to reflect regional fire regimes (Derr 2014).

Wind and water are the primary agents responsible for the dispersal of charcoal from its source location (Patterson III et al. 1987). Microscopic charcoal is generally much more susceptible to aeolian transport (Derr 2014). Much charcoal is also subject to fluvial transportation and several researchers have observed increased runoff after a burning event (Hibbert 1967; Patterson III et al. 1987) ultimately leading to increased erosion. Erosion can carry both inorganic particulate matter and large quantities of charcoal (Swain 1973; Cwynar 1978). Charcoal accumulations tend to be greater near the shores, outlets, and inlet streams of lakes and large bodies of water than in the central parts of the lake or in deep-sea sediments, reflecting both fluvial and aeolian deposition (Griffen & Goldberg 1975; Tsukada & Deevey 1967; Patterson 1978). Dispersal and deposition of much charcoal likely occurs soon after it is produced (Patterson III et al. 1987). In experimental studies, it has been found that when charcoal becomes wet it sinks rapidly (Davis 1967). Dispersal time may be shortest in areas of heavy precipitation, steep slopes, where drainage ditches exist, and in lakes where runoffs from spring snow melt is high (Patterson III et al. 1987). The charcoal record is ultimately a reflection of both fire events and hydrological events affecting the rate at which the charcoal is deposited (Clark 1983).

Depending on the goals of the study, ideal sampling locations are forest clearings or small lakes for a charcoal record reflecting the local area, medium-sized lakes for extra-local fires, and blanket bogs or large lakes to reconstruct regional fire events (Patterson III et al. 1987). Despite the preservation constraints, the island study location of this thesis provides a useful context for assessing localized fire regimes and environmental processes with surrounding waters acting as a barrier to burning events (Derr 2014). Burney (1997) describes island study areas as “paleoecological laboratories” with the potential of evaluating the ecological impact of humans upon arrival as well on vegetation communities overtime (Derr 2014). However, it is important to note that the locale of this study does not provide ideal coring opportunities because the island does not contain any lakes or wetlands which places limits on paleoecological research

Distinguishing between natural and anthropogenic burning events with much confidence has eluded researchers (Derr 2014). Charcoal peaks in sediment records relative to background levels are usually associated with natural fire events (Derr 2014). Since charcoal can still be deposited in lake basins years after a major fire has occurred, this continual natural background signal may obscure any human signal (McWethy et al. 2013; Mooney and Tinner 2011; Derr 2014). Fires are usually only attributed to anthropogenic sources when natural ignitions can be dismissed (Derr 2014). In some studies, microscopic charcoal peaks from pollen samples are used to infer human habitation in tropical environments for example where lightning-ignited fires are rare (Burney 1997; Haberle & Ledru 2001; League & Horn 2000).

Charcoal fragments can be characterized by their morphology. Enache and Cumming (2006) described seven different charcoal morphotypes encompassing charcoal produced from woody fuels, from the burning of leaves and shrubs, and also from grasses and sedges (Figure 3.4). Determining charcoal morphotypes can be useful in reconstructing the extent of burn areas, assessing taphonomic processes affecting preservation, and inferring charcoal transport (Derr 2014). Recently, charcoal morphology has been included in charcoal studies to understand fire regimes and identify fire type (Enache & Cumming 2006; Morris et al. 2014). Determining the ratio of woody vegetation charcoal to that of grasses and sedges provides the potential to distinguish between natural and anthropogenic burning, depending on the past society in question. Typically, in non-agricultural societies, fire was used to clear grasses and understory fuels as opposed to large-scale forest stands (Derr 2014). Fire intensity or severity in addition to fuel type can also be inferred from the charcoal morphotypes identified. Moderate to high intensity fires in areas dominated by smaller trees should result in a higher percentage of woody charcoal, like Types C, B, and S, while lower intensity fires burning understory fuels like grasses and sedges are expected to produce mostly Types M, P, and F (Figure 3.4).

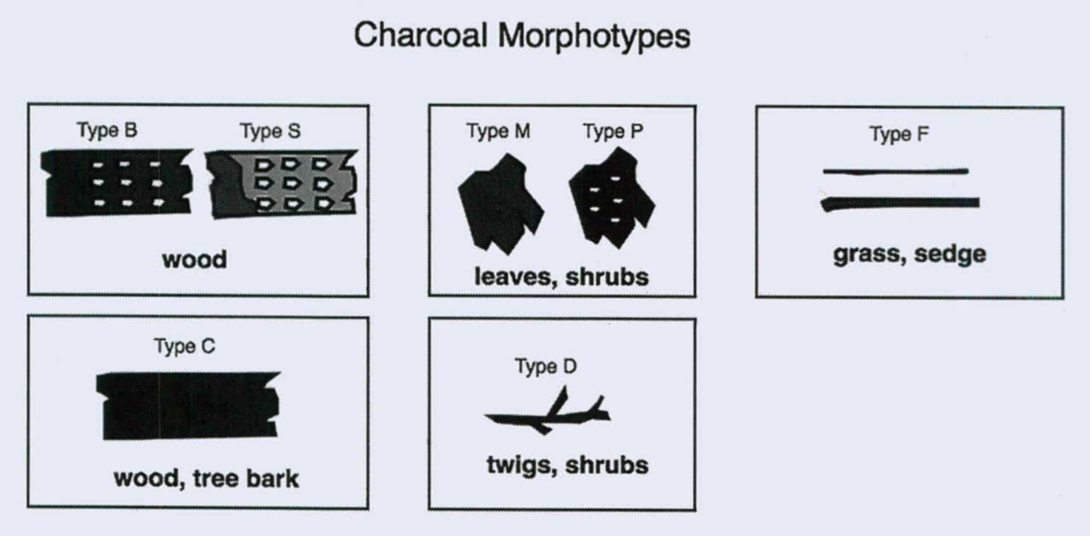


FIGURE 4. Generalized depictions of charcoal morphotype categories used in this study (typology adapted from Enache and Cumming [2006]). All charcoal identified fit into one of the seven types shown here. The left most group shows charcoal produced from woody fuels, the middle group are those produced by burning of leaves and shrubs, while charcoal produced by grass and sedge fires are shown on the far right.

Figure 3.4. Illustrations of the seven main charcoal morphotypes (Derr 2014)

In the context of this thesis, charcoal analysis can be a complimentary line of evidence for the identification of precontact gardening or any sort of manipulation of the land and habitat. Prescribed burning of the land was a common practice to prepare soils for food production purposes, among others. However, as mentioned, a common query involved in studies of this nature is whether the charcoal was produced by humans deliberately setting fire to the land or by natural burning events such as forest fires. The study locale of this thesis is extremely advantageous in this regard as an island's relative isolation from the mainland may prevent wildfires from reaching them, with surrounding waters acting as a barrier. Charcoal present in the soil samples collected may have a greater likelihood as being the result of human induced burning (as well as reflecting more locally-based fire events occurring on the island). Microscopic charcoal was chosen for analysis because it is regularly observed in microscopic slides already being used for microfossil analyses.

3.5. SOIL PHOSPHORUS

Soil chemistry can provide insight into past uses of the land in question. Of the many elements in soil, humans most significantly affect the levels of carbon, nitrogen, sodium, phosphorus, and calcium (Holliday & Gartner 2007). Though many of these elements and more can be telling of how land was used in the past, “few are as ubiquitous, as sensitive, and as persistent of an indicator of human activity as phosphorus” (Holliday and Gartner 2007: 301) and as such, it is commonly a focus for archaeologists to aid in the interpretations of a given site.

Anthropogenic sources of soil phosphorus (P) are wide-ranging and include human refuse and waste, burials, products of animal husbandry, and soil fertilizer in the case of agricultural societies (Holliday & Gartner 2007). While the above can significantly increase P levels in the soil, some human activities either hardly affect P levels or deplete them in some cases. Phosphorus and nitrogen (N) are major nutrients required by plants. Deficiencies in either can have serious implications for the health of the plant. In archaeological studies involving agricultural societies, levels of soil P are often analyzed to assess the nutrient status of past topsoil (Newman & Harvey 1997; Entwistle et al. 2000, 2007; Lauer et al. 2013). Regular use of the land for agricultural purposes would have placed constraints on the soil and its nutrients. Growing maize is particularly taxing on soils (Masood et al. 2011). Soil fertilizers like human or animal waste and other animal products would have been used to replenish nutrient levels thus maintaining soil fertility (Holliday & Gartner 2007). This was especially important for replenishing P levels “as the atmospheric return of P is very low” (Lauer et al. 2013). While nitrogen is quite mobile in soils, P remains relatively immobile (Lauer et al. 2013; Holliday & Gartner 2007). P is less susceptible than most common soil elements to leaching, oxidation, reduction or plant uptake (Holliday & Gartner 2007). Phosphorus is also an extremely useful proxy as anthropogenic P can exist in soils with many different pH values, making it useful in a variety of contexts (Holliday & Gartner 2007). For the above reasons, P is a very suitable element to analyze in studies involving ancient settlements and agriculture.

Phosphorus exists in many forms in soils causing complication among the related literature and methodology used in studies. Phosphate ($PO^{3-}{}_{4}$) is the most common form of P in soils (Holliday & Gartner 2007). Chemically, it can be represented in the soil as total P (Ptot), inorganic P (Pin), or organic P (Porg) Holliday & Gartner 2007). In biogeochemical terms, soil P can also be expressed as available P (Pav) or extractable P, labile P, and occluded P (Holliday & Gartner 2007). Ptot, the sum of Pin and Porg, may be the best indicator of anthropogenic P when compared to natural soils (Bethell & Máté 1989). Further, Skinner (1986) concluded after a comparing a series of methodologies that Ptot resulted in the highest correlation with anthrosols, though this was only the case 60% of the time. Similarly, Leonardi et al. (1999) found that Porg and Ptot best supported the interpretation of ancient agricultural use of buried soils, also noting that determining Ptot is quicker and less expensive than the former. Other similar studies like

Johnson (1956), Shipley & Romans (1962), and Conway (1983) also favour Ptot. After a comprehensive review of the literature and various methodologies, Holliday & Gartner (2007) conclude that Pin and Ptot appear to be the best indicators of human input of P in soil. Generally, the ideal indicator of human activity regarding soil P is still debated, however, Ptot was selected for this thesis. Overall, Ptot appears to be the most relevant, reliable, and cost-effective measure of soil P in studies of this nature (Leonardi et al. 1999; Holliday & Gartner 2007; Skinner 1986; Vranová et al. 2015).

The form, interaction and redistribution of P compounds in the soil are all influenced by several factors: the addition of organic material in the soil, microbial activity, weathering, and land-use (Holliday & Gartner 2007). Further, soil P forms are susceptible to dissolution, desorption, and transformation. Organic matter, pH, soil moisture, particle size, and mineral content all affect these processes (Holliday & Gartner 2007).

Incorporating soil P levels into the analysis of a site where typical lines of evidence are lacking or nonexistent, may shed light on the high-use areas of a site, delimit site areas, as well as provide an idea of the type of activities occurring at the site.

3.6. LIMITATIONS

3.6.1. Starch and Phytoliths (Microfossils)

The application of microfossil analyses to the field of archaeology has gained much attention in recent years, and the use proxies like starch and phytoliths has been instrumental to numerous archaeological and paleoecological studies. As with any proxy, limitations exist. For example, several types of phytoliths can occur in a multitude of different plant species, resulting in very few being diagnostic of specific taxa. A redundancy of phytolith types is encountered with *Aristida* and *Zea* for example, as both produce Pooid and Panicoid phytoliths (Twiss 1992). The study of starch and phytolith assemblages are also greatly impacted by taphonomic processes that affect microfossils after their deposition in soils and on artifact surfaces. Taphonomy here refers to chemical and physical processes that affect microfossil preservation, degradation, and post-depositional movement (Haslam 2006). These processes include starch movement in soils, mechanical wear and gelatinization of starch, and enzymes, bacteria, and fungi that decompose starch. Limitations also reach beyond taphonomic processes and include laboratory and identification issues like assemblage bias, identification discrepancies, and lastly, contamination from modern samples. The taphonomy will be the focus of this discussion to disclose how results and interpretations may be affected.

Taphonomic Processes

Starch collected from archaeological depths may not always be contemporaneous with the cultural layer they derive from (Haslam 2004). This is because starch can move in the surrounding matrix after deposition. Groundwater, for example, can displace starch grains through percolation though this mainly affects smaller grains such as transitory starch (Therrin 1998). Several studies calculated the downward percolation rate of pollen to be around 1cm every 4-30 years (Kelso 1994; Dimbleby 1985) and similar research involving phytoliths have also confirmed their movement in sediments (Hart & Humphreys 1997), likely making the same true for starch to some degree (Haslam 2004).

The soil conditions and overall environmental setting have a significant impact on the preservation and degradation of microfossils after deposition. Soil pH, oxygen content, and temperature are the main factors contributing to starch degradation (Haslam 2004; Torrence 2006). Enzymes, bacteria, and fungi present in soils also greatly limit the microfossil record, responsible for the majority of starch degradation encountered (Haslam 2004; Torrence 2006). Phytoliths are much more durable and can survive in many environments given their inorganic nature, though they can be influenced by a few factors. Like starch, phytolith preservation is also impacted by soil pH, often not surviving well in alkaline conditions where the pH is above nine (Cabanes et al. 2010; Piperno 1985). Another factor leading to differential phytolith preservation is their surface area and the presence of aluminum in surrounding matrix—the greater their surface area, the greater their solubility rate (Sangster & Hodson 2001).

Microfossils are susceptible to the effects of processing and cooking that some plants undergo when used for subsistence or utilitarian purposes. Common types of processing include milling, grinding, and pounding—all of which involve stone or other hard implements that break down the plant material. The degree to which the plant is processed affects the level of microfossil damage (Babot 2003). Chewing can also contribute to starch damage through the shearing of the plant material and the starch breakdown is exacerbated by the interaction with enzymatic saliva (Torrence 2006). Phytoliths are less susceptible to mechanical damage than starch grains (Henry et al. 2009). Starch grains can incur tears, breaks and altered extinction crosses and/or loss of birefringence as the result of mechanical wear (Babot & Apella 2003; Zarillo & Kooyman 2006; Lints 2012). Under cross-polarized light, the damaged grains may also appear incomplete, collapsed, burst, or truncated (Babot 2003). For example, damaged maize starch retrieved from grinding stones has the appearance of fissures or holes on the surface and a shifted extinction cross from its usual 90° position (Burchill 2014) (Figure 3.5).

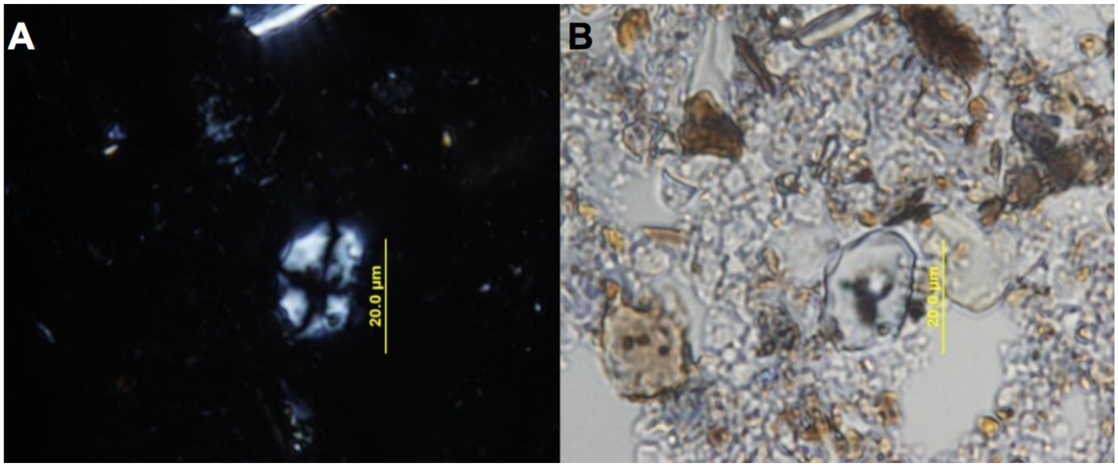


Figure 3.5. Maize starch from a grinding stone (Burchill 2014).

Starch grains are also affected when plants are cooked, specifically boiled or steamed, often resulting in gelatinization if temperatures are high enough. When in contact with water, starch begins a reversible process of swelling. Gelatinization occurs when starch grains begin to swell in water and are then heated beyond their threshold, when after a certain temperature the hydrogen bonds that hold the amylose and amylopectin chains together are disrupted. At this stage, the starch either remains swollen or forms a jelly-like mass. Grains with higher amylose content tend to have greater gelatinization thresholds and smaller starch grains can withstand higher temperatures than larger ones (Haslam 2004). Damage incurred from the processing and cooking of starch increases the difficulty of identifying the starch microscopically and taxonomically (Haslam 2004; Zarillo 2008). Biochemical staining of starch with stains like Congo Red and trypan blue can aid in the process as both have been used with success to stain damaged granules (Barton 2007; Lamb & Loy 2005). The degree to which these stains permeate the starch grains reveals the extent of damage thereby giving some insight into the level of processing that occurred.

Taphonomic processes can have a significant impact on the context that microfossils are recovered from as well as their state of preservation and therefore it is important to consider the above when analyzing and interpreting the microfossil data.

3.6.2. Microscopic Charcoal

Using charcoal as a proxy has some obvious complications and therefore should be used as a complimentary line of evidence in conjunction with others in a study of this kind. The main limitations that will be discussed here include difficulty distinguishing between natural and anthropogenic ignitions, separating regional, extralocal and local charcoal records, and the taphonomic processes that affect the charcoal record.

Natural or Anthropogenic?

Natural fires have always been a force of disturbance on the landscape. Sources include volcanic activity, spontaneous combustion, sparks due to rock fall, and the most significant natural ignition, lightning (Cope & Chaloner 1980). When humans began to modify their landscape, intentionally or unintentionally with fire, the severity, frequency, location, spatial extent, and seasonality would have differed from natural fire regimes (Lepofsky & Lertzman 2008; Cissel et al. 1999; Heyerdahl et al. 2001). However, as previously mentioned, identifying an anthropogenic fire event from the charcoal record data poses many challenges for researchers as no direct evidence can be teased out. Despite the difficulties, the pursuit of identifying such a telling signal is still very much a component of many paleoecological studies dealing with human impacts on the environment (Lepofsky & Lertzman 2008).

Some general statements can be made about the difference between natural and anthropogenic ignitions, though detecting these with much success from the charcoal record is much more difficult in practice. Cultural fires tended to be of lower severity and are limited spatially (Beckwith 2004). Human-induced burning also occurred more frequently in managed areas, for example, whereas the time in between natural fires can range from ten years to thousands of years depending on the climate (Heyerdahl et al. 2001; Lertzman et al. 2002; Gavin et al. 2003). Lastly, anthropogenic burning was not limited to the fire season normally associated with natural fires, and fire was likely strategically used during colder and wetter times of the year when the fire could easily be managed and restricted to a desired locale (Lepofsky & Lertzman 2008). As fire regimes are understood from parameters like frequency, severity, spatial extent, and location (Lertzman et al. 1998; Cissel et al. 1999; Heyerdahl et al. 2001), the potential exists to use changes to the above as indicators of human activity, if other factors could be accounted for, though the result would remain suppositional (Lepofsky & Lertzman 2008).

Regional, Extralocal or Local?

The charcoal record is a complex array of charcoal fragments both macroscopic and microscopic in scale, dispersed through fluvial and aerial forces. It is comprised of both primary and secondary sources of charcoal, primary referring to the material deposited during or soon after a fire event and secondary referring to charcoal that is introduced during non-fire years (Whitlock & Larsen 2001). The latter is the product of redeposition through surface run-off and lake-sediment mixing (Whitlock & Larsen 2001). Deposition of charcoal can be complex, with charcoal influxes into a basin occurring years after a burning event as the result of redeposition, sediment mixing and delayed charcoal transport, each of which can be affected by climate, water level changes, bioturbation, and human interference (Patterson III et al. 1987). These issues can create a perplexing stratigraphy with charcoal that could reflect regional, extralocal, or local fires (Figure 3.6).

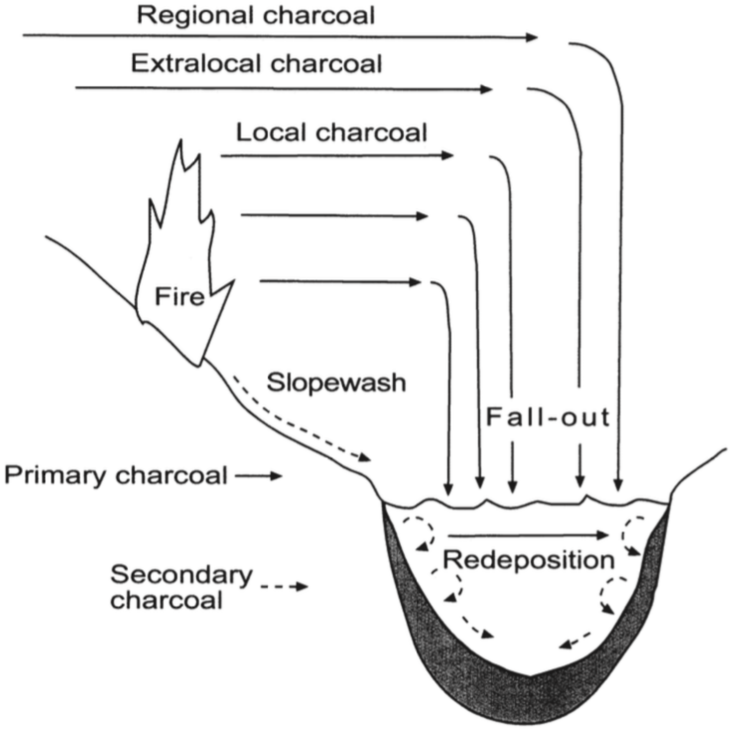


Figure 1. Schematic diagram of illustrating the sources of primary and secondary charcoal in a watershed.

Figure 3.6. Schematic diagram illustrating the deposition of charcoal in a watershed (Whitlock & Larsen 2001)

Taphonomy

Like many paleoecological proxies, charcoal is susceptible to several taphonomic processes that affect its structural integrity and context in the charcoal record. Dispersal, deposition, preservation, sampling preparation, and counting methods are all factors (Patterson III et al. 1987). The charcoal must first survive the travel to its deposition site through dispersal by wind or water. Once deposited, it can be affected by bioturbation, surface run-off, and erosion, which can cause sediment mixing and redeposition of the charcoal. Once collected, charcoal is then impacted by laboratory methods and procedures, which can result in breakage.

Sample preparation should involve protocols that limit further damage to the fragile charcoal and similarly, counting methods should limit contact with the charcoal to prevent breakage. Considerable charcoal breakage or mechanical damage can impact results with an overrepresentation of charcoal fragments and an artificial increase in the number of smaller particles. (Schlachter & Horn 2010).

3.6.3. Soil Chemistry and Phosphorus

Although soil phosphorus analysis has been the most explored application of soil chemistry to archaeology (Leonardi et al. 1999), there is need for further research into which form of soil P is most relevant as an indicator for human activity. A major drawback with Ptot analysis used in this thesis is that the measurement includes all inorganic phosphorus levels, which is much higher than anthropogenic phosphorus input (Holliday & Gartner 2007). This is problematic with areas high in natural phosphorus levels (Vranová et al. 2015). Lastly, assessing phosphorus levels at an archaeological site is simply a measure of the overall impact past human activities had on the land as seen through the soil chemistry. It does not necessarily provide the researcher with direct information on which specific activities are being represented, though as mentioned, some activities significantly add to the soil P while others deplete it, allowing for general interpretations to be made.

3.7. FIELD AND LABORATORY METHODS

The overview of field and laboratory methods used for this study are presented in chronological manner, beginning with sample collection in the field, followed by soil phosphorus testing and microfossil analyses conducted in laboratory settings, and finally, on- and off-site vegetation surveys.

3.7.1. Sample Collection

Soil samples from the Martin-Bird site and controls from the mainland surrounding Whitefish Lake were collected during the 2015 field season. The sample locations, sampling interval, sampling tools, transportation, and post-field storage are all discussed below.

Sample Locations

Gridlines from the 2009-2010 excavations seasons at the Martin-Bird site were reestablished with the aid of existing datum pegs from the site. The island is privately owned and a small trail system is regularly maintained where many datums were previously placed. As a result, some datum pegs were missing or disturbed. The datums of 500N/530E and 500N/535E were selected as starting points as they appeared to be undisturbed. From these known northing and easting points, two transects were established, spanning the vertical length of 50 metres (Figure 3.7). Much brush cutting had to be completed before the transects were accessible (Figure 3.8). These transects intersect the known habitation areas and also extend into areas of presumed low activity based on limited test-pit exploration of the area to the north of the site.

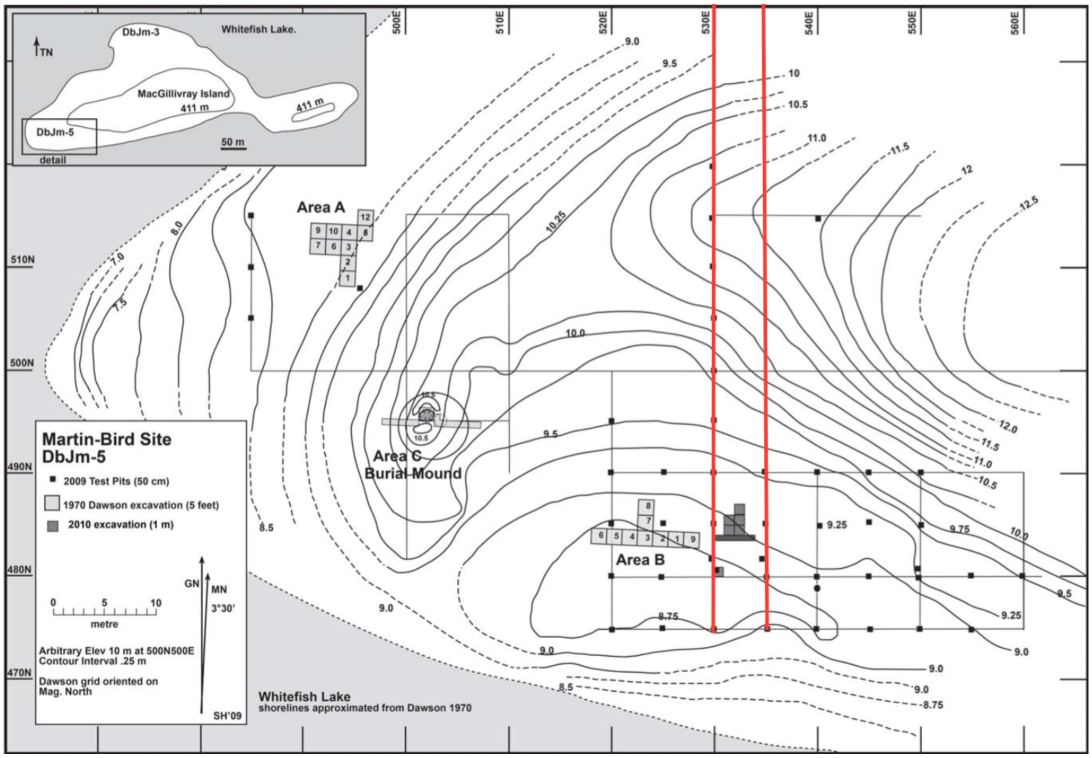


Figure 3.7. Map of the Martin-Bird site illustrating the location of the transects used for soil sampling (adapted from Hamilton 2011)

Sampling Interval

With the use of a measuring tape, a sampling location was marked with a pin every 2 m along the two transects. To avoid data redundancy and in the interest of time, a sampling interval of 2 m was selected as opposed to every metre. This resulted in the collection of roughly 25 soil samples per transect.

Sampling Tools

A soil probe was initially tested to procure soil samples from the site but the heavily compacted soil at the site made obtaining samples problematic and the cores that could be obtained were difficult to extract from the device and did not

Figure 3.8. Brush cutting (left) and a cleared transect (right)

Figure 3.9. Bulb planting tool used to procure soil sample cores

remain intact. Instead, a bulb planter was used (Figure 3.9). The force of jumping on the tool was enough to penetrate the soil and extract whole cores that routinely ended in a clay bottom, characteristic of much of the soil at the site. The archaeological deposits overlie the clay across the site. This gave the researcher confidence that the archaeological layers were encapsulated in each sample. The cores typically measured between 12-15 cm in depth with 1-3 cm of clay at the bottom.

Stratigraphy Pits

Several locations were selected to detail the stratigraphy of the site and surrounding area. One stratigraphy pit was dug near the known site area and care was taken to avoid back dirt areas from past excavations. Another pit was opened

Figure 3.10. Digging one of three stratigraphy pits

up 30m north of the first. A third was placed roughly midway between the Martin-Bird site and the Macgillivray site (Figure 3.10).

Transportation and Storage

After each core from the island was carefully ejected from the bulb planter, they were tightly wrapped in tinfoil and marked with the corresponding northing and easting numbers. Upon arrival in a laboratory setting, the cores were unwrapped and air-dried on trays to prevent mould growth. The trays were stored in a contained area, limiting the issue of dust particles and other contaminants.

Controls

Additional soil samples were collected from the mainland around the northwestern shores of Whitefish Lake to serve as control samples. Six areas that were thought unlikely to reflect much human disturbance were selected. These included boggy and rocky areas. These control samples serve as important points of contrast to the on-site samples tested for Total P. Ideal controls would have consisted of areas suitable to human occupation, and with similar soil to the Martin-Bird site, that were not actually occupied in order to obtain true controls, though such sites would have been difficult to isolate and sample with any certainty. The researcher acknowledges that the areas and soil samples selected for controls and tested for Total P may be inherently or naturally different in terms of phosphorus concentrations for reasons other than anthropogenic activity.

3.7.2. Phosphorus Testing

To limit costs and avoid data redundancy, every other sample was selected for phosphorus testing, with a total of 26 on-site samples and 3 off-site control samples included in the analyses.

Total phosphorus (Ptot) analyses began with the Modified EPA 3051A method through the Lakehead University Environmental Laboratory (LUEL). Each core was separated into 4 cm aliquots, usually resulting in each core (often 12-15cm in length) being split into three sections because as mentioned, the bottom few centimetres of each core were often just clay, which was seen as unnecessary to include in the analyses. This manner of dividing the cores resulted in Section 1 representing 0cm (surface)-4cm, Section 2 as 4cm-8cm, and Section 3 as 8m-12cm (bottom/start of clay). Each section had to be sifted through to remove organics as they may influence the phosphorus results. The sections then had to be homogenized by individually blending them with the use of a food processor. Around 2 milligrams of soil from each section was scooped and weighed and placed in its own vessel. A 3:1 ratio of concentrated nitric acid and concentrated hydrochloric acid was then added to each vessel under the fumehood. The samples were then heated in a microwave and left to cool overnight. The following day, the samples were filtered to remove particulates from the digest and decanted into glass vials to be analyzed via ICP-AES.

3.7.3. Microfossil Analyses

Microfossil analyses were completed in a clean laboratory setting, regularly assessed for contamination and throughly cleaned, where no major contaminants such as other microfossils are of concern.

The processing of soil samples for microfossil analyses unfolds in four major steps: (1) removal of clays; (2) starch extraction; (3) phytolith extraction; and (4) mounting of starch and phytoliths extracted from the soil samples.

Removal of Clays

The soil samples from the Martin-Bird site contained large amounts of clay and much defloccuating and gravity settling was necessary. This process involves filling a graduated cylinder to the 100 mL line and adding enough soil sample to raise the water level to the 150 mL mark. It is important to use a fairly large volume of sample as a significant amount of the original sample will be lost through subsequent deflocculation, sieving, and filtering procedures. The contents of the graduated cylinder are rinsed out and transferred to a 400-500 mL beaker with an 8 cm mark. The beaker then receives 25 mL of deflocculent solution and is topped off to the 8 cm mark with distilled (reverse osmosis) water. The beaker is placed on a hot plate with a magnetic stirrer function. A magnetic stirrer bar is placed at the bottom of the beaker and the magnetic stirrer is turned on to a low rpm for 30 seconds to disperse the soil. Setting the stirrer to a higher rpm can cause damage to the microfossils and is unnecessary as the calgon and agitation mechanically mix the sediment to break apart clays. The mixture is left to settle for an hour to allow the starch and phytoliths to settle but not the clay visible in the supernatant.

The supernatant is slowly pipetted with a 10 mL pipette equipped with a pipette pump, ensuring no sample is removed, and is then discarded. The above process is repeated until the supernatant is more or less clear. The samples are then ready to be filtered. A 250 μm sieve is affixed within a large funnel and the remaining sample is rinsed thoroughly from its original beaker and filtered through the sieve into another 400-500 mL beaker. The contents of the new beaker are again rinsed out and filtered, this time using a sieve with 118 μm nitex cloth, and transferred into another beaker. This final amount of sample is then poured to fill up 50 mL centrifuge tubes, filing each with roughly the same weight of sample. If there is not enough sample to completely fill a tube, reverse osmosis water is added to top it up to the 50 mL line. The tubes are then centrifuged for 5 minutes at 3000 rpm and the supernatant is removed from all tubes so that the material can be concentrated into a single tube.

Starch Extraction

From the concentrated material, starch extraction occurs first. About 0.5 mL of each sample is used and placed in a new 50 mL centrifuge tube. Each tube receives 5 mL of sodium metatungstate solution with a specific gravity of 1.7 g/L and centrifuged at 3000 rpm for 10 minutes. The supernatant is then decanted with a disposable pipette into a new 50 mL tube labeled with the sample name and starch extract. The material is re-centrifuged and re-pipetted to increase starch extraction, providing around 0-10 μL of extracted sample to work with. The material from the first centrifuge tube is saved for the phytolith extraction process. The tubes with the starch extraction are filled to the 50 mL mark with distilled water and centrifuged for 5 minutes and 3000 rpm. The supernatant is removed with a disposable pipette and this process is repeated two more times to remove all of the sodium metatungstate solution. A few drops of reagent alcohol are added to each tube and the starch extracts can then be pipetted from the bottom of each tube and decanted into 1.5 mL microcentrifuge tubes appropriately labeled with sample name and extract type. It is important to note that the starch extracts may also contain phytoliths.

Phytolith Extraction

The process for phytolith extraction is exactly the same as that of starch extraction, with one exception. In this step, the centrifuge tubes with concentrated sample used in the starch are also used to extract phytoliths and a sodium metatungstate solution at a specific gravity of 2.3 g/L is added instead of 1.7 g/L. After adding the solution, repeat the process outlined above.

Mounting of Starch and Phytolith Extracts

The final step in the processing of soil samples for microfossil analyses involves mounting the extracts from the previous steps on microscope slides. Goggles, gloves, and a lab coat should be worn and the fume hood must be turned on. Using a clean pipette, 1 to 5 drops of each sample are placed on clean slides with appropriate labels. The starch slides receive 10 μL of a staining agent called Trypan Blue that is placed on top of the samples. Both starch and phytolith samples are then smeared evenly on the slides and left to air dry under the fume hood for a few minutes or until dry. Four to six drops of Entellan New mounting media are added to each slide and topped with a coverslip. The slides are left for 2-3 days under the fumehood to dry completely.

Identification of Microfossils

The analysis of plant microfossils (starch, phytoliths, and charcoal) from archaeological soils was conducted using high-powered microscopy. Specifically an Olympus Differential Interference Contrast (DIC) microscope (BX51) was used to view all microscope slides and an Olympus digital camera (DP71) was used to take photographs. Phytolith slides appeared quite productive and were assessed using a 300 minimum count, including 50 rondels to increase the likelihood of finding diagnostic maize and wild rice ones. Microscopic charcoal fragments were also counted alongside until the 300 phytolith count was reached. Phytolith slides were also analyzed for a presence of pollen. Phytoliths were identified and recorded according to types described by Brown (1984) with the exception of rondels which were keyed using a combination of Surette (2008) and Pearsall et al. (2003). Starch slides were viewed with plain and cross-polarized light. No minimum count was applied to the starch slides as they were not very productive and thus the entire slides were scanned systematically to identify as many starch grains as possible. Starch grains exhibiting nearly all the key features of diagnostic maize starch grains but appearing significantly degraded and thus affecting features like the extinction cross, hilum or size were frequently encountered. Such starch grains were recorded in a cf (Latin: confer) category meaning that they had nearly all the characteristics of diagnostic maize starch except one aspect did not fit the description however they appeared so similar that they could not be identified as representing any other plant but maize.

3.7.4. Vegetation Surveys

During the second field season of this research, vegetation surveys were conducted on the island where the Martin-Bird site is located, another island in Whitefish Lake called Mound Island, and on the mainland around the northwest shoreline of the lake. The surveys at the Martin-Bird site and on the mainland were carried out using over twenty 5x5 metre plots and the percent cover method of assessing vegetation.

At the Martin-Bird site, 10 plots were selected at random, usually from areas of less disturbed vegetation indicated by the presence of larger trees for example. This type of sampling was necessary as the site has undergone a series of archaeological projects and is also impacted by beaver activity. Each plot's location was recorded and 5x5 m squares surrounding each area were measured and marked by pins. Each plant in a plot was recorded and its percent cover within the plot was estimated. Plants that were unidentifiable in the field were collected and brought back to the lab for further analysis and identification. On the island, the area in the vicinity of the Macgillivray site was also surveyed as known historic gardening occurred near the site and elsewhere on the island and is still evident today. The garden area is mostly still maintained and a general walkabout survey of the area was done. Unidentifiable plants were again collected to be identified later in the lab or by the Lakehead University Herbarium. (See Chapter 2 and Appendix 1)

Mound Island, an island in the eastern portion of Whitefish Lake was also considered in the vegetation surveys, however this finger-like island was difficult to step onto being very rocky and heavily forested. Nonetheless, an attempt was made to describe the general vegetation for comparison.

Finally, several locations around the northwestern shores of Whitefish Lake were selected and multiple plots were surveyed from each. Three areas that appeared relatively undisturbed were chosen and four 5x5 m plots were surveyed resulting in a total of 12 plots from the mainland.

CHAPTER 4: RESULTS

4.1. INTRODUCTION

This chapter presents the results obtained from soil samples from the Martin-Bird Site, beginning with the microfossil analyses and ending with the total phosphorus results. The soils from the Martin-Bird site are described first, followed by a general summary of the overall trends observed from the results. This is followed by a more detailed discussion of the results of each proxy, which are grouped by the area of the island the soil samples were taken from. The soil samples analyzed in this thesis were grouped into a within-site category ("Area B") (475N to 490N) and north of site category (490N to 525N) based on their location. These groups were determined on the basis of artifact densities deriving from the 2009 test excavation of the Martin-Bird site (Figure 4.1). This showed recoveries concentrated around 475N to 490N and with a clear drop off north of this range, as one moves upslope. This area will be referred to herein as "Area B" (Figure 4.1).

4.1.1 Description of Soils

Starting from the surface, the soil profiles of stratigraphy pits (Figure 4.2) at the Martin-Bird site showed 10 to 15 centimetres of silty, dark grey topsoil with small granular peds (1-10 millimetres) and an abundance of roots and organic matter. The next 5 to 7 cm tended to be mottled soil of light medium brown to brownish grey, with some transitioning into reddish-coloured clay. The bottom 15 to 25 cm of the pits either consisted completely of reddish clay or of sandy, packed silt light to yellowish brown in colour.

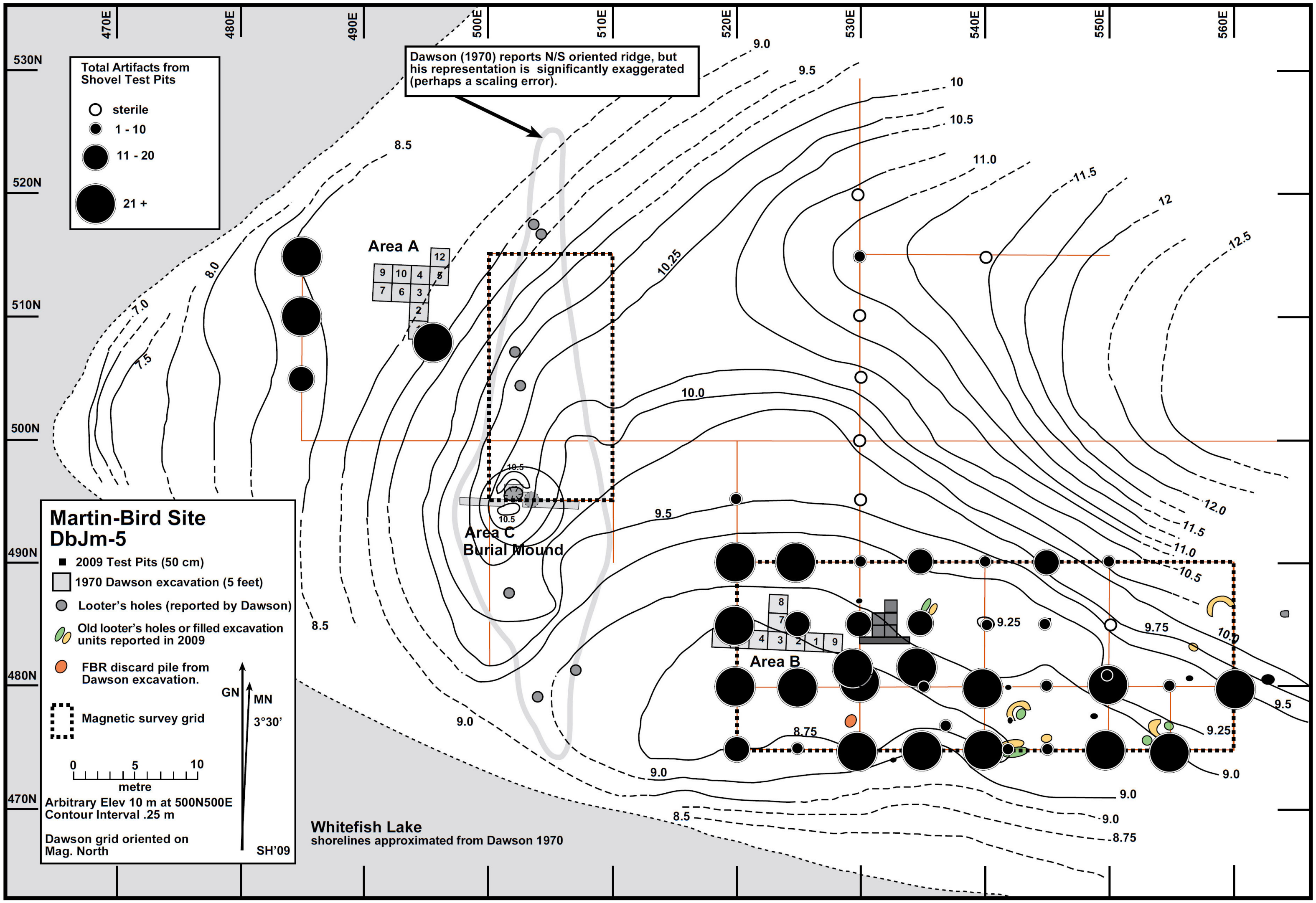


Figure 4.1. Map showing total artifact recoveries from shovel test pits on the Martin-Bird site. Note the mostly sterile test pits north of 490N, giving the impression that the site does not extend beyond this point.

Figure 4.2. Example of stratigraphy pit from Macgillivray Island. The ‘A’ horizon from the surface is 10-15cm thick, followed by tan to reddish-brown silt and sand transitioning into red clay at the bottom (Hamilton 2011).

4.2. STARCH AND PHYTOLITHS

The soil samples processed for microfossils produced an ample amount of phytoliths to permit a 300 minimum count per sample. A significant number of carbonized phytoliths (Figure 4.3), mainly elongate plate types (both smooth and gramineae) were also identified. Pollen grains, mostly cf *Poaceae*, were identified in a number of samples. Varying frequencies of starch were recovered and some samples produced no starch grains, while others showed upwards of fifty starch grains. Overall, the microfossil results include diagnostic microfossils of maize, wild

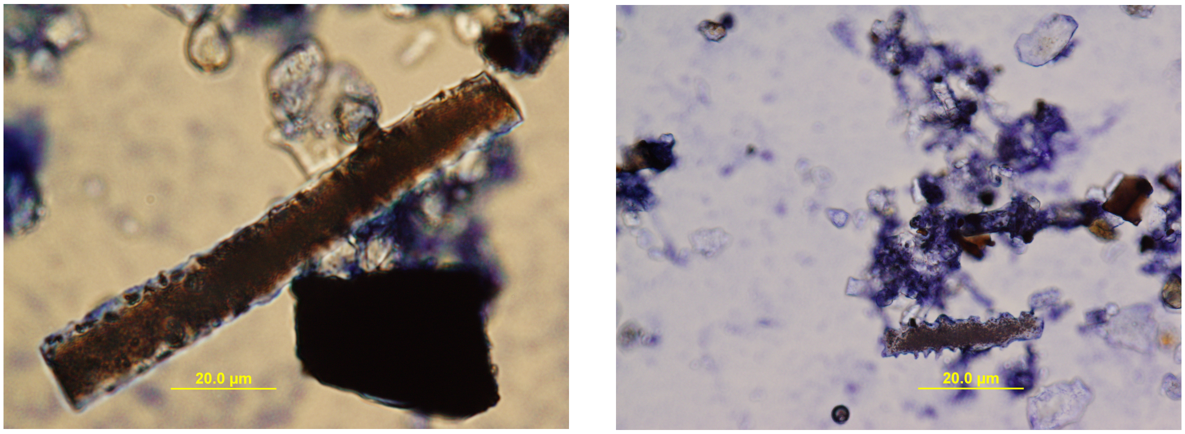


Figure 4.3. Examples of carbonized elongate plate phytoliths identified.

rice, and possibly bean and squash, as well as a large quantity of microfossils typical of common grasses and other plants and a presence of pollen from some samples.

4.3. MICROSCOPIC CHARCOAL

An abundance of microscopic charcoal (Figure 4.4) was noted from every sample analyzed for microfossils. While the trend in both transects appears to show a slight decrease in charcoal to the north of Area B, some inconsistencies are apparent. It is important to note that the microscopic counts are subjective and the results probably under-represent charcoal as tiny fragments (<10 microns) were not counted to account for breakage. Refer to Figure 4.4 to see those types that were included as well as those particles that were not considered in the total charcoal counts. Also note that carbonized phytoliths will be discussed in tandem.

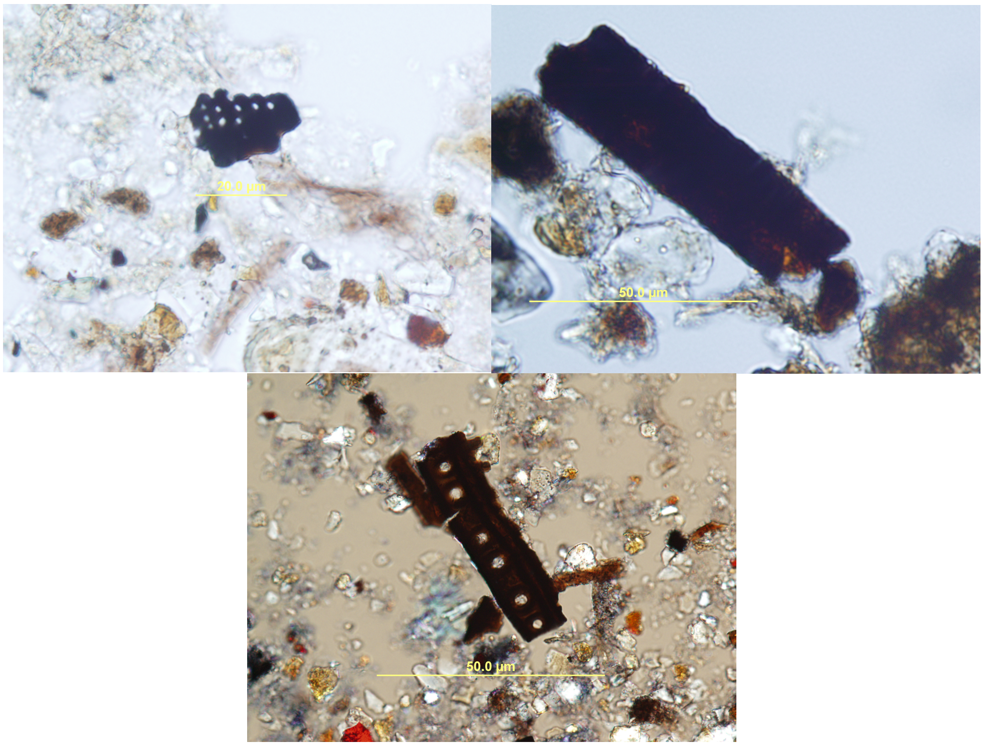


Figure 4.4. Examples of microscopic charcoal fragments recovered from the soil samples and included in the total charcoal counts. Note the smaller charcoal particles seen in the bottom example were frequently encountered but not included in the total count as they likely represent breakage and would create an overrepresentation of charcoal if included.

4.4. TOTAL PHOSPHORUS

The total phosphorus results from the island are separated by the depth of soil they represent: 0cm/surface to 4cm, 4cm to 8cm, and 8cm to 12cm. Higher phosphorus values are generally found in Area B but a trend can be observed where the values increased at the 8cm to 12cm depth in sample locations north of the site. Control samples collected from off the island revealed total P values significantly lower than nearly all of the values obtained from soils on the island.

Control Samples

To assess the anthropogenic signal in soils from Macgillivray Island and the Martin-Bird site, control samples were collected from seemingly undisturbed locations around the northern and northwestern mainland of Whitefish Lake and also analyzed for total phosphorus. All test pits where the samples were collected from were sterile, yielding no artifacts. The results from the total phosphorus testing revealed roughly the same P concentration across the controls (Figures 4.18-4.19; Appendix 3).

4.5. SAMPLES FROM AREA B

4.5.1. Starch and Phytoliths

The most productive samples for starch recovery within Area B were 475N/535E and 479N/535E, with the former containing 35 starch grains in total, and the latter, 51 (Figure 4.11). Only a single diagnostic maize starch was identified at 479N/535E (Figure 4.5) but 16 starch grains that had nearly all of the features of diagnostic maize but lacked an important criterion (size of 20μm or more, 90º extinction cross, “Y” or “X” shaped hilum) were recovered from these two samples (Figure 4.5). Other samples along the 535E transect, like 483N/535E produced 14 unknown starch grains while 487N/535E had zero starch grains. Samples along the 530E transect all had fewer than 4 unknown starch grains (Figure 4.9).

Along the 530E transect, a total of seven diagnostic rondel phytoliths were identified, consisting of one *Z. mays* ssp. wavy-top rondel (Figure 4.6) and six from

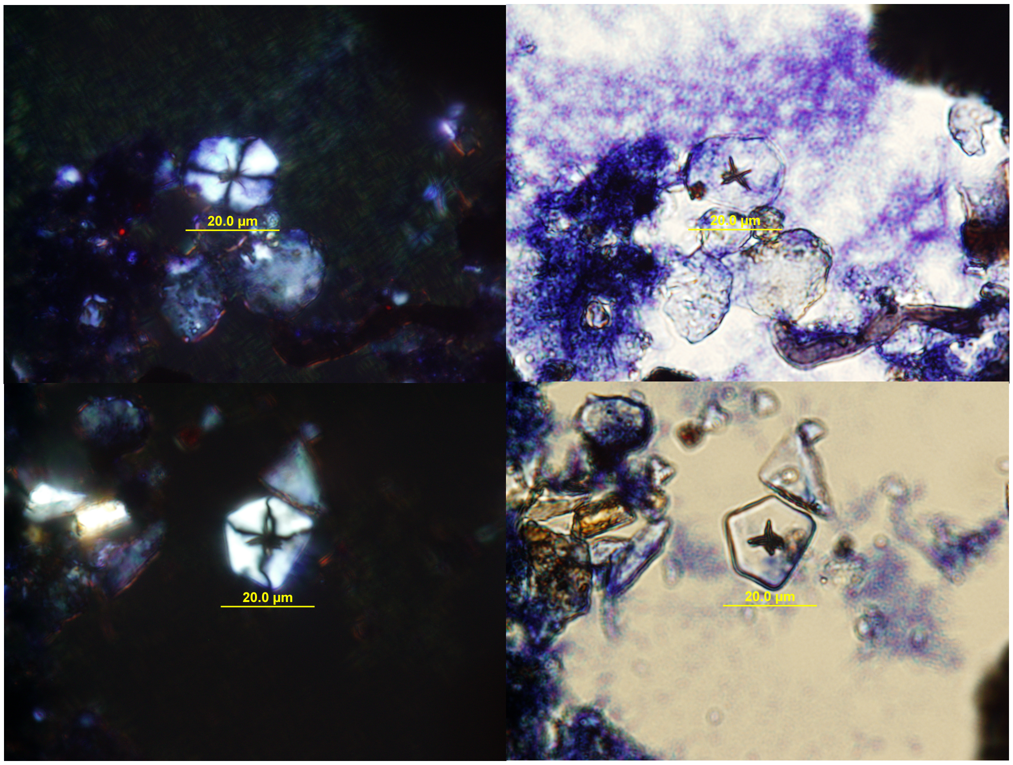


Figure 4.5. The top two micrographs are of a diagnostic Z. mays ssp. starch grain viewed under XPL and PPL light. The bottom two micrographs are an example of the many cf Z. mays ssp. starch grains encountered. Note the bottom starch grain exhibits nearly all features of the diagnostic maize one including faceted sides, size of ~20µm, 'X' or 'Y' shaped hilum but it lacks a 90º extinction cross under XPL like the above starch grain produces.

Zizania sp., all recovered from 481N/530E soil sample (Figure 4.7). An additional two cf *Zizania* sp. rondel phytoliths were also recovered from the same location. Samples from the 535E transect within Area B produced four diagnostic rondel phytoliths. One diagnostic *Z. mays* ssp. wavy-top rondel phytolith was identified from 475N/535E (Figure 4.6). Three Ziziania sp. rondel phytoliths were recovered from 475N/535E, 483N/535E, and 487N/535E. A possible bean phytolith was also identified from 487N/535E though the tip of the characteristically hooked-shaped phytolith was less defined.

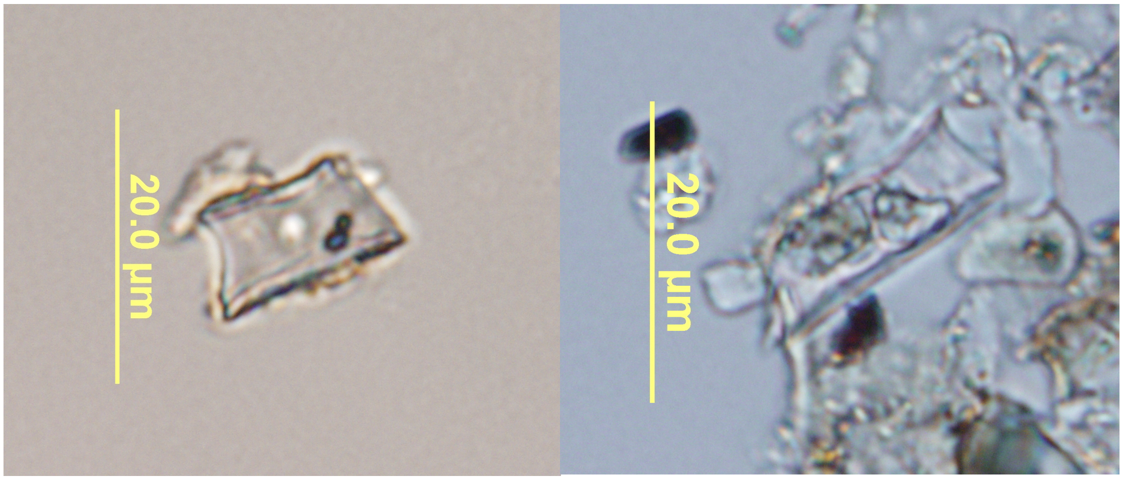


Figure 4.6. The two wavy-top Z. mays ssp. rondel phytoliths recovered from samples within Area B.

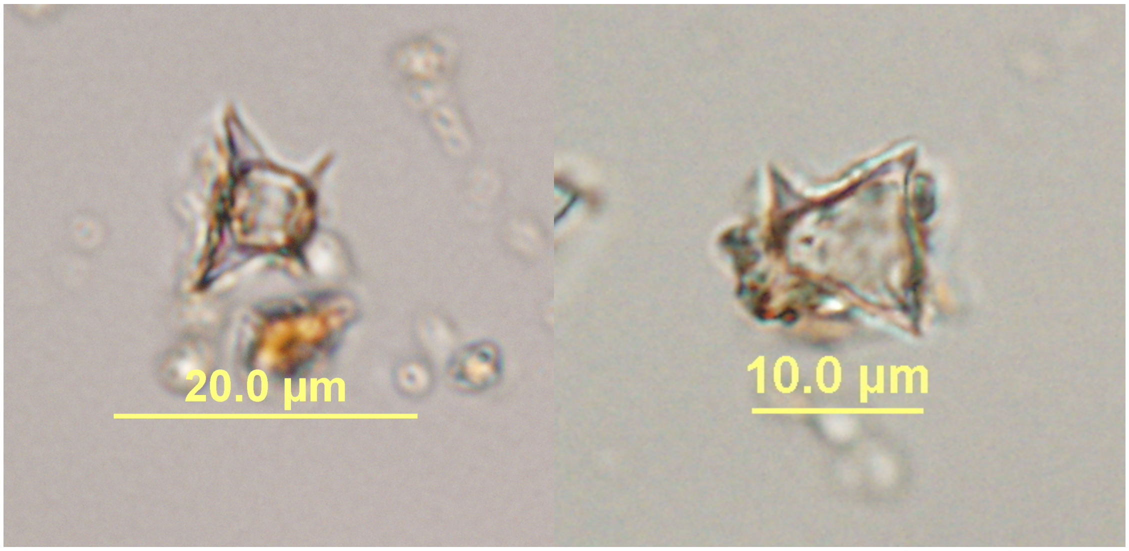


Figure 4.7. Examples of Ziziania sp. rondel phytoliths recovered from samples within Area B.

The non-diagnostic phytolith assemblage for samples from Area B displayed an abundance of smooth elongate plates, long and short non-sinuous trapezoids, saddles, trichomes, short sinuous trapezoids, and rondels (Figures 4.8 and 4.10). A presence of pollen grains was also noted from the phytolith slides of many samples, though preservation was poor. One pollen grain, likely belonging to a bryophyte and one probable *Ambrosia* sp. pollen grain were recovered. A number of probable grass pollen grains (cf *Poaceae*) were also encountered and one pollen grain that appeared maize-like but preservation issues prevented positive identification.

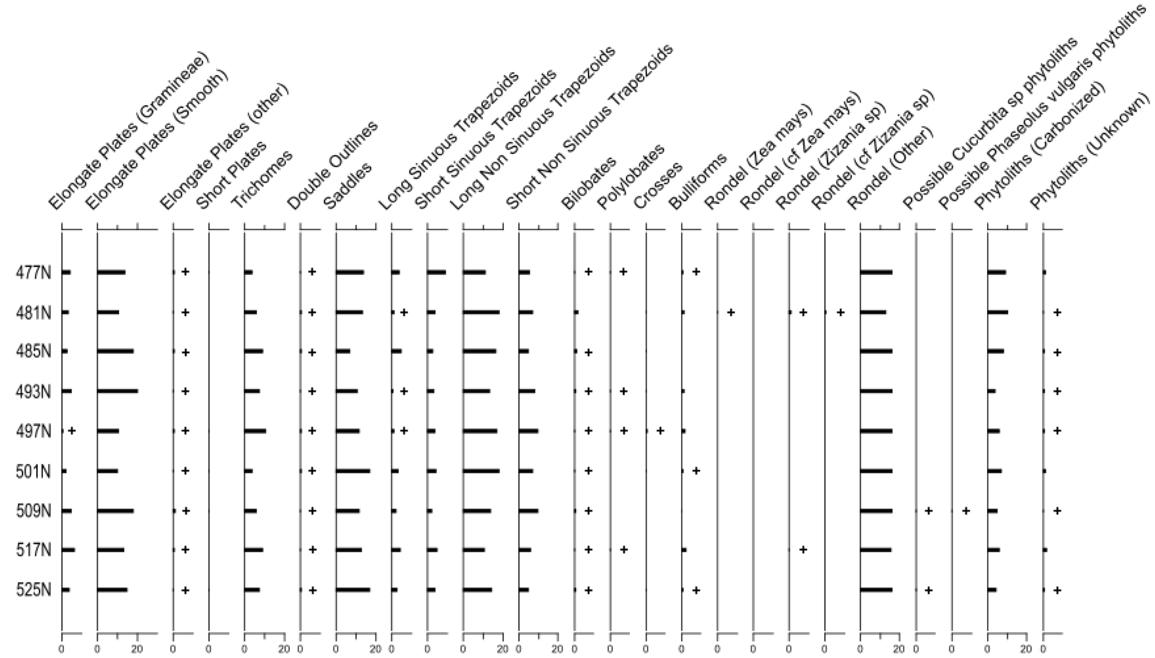


Figure 4.8. Phytolith assemblage recovered from soil samples along the 530E transect. Amounts are expressed as percentages of the total phytolith count (n=300). Trace quantities marked by a plus (+).

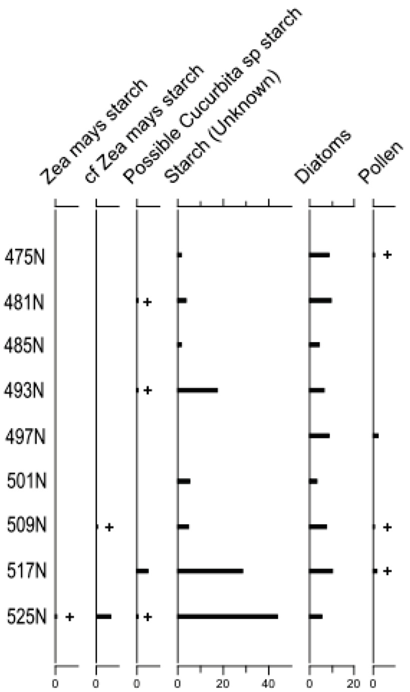


Figure 4.9. Starch and pollen assemblage recovered from soil samples along the 530E transect. Amounts represent actual frequencies. Trace quantities marked by a plus (+).

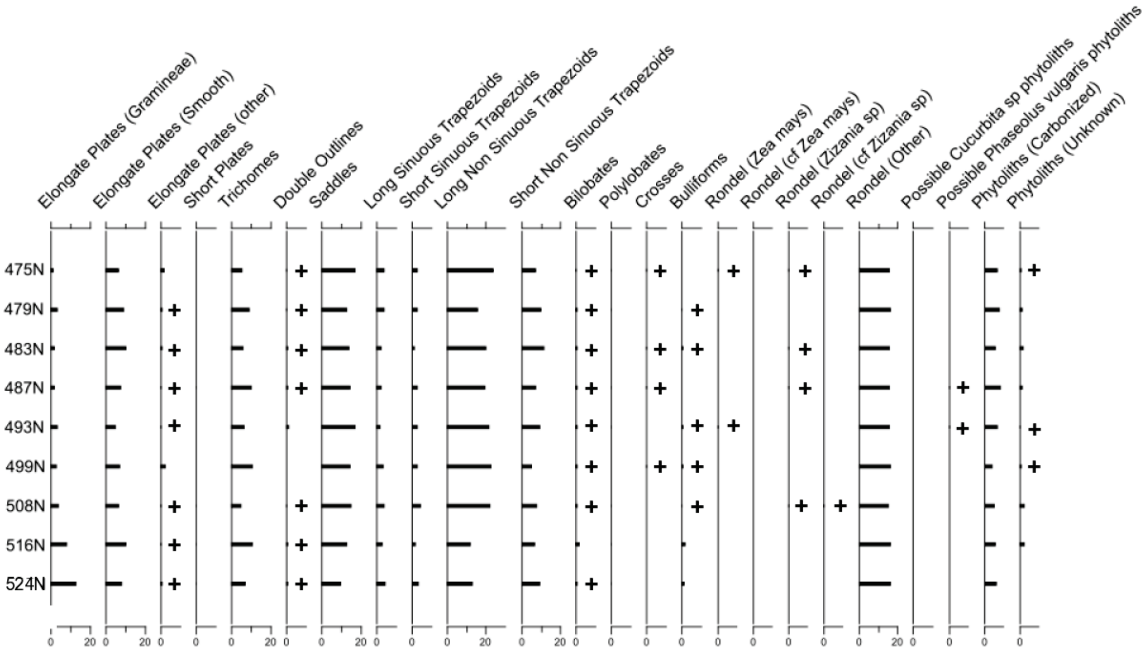


Figure 4.10. Phytolith assemblage recovered from soil samples along the 535E transect. Amounts are expressed as percentages of the total phytolith count (n=300). Trace quantities marked by a plus (+).

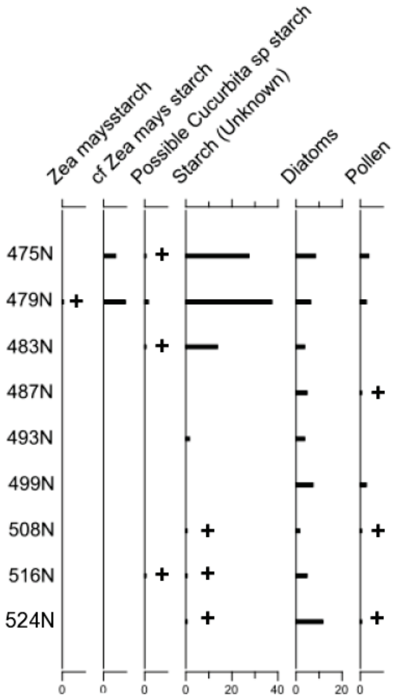
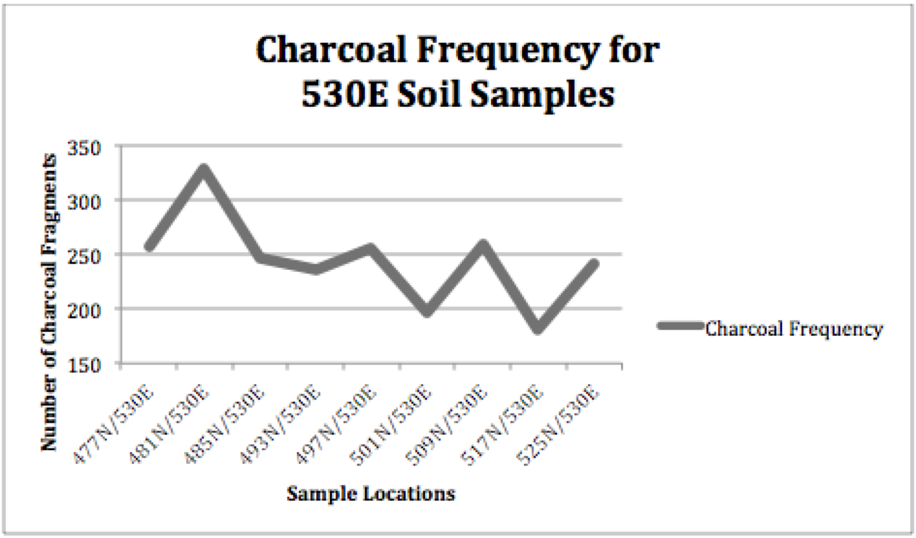


Figure 4.11. Starch and pollen assemblage recovered from soil samples along the 535E transect. Amounts represent actual frequencies. Trace quantities marked by a plus (+).

4.5.2. Microscopic Charcoal

Results of the microscopic charcoal counts from samples within Area B reveal a trend of overall higher charcoal counts compared to samples outside the area (Figure 4.12). Several locations had especially high amounts with over 300 microscopic charcoal fragments counted within the minimum phytolith count for 479N/535E and 481N/530E. The average number of charcoal fragments counted was 275. The number of carbonized phytoliths were also typically higher within Area B but not by any large amount as comparable frequencies were also found to the north of the site (Figures 4.8 and 4.10). The highest amount of carbonized phytoliths occurs at 481N/530E with thirty-two and similar numbers are recorded for other samples within the known site area.



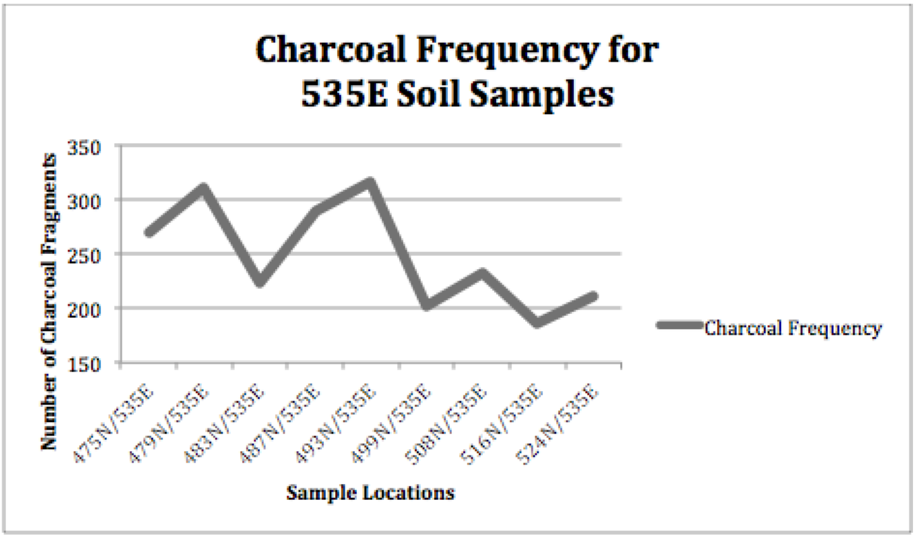


Figure 4.12. Charts illustrating the number of charcoal fragments from each soil sample along both transects. Amounts represent actual frequencies within minimum 300 phytolith count.

4.5.3. Total Phosphorus

Depth: Surface (0cm) - 4cm

The results from the above soil depth within Area B reveal high phosphorus levels at the four most southern occurring soil sample locations (Figure 4.13). Particularly high values occur at 477N/535E and 479N/530E, the latter of which produced between 2 to 10 times the amount of phosphorous content of all other samples on the island. This spike in phosphorus was followed by a sharp decrease in levels from the next sample to the north of it at 483N/530E. The high levels from 477N/535E also saw a significant but more gradual decrease in the next two samples north of it, with 485N535E producing only a third of the P content as

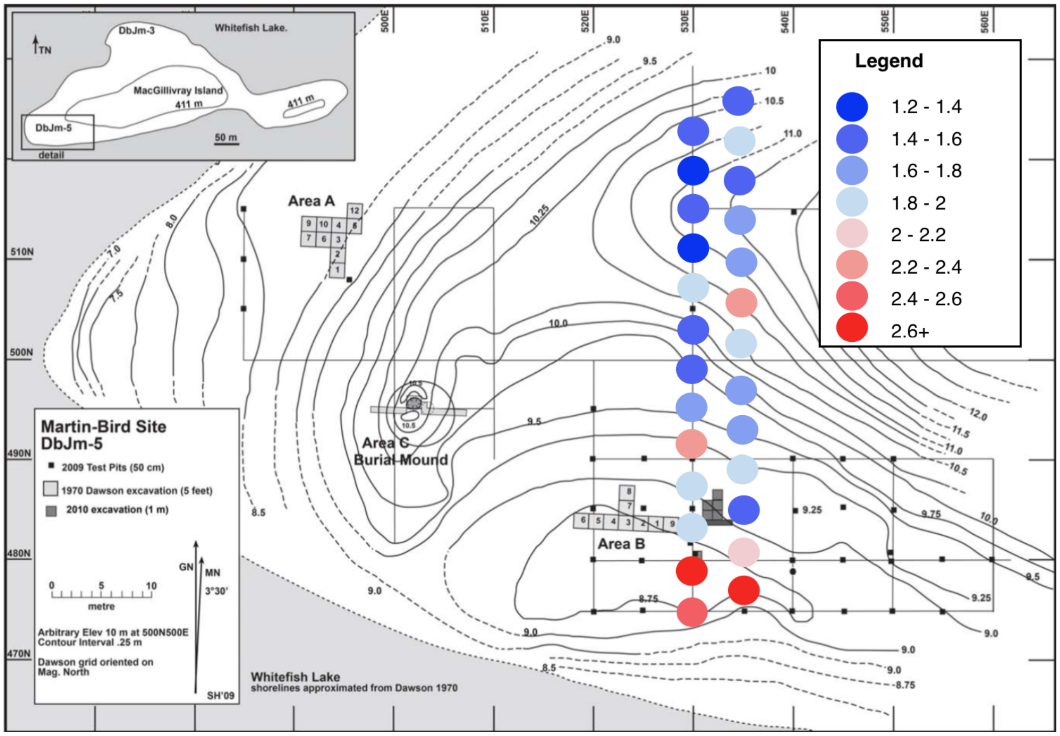


Figure 4.13. Total P values (mg/g) for 0 to 4 cm soil depth. Circles represent actual locations of soil samples while colours represent varying Total P measurements.

477N/535E. The remaining soil samples from Area B were from locations straddling the FCR feature excavated by Drs. Matt Boyd and Scott Hamilton and colleagues in 2010 and all revealed lower P levels, a noticeable contrast to the aforementioned soil samples directly to the south.

Depth: 4cm - 8cm

The outlined trends for the above depth continued into the 4cm-8cm depth (Figure 4.14). The exceedingly high P levels at 479N/530E were nearly the same for this depth though the decrease seen to the next sample to the north, 483N/530E, was slightly greater. High levels from 477N/535E were also almost identical though the decrease in concentration over the next two samples to the

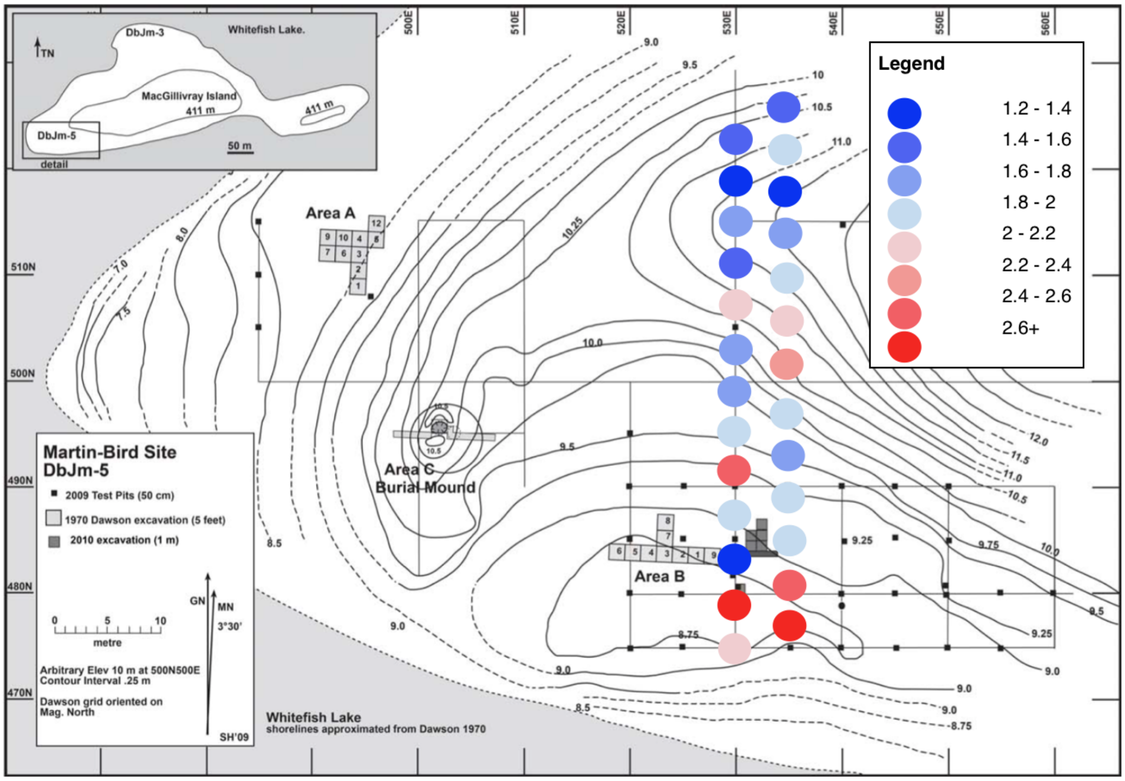


Figure 4.14. Total P values (mg/g) for 4 to 8 cm soil depth. Circles represent actual locations of soil samples while colours represent varying Total P measurements.

north of it was less apparent and occurred gradually as both 481N/535 E and 485N/535E saw significant increases compared to the above depth. The P concentrations from samples straddling the FCR pavement feature were still noticeably lower.

Depth: 8cm - 12cm

The bottom depth of soils analyzed for Total P produced the overall highest amounts of phosphorus (Figure 4.15). At this depth, the southernmost soil samples within the known site area (475N/530E, 477N/535E, 479N/530E, 481N/535) continued to have the highest concentrations and 479N/530E, the sample which already had the highest concentration from the previous two depth, saw a large

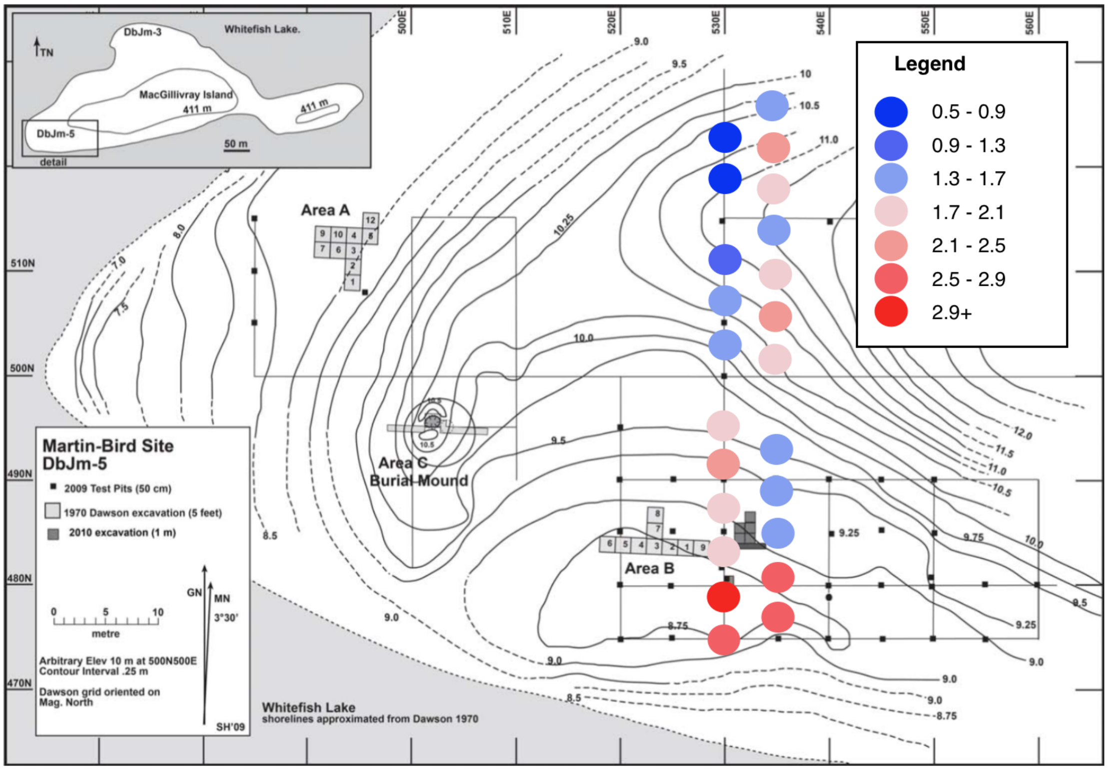


Figure 4.15. Total P values (mg/g) for 8 to 12 cm soil depth. Circles represent actual locations of soil samples while colours represent varying Total P measurements.

increase. All other samples along the 530E transect within the site also saw an increase, while most samples along the 535E transect saw a decrease but values remained fairly similar to the above depth.

4.6. SAMPLES NORTH OF AREA B

4.6.1. Starch and Phytoliths

A diagnostic maize starch grain was recovered from 525N/530E (Figure 4.16) and this sample also produced seven cf *Z. mays* ssp. starch grains. One cf *Z. mays* ssp. starch grain was also identified from 509N/530E (Figure 4.16). Starch recovery was mostly sparse from samples north of Area B, but peaked at several locations (Figures 4.9 and 4.11). All samples along the 535E transect had 2 or fewer starch grains. From the 530E transect, samples 497N/530E to 509N/530E had fewer than 7 starch grains. Eighteen unknown starch grains were recovered from 493N/530E and this number was nearly 2 to 3 times greater at 517N/530E with 34 starch grains, and 525N/530E that produced 53 starch grains.

A total of three confirmed diagnostic rondel phytoliths were recovered from samples north of the known site area. One *Z. mays* ssp. rondel phytolith was identified from 493N/535E and two *Ziziania* sp. rondel phytoliths were recovered from 508N/535E (Figure 4.17). An additional cf *Zizania* sp. rondel phytolith was found at 508N/535E. Phytoliths from other key economic plants like bean (*Phaseolus vulgaris*) and squash (*Cucurbita* sp.) may have also been identified from 493N/535E, 509N/530E, and 525N/530E (Figure 4.17). Pollen grains were also present on phytolith slides from samples north of the known site area, with two notable pollen grains recorded as cf Poaceae but measuring nearly 50μm in size, much larger than the 20μm size of most grass pollen.

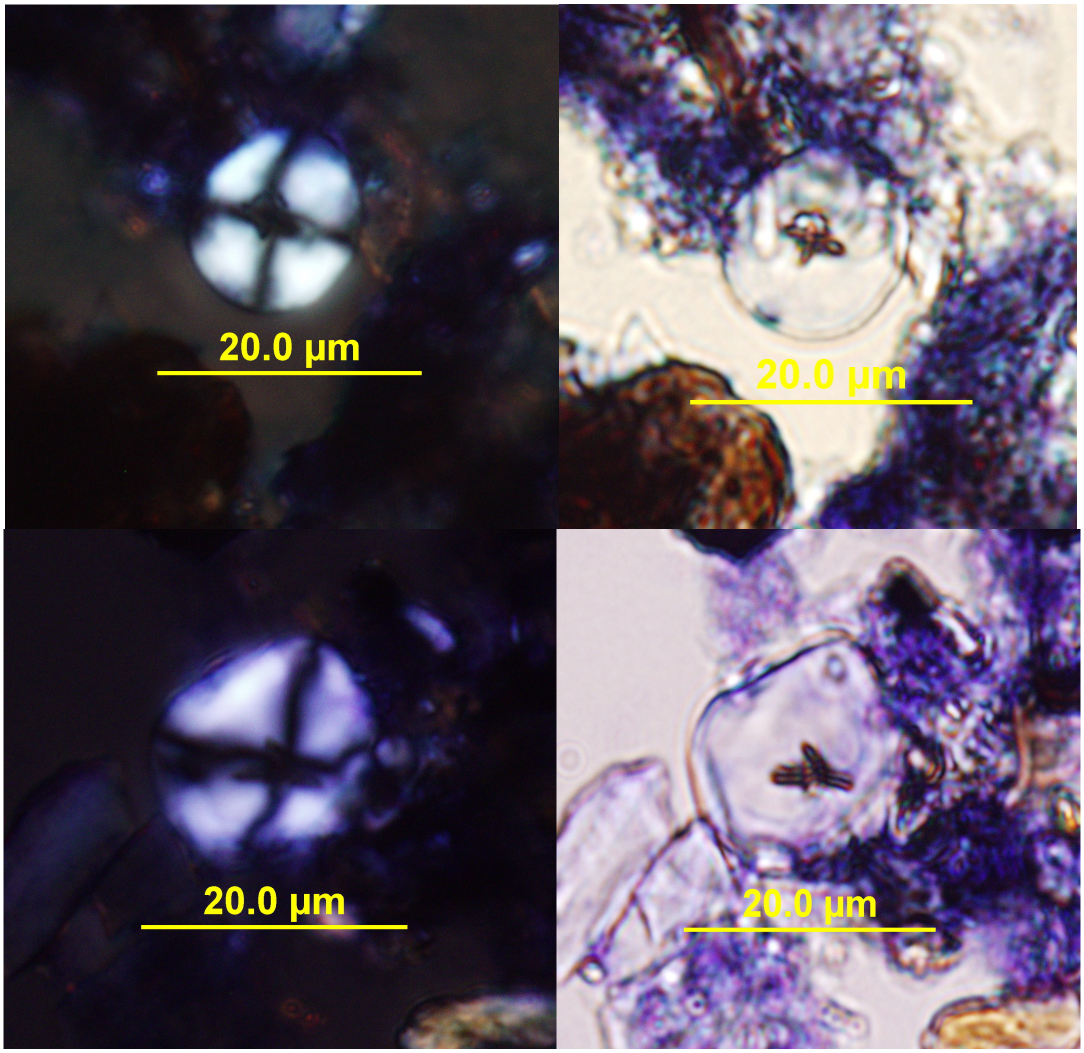


Figure 4.16. Examples of cf *Z. mays* ssp. starch grains recovered from north of Area B, viewed under XPL (left) and PPL (right) light.

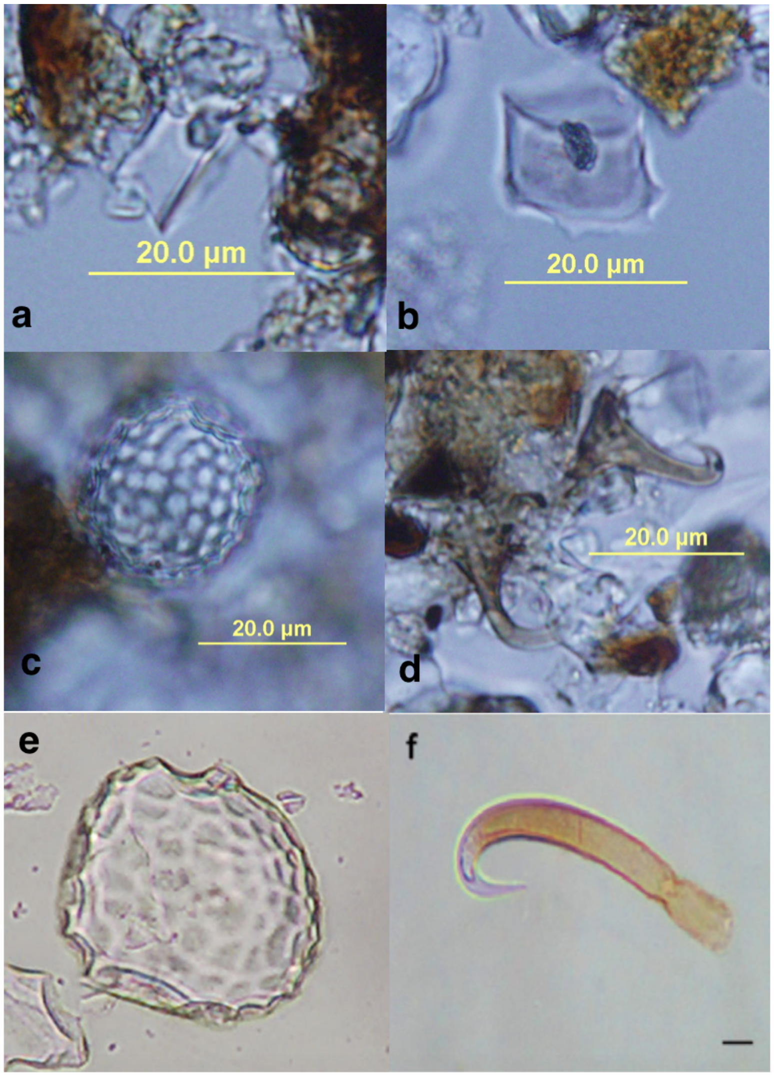


Figure 4.17. Phytoliths from north of Area B (a-d) and comparative images of phytoliths from *Cucurbita* sp. and *Phaseolus vulgaris* (e-f). (a) Wavy-top *Z. mays* ssp. rondel, (b) *Ziziania* sp. rondel, (c) possible *Cucurbita* sp., (d) two possible *Phaselous vulgaris* phytoliths, (e) Piperno et al. 2007, (f) Diaz et al. 2016.

4.6.2. Microscopic Charcoal

Half of all microscopic charcoal frequencies from samples north of Area B reached comparable numbers as those from Area B but the other half produced frequencies around or below 200, which was not seen from any samples within the site. These drops can be seen at 499N/535E, 501N/530E, 516N/535E, 517N/530E, and 525N/530E (Figure 4.12). The highest charcoal count, and the only to surpass 300 charcoal fragments from north of the site, came from 493N/535E, a sample only a few metres outside the delineated site boundaries. The number of carbonized phytoliths per sample was generally lower, though the highest counts of carbonized phytoliths from north of the known site were comparable to samples within the known site area with some of the lowest counts of carbonized phytoliths (Figures 4.8 and 4.10). For example, 501N/530E produced 23 carbonized phytoliths, the highest amount among samples north of the site, while samples from within the known site area with comparable counts like 475N/535E and 483N/535E produced 22 and 18 carbonized phytoliths, but these numbers were the lowest of all other samples within the site.

4.6.3. Total Phosphorus

Depth: Surface (0cm) - 4cm

The total phosphorus concentrations at the shallowest depth for samples north of Area B are significantly lower than within-site values (Figure 4.13 and Figures 4.18-4.19) . The lowest levels occur at 511N/530E and 519N/530E. Although, higher values do occur at 491N/530E and 506N/535E with concentrations closer to the high concentrations seen within the known site area.

Depth: 4cm - 8cm

At this depth, nearly all samples have a slight increase in phosphorus but remain noticeably lower than within site (Figure 4.14 and Figures 4.18-4.19). The increase is most apparent among the samples closer to the known site area (between 491N and 510N along both transects). The more northern extent of soil samples locations (between 511N and 526N along both transects) showed a much smaller increase, with most samples having produced similar levels of phosphorus as the above depth.

Depth: 8cm - 12cm

The trend of increasing phosphorus with depth continues and many samples see an even greater increase than the previous depth (Figure 4.15 and Figures 4.18-4.19). Levels at 491N/530 and 495N/530E, and between 518N/535E and 526N/535E appear to have significantly increased compared to samples between 511N/530E to 523N/530E that have remained relatively unchanged from previous depths. The aforementioned samples that saw increased concentrations were more similar to within-site values but still much less intense than the most southerly group of samples (475N/530E, 479N/530E, 477N/535E, and 481N/535E).

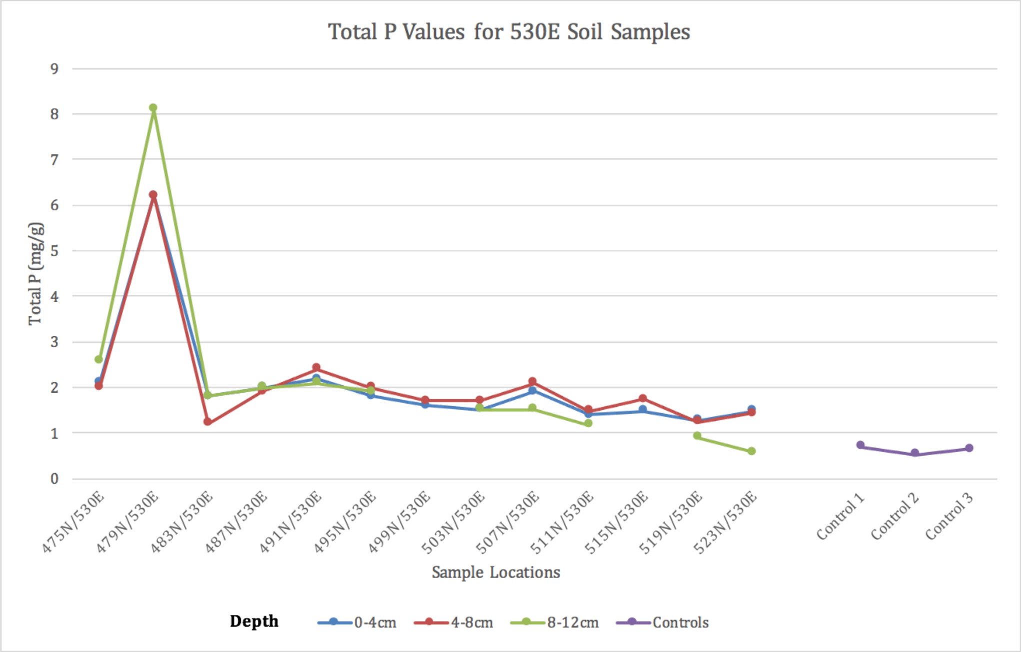


Figure 4.18. Chart illustrating Total P results from soil samples along the 530E transect and off-site controls.

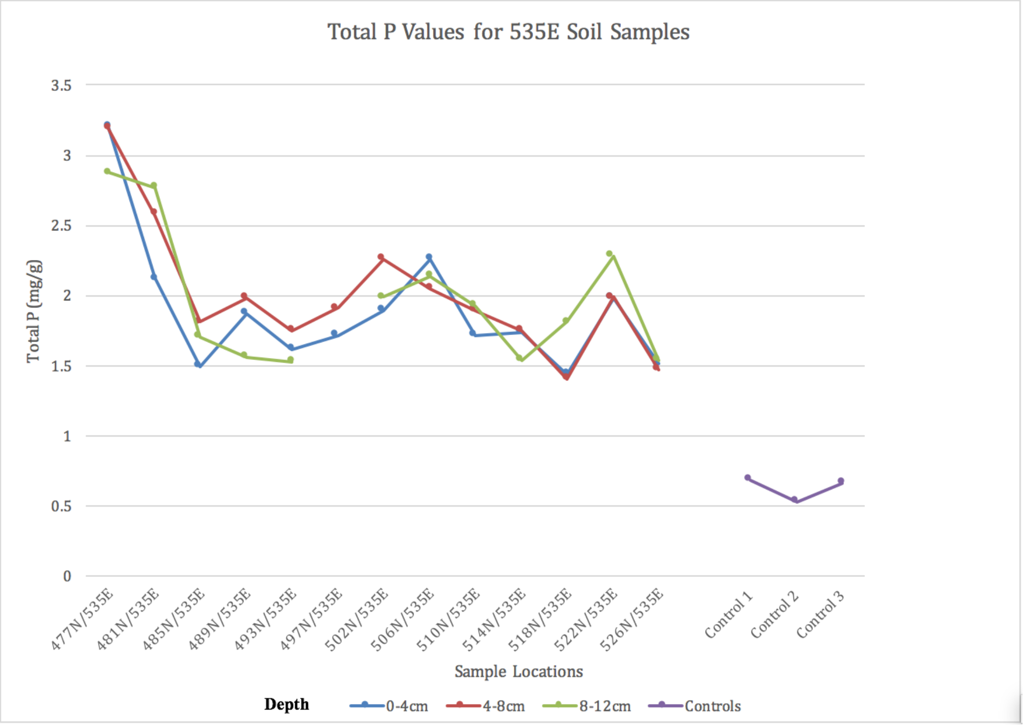


Figure 4.19. Chart illustrating Total P results from soil samples along the 535E transect and off-site controls.

CHAPTER 5: INTERPRETATIONS AND DISCUSSION

5.1 INTRODUCTION

This discussion is divided into two sections. The first section considers the spatial component of both the plant microfossil assemblage and the soil phosphorus (P) concentrations and whether the two datasets are correlated with past activity areas at the Martin-Bird site. The second section discusses how plant microfossil assemblages vary depending on the archaeological context. Specifically, this section will compare my findings from soil samples to data from food residue samples adhering to pottery and grinding stone artifacts recovered at the Martin-Bird site and elsewhere in the Whitefish Lake basin (Appendix 5). Throughout this chapter, an evaluation of the application of plant microfossil and soil P analyses is provided in order to address the effectiveness of these subtle and non-traditional lines of evidence to interpret past human behaviours at sites affected by severe taphonomic issues. Overall, the use of a multiproxy approach and analysis of various contexts to reconstruct aspects of paleodiet and land-use will be emphasized, particularly for disturbed sites like the Martin-Bird and others in the Boreal Forest where organic preservation and site stratigraphy are poor. Ultimately, this thesis represents a novel application of soil chemistry to archaeological sites in the Canadian Boreal Forest.

5.2 SPATIAL ANALYSIS OF PLANT AND LAND-USE

One of the main research objectives of this thesis is to determine if the spatial distributions of microfossil (starch, phytoliths, and charcoal) and soil P results can provide information on past land-use patterns. This may include the identification of activity areas (i.e. food processing) involving economic plants, or possibly ‘invisible’ middens where plant remains and other materials were disposed of. To explore the potential for documenting the spatial aspect of such activities, the major trends observed from the results of each proxy is summarized, followed by a discussion of the related literature that facilitates interpretation.

5.2.1. Plant Microfossils

Observations and Trends

One of the most apparent trends observed from the microfossil data is the clustering of certain microfossils at several soil sample locations. Nearly all of the *Z. mays* ssp. and cf. *Z. mays* ssp. starch grains were recovered from three locations. Two (475N/535E and 479N/535E) fell within Area B and the third, 525N/530E was interestingly the most northerly soil sample collected from the island (Figure 5.5). These three samples were also all the most productive samples for starch recovery in general. Similarly, a clustering of *Zizania* rondel phytoliths was observed from the data, with the majority being identified from soil at 481N/530E (Area B). Aside from these examples of more concentrated economic plant microfossil recoveries, many soil samples yielded little to none at all. Though recovered in small amounts, domesticated plant microfossils from maize (starch and phytoliths) and possibly bean and squash were found. Observations and trends from the microscopic charcoal component of the microfossil assemblages include an overall abundance of charcoal across the soil samples but slightly more within Area B as with carbonized phytoliths. The highest frequencies of both proxies were observed among the southernmost soil samples collected. It is important to recognize the sampling limitations which may lead the researcher to observe certain trends that may not apply to the entirety of the site or even a smaller area within the site. The samples in this thesis are separated by 4 or more metres and the comparatively broad sampling interval used in this research and by many archaeologists due to time and budget constraints may intercept features (middens, food processing areas, etc.) but likely miss many entirely, especially at smaller sites where activity areas may be very localized. Greater spatial resolution in further studies would be ideal to allow for better reconstruction of past plant and land-use.

Maize Starch Concentrations, Distributions and Taphonomic Considerations

Several explanations are possible for the recovery of maize starch in soil at the Martin-Bird site. Before these explanations are explored, however, it is important to note that only two starch grains were positively identified as *Z. mays* ssp. while two dozen starch grains were categorized as cf. ('possible') *Z. mays* ssp. It is unlikely that these starch grains represent some wild grass species since control matrix samples taken from the surface of the site did not produce any evidence of maize, or maize-like microfossils (Boyd et al. in prep.) (Appendix 5). These cf. *Z mays* ssp. starch grains vary from diagnostic maize starch grains on the basis of some distinctive features (in descending order of frequency) in terms of: altered extinction crosses, smaller size, altered hila, and grains with a burst appearance. These distinctions were determined using Babot's (2006) chart illustrating types of

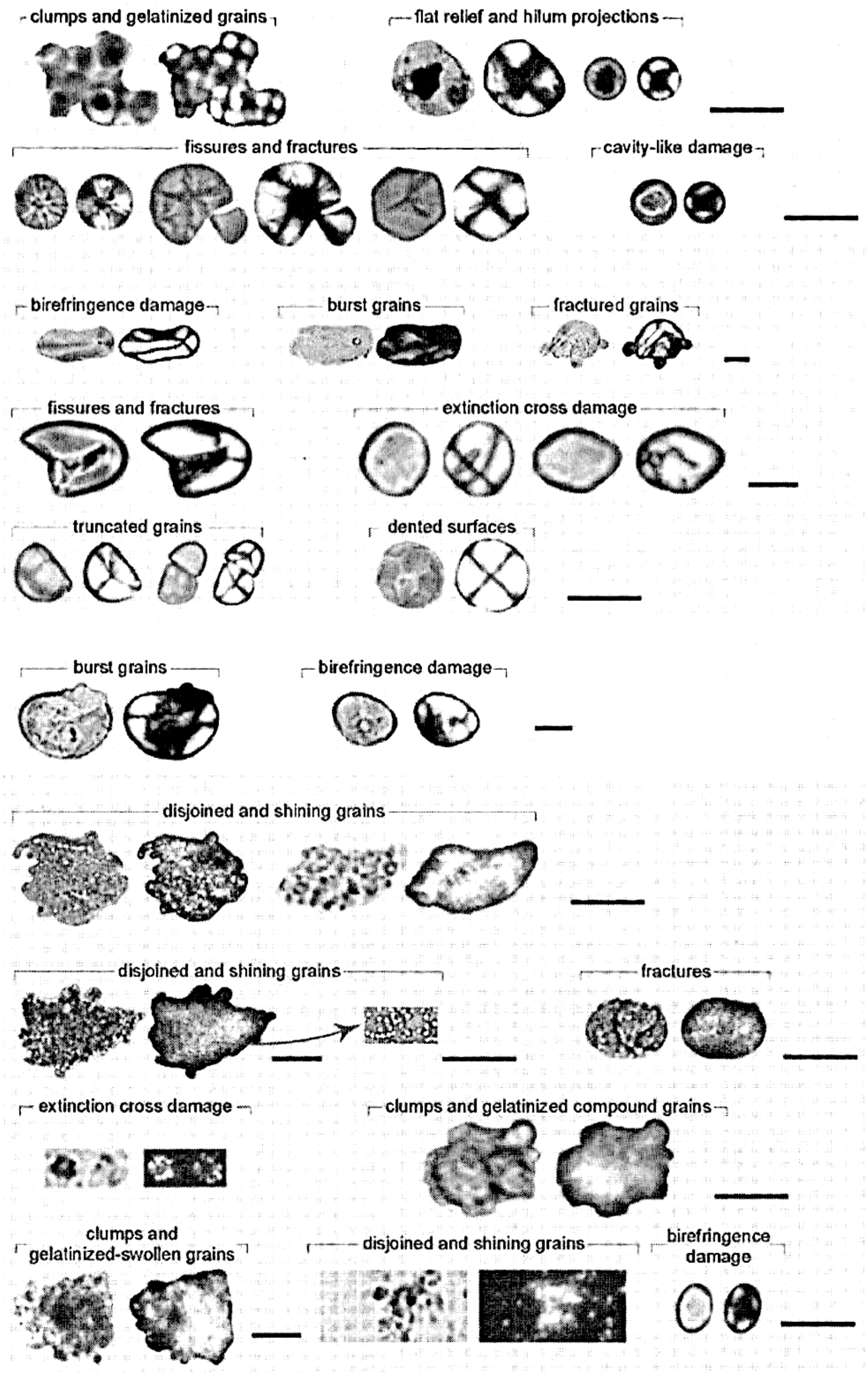
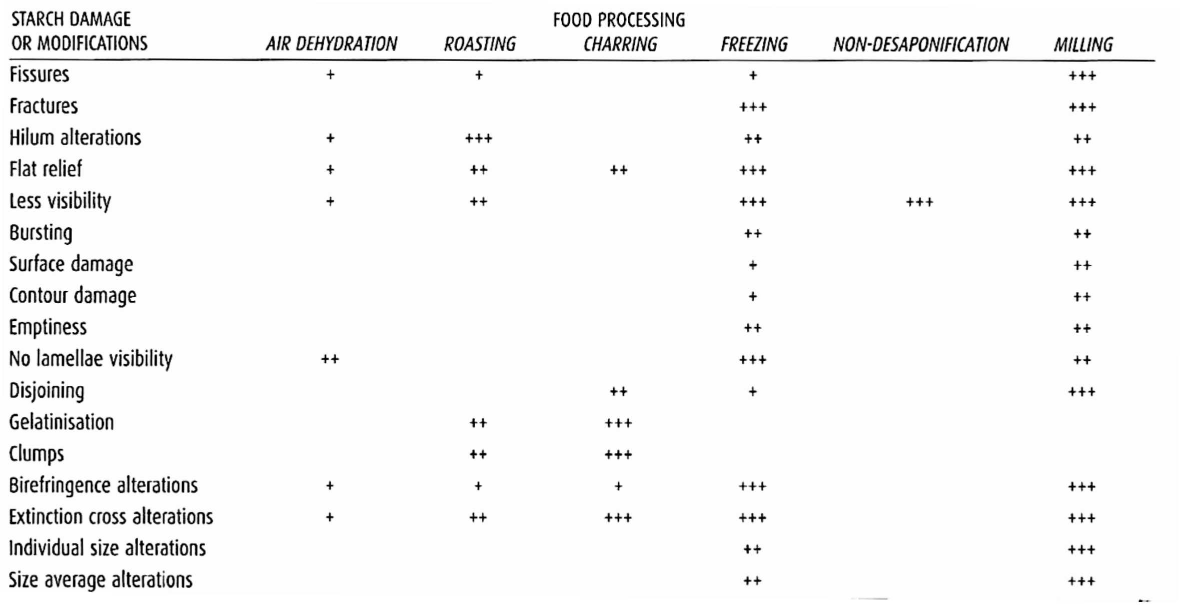


Figure 5.1 Types of starch damage from food processing (Babot 2006)

starch damage incurred from food processing activities (Figure 5.1). Altered extinction crosses are primarily the result of milling, freezing, charring, roasting, or air dehydration (Babot 2003) (Figure 5.2). Furthermore, a study by van den Bel (2015)



STARCH DAMAGE OR MODIFICATIONS	FOOD PROCESSING					
	AIR DEHYDRATION	*ROASTING*	*CHARRING*	*FREEZING*	*NON-DESAPONIFICATION*	*MILLING*
Fissures	+	+		+		+++
Fractures				+++		+++
Hilum alterations	+	+++		++		++
Flat relief	+	++	++	+++		+++
Less visibility	+	++		+++	+++	+++
Bursting				++		++
Surface damage				+		++
Contour damage				+		++
Emptiness				++		++
No lamellae visibility	++			+++		++
Disjoining			++	+		+++
Gelatinisation		++	+++			
Clumps		++	+++			
Birefringence alterations	+	+	+	+++		+++
Extinction cross alterations	+	++	+++	+++		+++
Individual size alterations				++		+++
Size average alterations				++		+++

Figure 5.2 Types of starch damage and their causes based on intensity, marked by crosses (+) (Babot 2003)

identified cf. maize starch recoveries from grinding stones, noting that their unusual extinction crosses prevented positive identification. An additional cause, not necessarily related to food processing, is fermentation. Henry et al. (2009) found alterations in the extinction cross of fermented starch grains in the form of what is described as “extra arms radiating from the center of the grain” (p. 921). A similar finding was noted in my results with several starch grains wherein their extinction crosses appeared to have a bend or some other alteration (see Figure 5.1

‘extinction cross damage’; Figure 5.3). Secondly, many cf. maize starch grains recovered

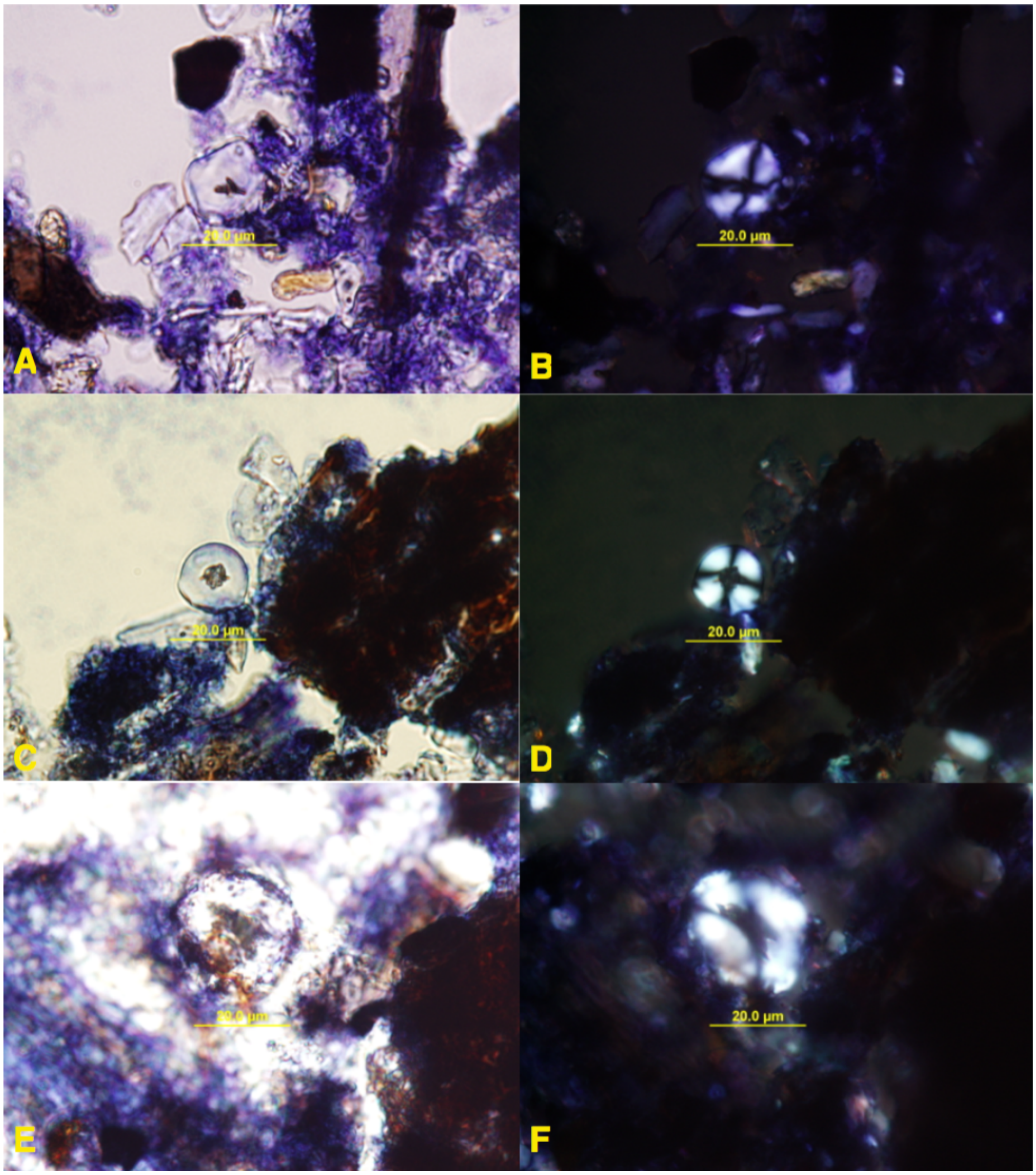


Figure 5.3 Examples of cf. maize with starch damage as described by Babot (2006) under plain polarized light (PPL) and cross-polarized light (XPL): (A) ‘Extinction Cross Damage’ PPL; (B) ‘Extinction Cross Damage’ XPL; (C) ‘Flat Relief and Hilum Projection’ PPL; (D) ‘Flat Relief and Hilum Projection’ XPL; (E) ‘Burst Grain’ PPL; (F) ‘Burst Grain’ XPL

could not be considered diagnostic because they were determined to be too small in size. Babot (2003) notes a change in the size of certain starch grains can occur due to milling and freezing (Figure 5.2). Altered hila in starch grains occurs primarily from roasting but also from freezing and milling (Babot 2003) (Figure 5.2). Many cf. maize starch grains and unknown starch grains displayed a quality where the hilum appeared enlarged or swollen, thus obscuring the definitive “X” or “Y” shape required for positive identification of maize (see Figure 5.1 ‘flat relief and hilum projections’; Figure 5.3). Lastly, several cf. maize starch grains exhibited a burst appearance, affecting nearly all characteristics of the grains including their birefringence, extinction cross, and hilum (see Figure 5.1 ‘burst grains’; Figure 5.3). Potential causes of this are milling and freezing (Babot 2003) (Figure 5.2). Similar descriptions of this sort of starch damage caused by heating with water also note a “softer” or blurred appearance to the grain (Henry et al. 2009). The multiple causes associated with starch damage and the prevalence of starch damage gives credibility to the many cf. maize starch grains identified in this thesis and their characteristics which are often lacking in one criterion that allows for positive identification of diagnostic maize. Milling and freezing appear to be the most prevalent causes of the types of starch damage encountered with the cf. maize identified in this research. Both processes would make sense given the northerly latitude of the site and the inevitable freezing of soils that occurs, and that milling or grinding is a common processing technique applied to the food (Mauldin 1993; Biskowski 2000). Although starch damage can sometimes hinder identification to species, the types of damage seen will also be useful when inferring activity areas and particularly when interpreting what sort of food processing may have produced such damage.

An important feature at the Martin-Bird site is the FCR feature, partially exposed through a block excavation in 2010 (Figure 5.4). The many pieces of FCR appear to have been strategically selected and deliberately arranged in order to maximize contact between adjacent rocks (see Chapter 3), creating an extensive feature interpreted as a roasting pavement for maize (Boyd 2013; Boyd et al. in prep.). This interpretation was further guided by microfossil analyses of over twenty pieces of FCR that revealed upwards of one hundred maize starch grains on several of them, while others yielded no maize starch at all (Boyd et al. in prep.)

Figure 5.4 Composite image of the possible FCR feature at the Martin-Bird site

(Table 2). Spatial analysis of the rocks revealed that those samples producing dozens of maize starch grains were from the perimeter of the feature while those with little to no maize starch were samples obtained near or from the centre of the feature (Boyd et al. in prep.). One explanation for this distribution of starch is that the intense heat used for cooking at the centre of the possible feature would destroy all or most of the starch in these locations. This research further illustrates the importance of considering starch taphonomy when interpreting spatial patterns or past use of an area, or feature in this case. The differential recovery of starch due to varying degrees of heat may be an important factor contributing to the concentrations of starch at certain locations as well as the total absence of starch from many others, although further research and greater spatial resolution in the data is required.

Dense starch accumulations in other archaeological sedimentary contexts have often been interpreted as evidence of activity areas (Haslam 2006; Torrence 2006; Horrocks et al. 2004; Balme & Beck 2002). These may include food processing areas, storage areas, or middens (Torrence 2006). Some of these studies involve the collection and analysis of starch from sediment within features of unknown purpose to determine their past use (Haslam 2006; Horrocks et al. 2004). Balme & Beck (2002) assessed the potential of starch and charcoal in sediment to identify activity areas within a sandstone rock shelter in New South Wales, Australia. The researchers analyzed various processes at the site that could affect the horizontal distribution of starch and charcoal that included pH, moisture content, and sediment compaction from human trampling (Balme & Beck 2002). Ultimately, they found that these factors did not interfere with the original depositional context, and that starch and charcoal recoveries were useful measures of land-use patterns within the rockshelter. Major findings include an association between charcoal and hearths but none between hearths and starch. This would be expected as starch is often destroyed by intense heat, as indicated by the FCR feature at the Martin-Bird. Starch concentrations were interpreted to indicate areas where plant fruits, seeds, or leaves were brought into the rockshelter for food preparation,and decomposed *in-situ* (Balme & Beck 2002). However the analysis did not identify the starch grain species, nor assessed them for damage. Consequently, determination of the details of human activities contributing to the micro-botanical accumulations are limited.

While studies assessing starch distribution and concentrations to identify activity areas involving plants can advance interpretations of intra-site land-use at an archaeological site, Dozier (2016) cautions that their behavioural 'meanings' can be over-emphasized. In an experimental study, airborne starch dispersal from a grinding stone activity area was examined to determine how far starch may travel from the milling loci (Dozier 2016). The activity was practiced indoors and outdoors to assess how wind conditions affect starch dispersal. Water traps were placed at various intervals from the activity centre to collect airborne starch. The results showed that starch can be carried up to 10 metres away outdoors when downwind, while indoors, the densest concentrations of starch occurred within 40cm of the grinding stone locale (Dozier 2016). It is important to note that most milling and grinding activities were likely practiced in a sheltered environment to reduce loss of flour through wind action (Adams 2002). The findings give credence to the Balme & Beck (2002) study that took place within a rockshelter, but for open-air study sites like Martin-Bird, starch concentrations should be interpreted with more caution.

Wild Rice Phytolith Concentrations

Phytolith evidence of domesticated plants was generally scarce and spotty. The most frequently recovered economic plant phytoliths were *Zizania* sp. rondel phytoliths. One soil sample in particular (481N/530E) (Figure 5.5) yielded over half of all diagnostic *Zizania* phytoliths identified in this study. This area also produced high artifact densities with one particular test pit nearby at 480N/530E producing

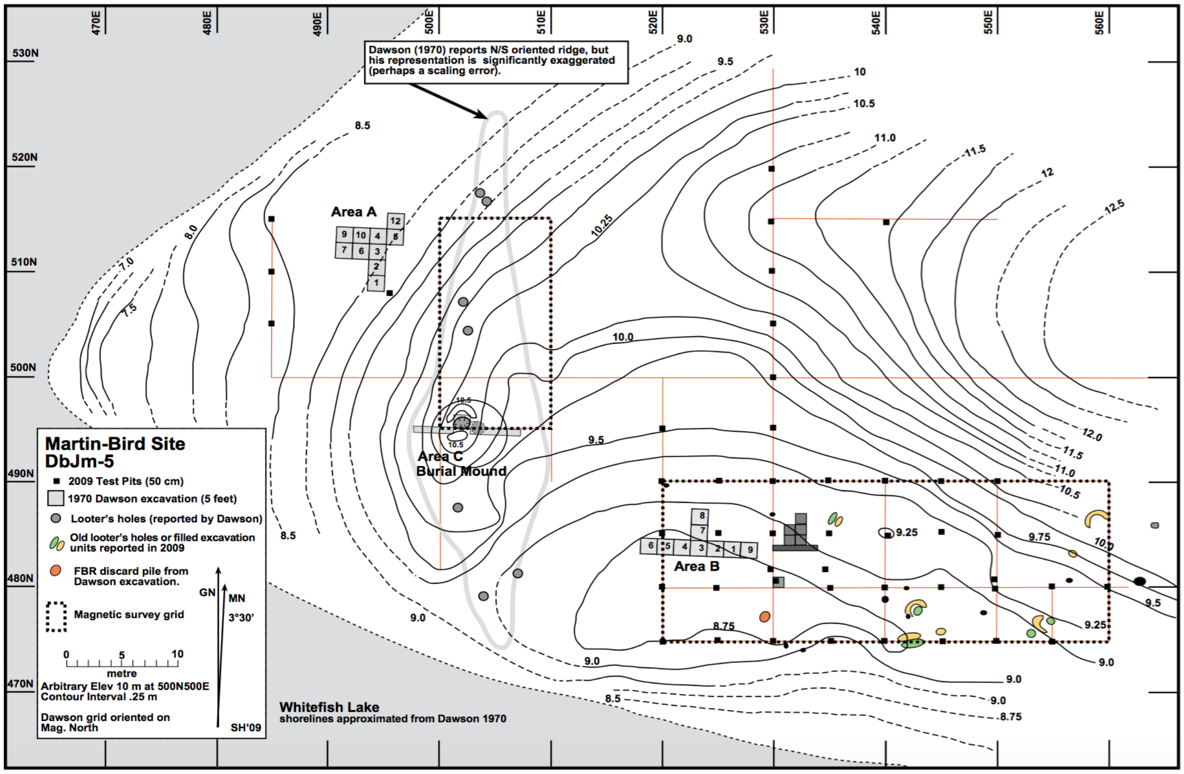


Figure 5.5. Topographic map of the Martin-Bird site (Hamilton 2011)

376 artifacts and the closest P sampling to this location, 479N/530E had the highest P concentration of all samples. Phytolith accumulations in soil can also indicate many of the same things as starch. Piperno (2006) notes that archaeological middens tend to reveal clusters of phytoliths from economic plants discarded by past people after their use. The part of the wild rice plant that produces these diagnostic rondel phytoliths is an important consideration given their location in the chaff (glumes) of the plant that would be removed prior to consumption. After the harvest, wild rice was first dried by parching or smoke-drying the grains (Stickney 1896; Syms 2008b). Once dried, the grains were separated from the chaff through a process called hulling (Vennum 1988; Syms 2008b). A pit was dug in suitable ground such as on a sandy beach, and a sack filled with dried grain was placed in the hole (Stickney 1896; Syms 2008b; Spencer & Jennings 1977). These pits, referred to as ricing jigs (Syms 2008b), are features sometimes identified at Woodland archaeological sites in the Upper Great Lakes region (Arthurs 1978; Rapp Jr. et al. 1995). The final step in wild rice processing was winnowing, which separated the detached chaff from the grains (Vennum 1988; Syms 2008b). The grains were placed in a birch bark tray and tossed or swirled, allowing the natural motion and sometimes wind to lift away the remaining chaff (Vennum 1988; Syms 2008b; Stickney 1896). The wild rice was then ready to be stored, eaten, or traded (Syms 2008b). Given the process of preparing wild rice before it can be cooked and consumed, the concentrations at 481N/530E may represent a combination of a food processing area where the grains were prepared and a midden of sorts where the chaff from the grains was disposed. Other notable

microfossil results from this soil sample include the highest amount of both charcoal and carbonized phytoliths occurring at this location. Similar findings of charred phytoliths and charcoal accumulations have been noted within middens and interpreted as *in-situ* burning of the refuse (Shillito et al. 2011; Ryan 2000).

Charcoal Frequencies Across Samples

Microscopic charcoal counts produced less strongly expressed trends in the data, although there were slightly higher concentrations within Area B than in samples north of the main site area (Figure 4.12). The southernmost samples, consistent with the concentrations of maize starch and wild rice phytoliths (475N/535E, 479N/535E, 481N/530E) (Figure 5.5), also produced some of the highest charcoal counts as well as carbonized phytoliths. Given the clustering of economic plant microfossils in this area and the higher charcoal and carbonized phytoliths accumulations among these southerly samples, perhaps a case can be made for the deliberate burning of these potential midden areas. However, an important nearby feature and possible source of the charcoal is a hearth noted in XU 9 at roughly 483N/528E excavated by Dawson (1970) as well as the adjacent FCR feature (Figure 5.4). While microscopic charcoal may not be as sensitive an indicator of burning-related activity areas, the overall abundance seen across the soil samples still likely represents an anthropogenic source given the known archaeological sites on the island. Additionally, the island's geographical isolation from the mainland offers some protection from naturally occurring fires, although microscopic charcoal can still travel a great distance (see Chapter 4). The addition of carbonized phytoliths to the discussion of microscopic charcoal can help with the spatial interpretation of the data since phytoliths are generally deposited *in-situ* in soil when the plant decays (Piperno 2006). Carbonized phytoliths are often recognized as the result of past plant burning (Piperno 2006; Corteletti et al. 2015; Kealhofer 1996; Boyd 2002) but a recent study (Evett & Cuthrell 2016) found that phytoliths with a carbonized or burnt appearance can sometimes be the result of weathering or degradation, though this likely wouldn't vary across the island soil samples. In sum, while charcoal and even carbonized phytoliths may not be sensitive indicators of specific activities involving fire, the overall higher counts of both within Area B support it as the most intensely utilized archaeological zone.

5.2.2. Total Phosphorus

Observations and Trends

The results from the Total P testing of soil samples from Macgillivray Island and the Martin-Bird site revealed significantly higher soil P concentrations than from control samples at undisturbed locations on the mainland. On the island, the four southernmost soil sample locations (475N/530E, 477N/535E, 479N/530E, 481N/535E) from Area B consistently produced higher P levels from each depth analyzed compared to most other samples. A trend of increasing P with depth in nearly all samples on the island is also observable in the data. It is important to note that in the late stages of this thesis, the researcher realized that when soil core extraction occurred in the initial sample collection process (see Chapter 3), the action compressed the soil, resulting in inaccurate recording of depth of recovery. This issue was somewhat remedied by comparing the cores to the profiles of the stratigraphy pits opened on-site. Both the cores and the stratigraphy pits had the same red clay bottom meaning that the cores did collect all of the layers described from the soil profiles. The length of the cores was typically around 15cm while the stratigraphy pits reached a depth of roughly 40cm. Assuming that the same amount of compaction of the soils occurred throughout the entirety of the cores, Section 1 (0-4cm) actually represents the surface to 12 cm, Section 2 (4-8cm) represents 12-24cm, and Section 3 represents 24-36cm roughly as the last few centimetres was clay and was not included in the soil P analysis. This will allow for some comparisons to be made between the soil P values and the depth of artifact recoveries.

Intra-Site Soil P Comparisons

It is clear from the comparisons of Macgillivray Island soil samples to control soil samples from the mainland that an anthropogenic signal from soil P is detectable and supports the use of P testing as an archaeological prospecting tool. Holliday (2004) notes that most research comparing on and off-site soil P is used for "gauging the degree of human impacts or for defining the limits of sites or individual occupation zones" (p. 312). Based on the test excavation artifact densities, Area B is thought to represent the densest occupation zone of the Martin-Bird site. Some of the highest P values repeatedly occur within Area B, while some of the lowest P values generally occur in samples north of Area B, supporting the interpretation drawn from the artifact densities. One area in particular within Area B, the four southernmost samples (475N/530E, 477N/535E, 479N/530E, 481N/535E) consistently yielded high P values (Figures 4.18 and 4.19). Phosphorus can be added to the soil through a range of anthropogenic activities and sources, such as burials, human and animal waste, plant and bone refuse, ash from fire, animal husbandry, and soil fertilizer for agricultural purposes (Holliday & Gartner 2007; Lippi 1988; Frahm et al. 2016). In many intra-site land-use studies, areas with higher P concentrations have frequently been attributed to one or more of the anthropogenic inputs above (Holliday & Gartner 2007; Lippi 1988). Since accumulations of organic remains contribute the highest amounts of P to archaeological soils, high P levels are most often associated with organic middens, food preparation, or storage areas (Parnell et al. 2002; Eberl 2012; Holliday & Gartner 2007; Lippi 1988). Soil P analysis can also help to detect features like middens composed of both organic and nonorganic waste (Eberl 2012). As hypothesized by Parnell et al. (2002), dense concentrations of artifacts likely to have organic residue adhering to them like ceramics that would have stored food, and lithics employed in food processing should correspond with higher P in the soil. Upon comparing the two datasets, the researchers found that all areas with high P concentrations did in fact intercept areas with dense (1000+) artifact recoveries and concluded that soil P testing is an effective archaeological prospection technique (Parnell et al. 2002). In a similar study Eberl (2012) also examined the relationship between high P and archaeological middens. Three middens, based on ceramic artifact density (200+ sherds), were identified and matrix from each was tested for P. It was found that high P levels only partially corresponded with ceramic middens, with only one of the three middens producing high P levels (Eberl 2012). Given that the high P signal is reliant on organic waste accumulations, the study highlights how other important features like lithic workshops may be overlooked if soil P analysis is used as a method of prospection to direct archaeological excavation (Eberl 2012). At sites with poor organic preservation, like in the Boreal Forest, incorporating microfossil analyses into the research can allow for betterinterpretation of areas with high soil P values and can help to identify plant remains from suspected middens or food processing areas. At a Late Woodland site in southeastern Minnesota, for example, Frahm et al. (2016) found that a spike in P levels occurred at the same depth as a concentration of phytoliths. Similarly, at a 17th century Virginia house lot, Sullivan and Kealhofer (2004) found that areas with high P values, located south of a kitchen, showed not only an abundance of phytoliths but also much diversity from one phytolith assemblage to the next sample, a finding interpreted as an area where a multitude of household activities took place or a midden with plant remains from a variety of sources. At the Martin-Bird site, almost all of the concentrations of economic plant microfossils came from samples where high P values are represented. The especially high concentration of P seen at 479N/530E (Figure 4.18) is located near a test pit at 480N/530E that yielded 376 artifacts, mostly pottery sherds (Hamilton 2011) which may suggest a midden itself. In light of the current literature, it seems reasonable that the high P values within Area B at the Martin-Bird site are consistent with a midden or food preparation area.

While many human activities can enrich P in the soil, others also deplete the element (Frahm et al. 2016; Holliday & Gartner 2007) so unexpectedly low P concentrations in certain locations compared to others can be equally informative, like those soil samples north of Area B. Phosphorous is a macronutrient vital to plant life and certain plants, especially maize, are heavily reliant on P in the soil in order to produce high yields (Chen et al. 1994; Masood et al. 2011). Since growing crops deplete natural soil P levels over time, lower P levels in archaeological soils are often associated with agricultural fields (Meyer et al. 2007; Holliday & Gartner 2007; Leonardi et al. 1999; Eberl 2012). A lack of artifacts from the suspected agricultural fields can also support this interpretation (Sullivan & Kealhofer 2004). Though less extensive test excavation occurred, the area north of Area B at the Martin-Bird site was nearly void of cultural material (Hamilton 2011). Looking closer at the relationship between soil chemistry and microfossil analyses, Korstanje and Cuenya (2010) found that low P and high phytolith frequencies from soil samples could be used to identify cultivated soils. Additionally, if specific crops can be identified from the phytolith assemblage, this may be telling of what was grown in these locations (Korstanje & Cuenya 2010). My results revealed sparse phytolith recoveries of the Three Sisters crops and inconsistent recoveries of maize starch, which is consistent with previous data from the site (Boyd & Surette 2010; Boyd et al. 2014). The question of how the occupants of the site acquired domesticated plants, whether through trade or local gardening, remains unknown but the soil P and additional microfossil data presented in this thesis may provide further evidence in favour of *in-situ* horticulture (Boyd et al. 2014 and Boyd et al. in prep.). This interpretation should not be overstated however as studies involving intra-site comparisons of soil P have also interpreted lower P values to indicate high traffic or ritual areas as waste would likely be cleared from frequently used or sacred areas (Holliday & Gartner 2007). Pathways, communal gathering locations, and ritual areas have been found to produce lower P values as these are generally well-maintained areas where waste would not be left to accumulate (Sarris et al. 2004; Wells et al. 2000; Fernández et al. 2002; Hutson & Terry 2006).

Vertical Distribution of Soil P

A clear trend in the data, seen in nearly all of the samples, is the increase of P with soil depth. A gradual increase in soil P is apparent as depth increases with some of the highest P amounts produced at the lowest depth analyzed. This observation correlates with the archaeological deposits seen at lower depths and indicates that soil P is higher in these archaeological layers than the modern soils although it is important to note that there are several factors impacting the accumulation of artifacts such as severe bioturbation and freeze-thaw cycles among others. The P concentrations across all samples are also much greater than the control samples suggesting that the Martin-Bird site and Macgillivray Island represent more than just a typical hunter-gatherer campsite that was only transiently occupied. Artifact densities, the presence of several burial mounds and the multicomponent nature of the recoveries corroborates this and reflects a repeatedly occupied aggregation site extending over at least a couple of thousand years. Though research on soil chemistry from transient occupation sites are scarce (Holliday 2004), it is thought that they typically do not leave any lasting chemical signatures in the soil (McDowell 1988). The high P levels likely reflect an extensively occupied site where a wide range of plant processing activities took place. It is important to note that there are no cairns or other obvious signs that European settlers used the western portion of the island where the Martin-Bird site is located in any significant way, favouring instead the higher central region near the Macgillivray Site were the area was reutilized as a garden and orchard in the early 20th Century.

5.2.3 Conclusion: Integrating Plant Microfossils and Soil Phosphorus

The spatial dimensions of my results reveal a convergence of the plant microfossil and soil P data with noticeably higher concentrations of both at the southernmost extent of Area B. Starch recoveries were mainly limited to several locations, mostly within Area B. Many were classified as cf. maize starch and had likely undergone some form of alteration. The type of damage observed was primarily consistent with milling and freezing, both likely sources of the damage given that milling is a common maize preparation method and freezing would occur during the winter months. Starch concentrations have often been interpreted as food preparation areas or middens. Phytolith concentrations have also been interpreted in this way. The clustering of wild rice phytoliths in the same area as the maize and cf. maize starch may also indicate a midden or food processing area. The diagnostic wild rice phytoliths are located in the chaff of the plant which is traditionally removed and discarded. The same sample in which the majority of wild rice phytoliths were identified also yielded the highest amount of microscopic charcoal and carbonized phytoliths and similar high frequencies were produced in other soil samples at the southernmost extent of Area B. This may represent a food processing method involving fire or perhaps *in-situ* burning of middens to rid the site of accumulating waste. Soil P values in the same area as the concentrations of microfossils and higher amounts of charcoal and carbonized phytoliths are also consistently the highest. Given that phosphorus tends to accumulate in the soil where organic remains are concentrated, the combination of the microfossil and soil P data may further support the use of this area as a food processing area or midden. Other input sources of soil P like animal waste should not be ruled out as plant matter is not the only contributing source of soil P however.

5.3 PLANT MICROFOSSIL ASSEMBLAGES AND ARCHAEOLOGICAL CONTEXT

The second thesis research objective is to determine if there is any important variation in plant microfossil recoveries from different archaeological contexts. Primarily, microfossil assemblages collected from this and other soil sampling rounds at the Martin-Bird site will be compared with microfossil assemblages from food residues on pottery and other artifacts like grinding stones and FCR pieces (Boyd et al. 2014; Boyd et al. in prep). This discussion will address two closely linked ideas: differential preservation of plant microfossils and the differential representation of plant microfossils in the archaeological record. The value of investigating multiple archaeological contexts for plant microfossils, particularly for ‘worst case scenario’ sites, will be assessed throughout.

5.3.1. Differential Preservation

The recovery of plant microfossils can be significantly impacted by preservation conditions that can vary depending on the archaeological context. Collectively, the datasets from previous research (Boyd et al. 2014; Boyd et al. in prep) and those from this thesis illustrate a relative scarcity of economic plant microfossils from matrix samples across the Martin-Bird site although some samples analyzed by Boyd et al. (in. prep.) surrounding and underlying the FCR feature yielded higher amounts of maize starch (Appendix 5). Artifacts like pottery and FCR tend to yield higher economic microfossil recoveries (see Appendix 5). The difference seen in the overall frequencies of economic plant microfossil among soil samples and residues on artifacts can be explained by the following considerations: microbial activity in soils, microgrooves on artifacts, and varying levels of heat exposure affecting both soil and artifact contexts.

Microfossil assemblages recovered from soils only reflect a small proportion of the total microfossils deposited through plant decay and other means. Since starch granules are organic compounds, they are particularly susceptible to taphonomic processes within the soil, primarily microbial activity. Starch-degrading organisms like bacteria and fungi produce enzymes that consume much of this high-energy food source (Barton & Matthews 2006; Haslam 2004). These organisms are also estimated to account for the decomposition of 95 to 99 percent of all organic matter in soils (Barton & Matthews 2006). Further, studies have found that most organic material decomposes within the first few days after their deposition in soils (Haslam 2004; Barton & Matthews 2006). The paucity of starch encountered in archaeological soils therefore is to be expected. Several cases where starch preservation in soils may be more likely are the deposition of starch from charred organic remains and the deposition of starch clusters, both of which may provide an additional protective barrier against bacteria and fungi (Langejans 2010; Fullagar et al. 2006). Phytoliths are comparatively hardier than starch as they are composed of inorganic silicate material though they remain susceptible to degradation under certain soil conditions. They tend to exhibit better preservation in dry soils in contrast to organic microfossils (Boyd 2005). Additionally, the rate of decomposition of enclosing plant litter can affect the dissolution rate of phytoliths (Piperno 2006). For example, deciduous species decay much quicker than coniferous ones and the enclosed phytoliths will be susceptible to faster dissolution in the soil (Piperno 2006).

While microfossils in soils are exposed to various agents of decay, microfossils adhering to artifacts generally have more protection and therefore exhibit better preservation. Micro-fissures or cracks on lithic and ceramic artifacts provide a sheltered setting for plant and animal residues like microfossils and protein (Zarillo & Kooyman 2006; Barton 2007; Lamb & Loy 2005). FCR and pottery sherds from the Martin-Bird site included in microfossil analysis yielded much higher and more consistent recoveries of economic plant microfossils than did the soil samples, likely due in part to the protection conferred by the artifacts' micro-fissures. As mentioned in relation to soils, charred organic material may be better protected from starch-decaying enzymes. The better representation of economic plant microfossils on the artifacts may then be attributed to the charring of their surface, in the case of carbonized food encrustations on pottery.

Lastly, varying levels of heat exposure can also contribute to differential preservation of microfossils both in soils and on artifacts. Starch is primarily affected since intense heat often destroys starch (Haslam 2004). Maize and cf. maize starch granules were recovered from only three soil samples analyzed in this thesis, with each yielding upwards of six granules, while all others yielded none at all. Similarly, FCR pieces from the periphery of the suspected roasting feature produced between 25 and 100+ maize starch granules while others from or near the centre yielded little to none at all, an observation explained by the centre being the area of most intense heat and likely destroying all starch. Maize starch was also quite sparse within carbonized food residues adhering to pottery, possibly for similar reasons as the heat involved in the cooking of the vessels and their contents may have obliterated most of the starch, although the amount of residue was typically very small, especially relative to the amount of soil processed for microfossils.

5.3.2. Differential Representation

Another important consideration when assessing the variability among microfossil assemblages from soil and artifact contexts is the plant parts that produce diagnostic microfossils. If the diagnostic microfossils are located in the inedible or discarded portions of the plant, they should be underrepresented in pottery residues (Boyd et al. 2014). For example, diagnostic squash phytoliths are produced in the rind of the plant and diagnostic wild rice phytoliths are located in the chaff or glumes of the plant that is removed during winnowing (Boyd et al. 2014; Surette 2008; Vennum 1988). These microfossils should be better represented in soil samples compared to pottery residues since they are more likely to be disposed of, and not integrated into the cooking vessels during food preparation. Higher amounts of wild rice phytoliths especially would be expected due to the availability and abundance of this plant in the Whitefish Lake basin. Not only would wild rice have likely been heavily exploited by the Woodland groups occupying Macgillivray Island and the Martin-Bird site, but the plant would have also been an important food source for waterfowl and migratory birds, which may have resulted in some microfossil dispersal onto the site (cf. McAndrews & Turton 2007). From the total microfossil assemblage recovered from various archaeological contexts at the Martin-Bird site, only 6 possible *Cucurbita* phytoliths were identified and 5 of them were obtained from soil samples. *Zizania* phytoliths were surprisingly well represented in the carbonized food residues, with 58% of cases of carbonized food residues on pottery from the Martin-Bird site yielding wild rice, while soil samples from this thesis yielded *Zizania* phytoliths in 33% of cases (Boyd et al. 2014). Some explanations for the greater representation of wild rice in pottery residues may be that small pieces of the chaff still adhered to cooked grains or that the chaff itself was deliberately consumed. Densmore (1974) notes how cooking wild rice with some of the chaff was quite common as it added more flavour to the dish. Thompson et al. (1994) also notes how the micro-chaff was considered somewhat of a delicacy and sometimes consumed alone or again, cooked with the wild rice grains. The representation of *Zizania* phytoliths in the soil samples may also be affected by the sampling interval and perhaps greater resolution is needed to obtain a more accurate assemblage. Overall, the differences seen in the economic plant microfossil assemblages from soils and artifacts whether due to preservation issues or the parts of the plant that produce diagnostic microfossils makes analyzing several archaeological contexts important to obtain a more complete picture of past plant use and consumption.

The interpretations of the results in this thesis were guided by discussions of the spatial analysis of the data to infer past plant and land-use as well as the variation in the microfossil assemblages depending on archaeological context. Spatial considerations of the data revealed a clustering of economic plant microfossils among the southernmost soil samples collected, an area that also includes some of the highest phosphorus values and artifact densities. These results combined with an investigation into the related archaeological literature led the researcher to interpret this portion of Area B to represent a midden and/or food preparation area and supports Area B as the denser archaeological zone of the Martin-Bird site. This should not be overstated however as animal matter could have also contributed to the higher P values seen here. Interpretations of the site could be furthered by analzing soil samples for bone fragments.

The overall lower P levels and sparse economic plant microfossil remains north of Area B may be attributed to the use of this area for ritual activity in which case it would likely have been kept clean of any plant debris and other waste. If local horticulture, as opposed to trade, produced the domesticated plant foods like maize and squash seen from multiple archaeological contexts at the site, this area may have served as the garden given the lower P values and artifact densities here, consistent with agricultural fields. These claims should not be overstated however as they essentially originate from an absence of data and further investigation is needed. An analysis of the microfossil assemblages from different archaeological contexts revealed an overall scarcity of economic plant microfossils from matrix samples which may be a function of their exposure to fungi, bacteria and enzymes in the soil while some protection is conferred by microgrooves on artifacts. Sampling limitations are also an important factor contributing to seemingly lower economic plant microfossils recoveries from soil contexts. It may be that the soil samples analyzed in this thesis do not reflect usual distributions of economic plant microfossils in soils at the Martin-Bird site. Another important consideration when interpreting past plant and land-use is the portion of the plant that produces diagnostic plant microfossils. As discussed, major economic plants like wild rice and squash produce diagnostic phytoliths in the discarded or inedible portions of the plants and their representation may differ significantly across various archaeological contexts.

CHAPTER 6: CONCLUSIONS

Boreal Forest archaeology is comparatively understudied due to the constraints associated with the ecozone such as working in often remote areas and the range of taphonomic issues encountered. The sites are often a ‘worst case scenario’ for archaeologists, exhibiting poor organic preservation and disturbed, thin site stratigraphy. As a result, the culture history of Northwestern Ontario and the Eastern Subarctic on the whole is not well understood and is based on dated research often hidden in the grey literature.

The Whitefish Lake basin and the immediate area exhibit a sparse archaeological record until the Middle Woodland period, thereafter revealing a number of sites along the modern shore and on islands within the lake containing Woodland components. This influx of human occupation in the area suggests the lake was an important locale during the Woodland period. Whitefish Lake would have been an appealing locale to Woodland peoples being within the transitional zone of the Boreal Forest and the Great Lakes-St. Lawrence Forest fostering a diverse resource base of flora and fauna. Particularly notable is the lake’s abundance of wild rice (*Zizania* sp.), an economic plant thought to have been heavily exploited during the Woodland in the Upper Great Lakes region (Emerson et al. 2002; Reid & Rajnovich 1991; Mason 1981). Sites in the Whitefish Lake basin are characteristic of Boreal Forest archaeology and the range of taphonomic issues encountered. Recent paleodietary research involving plant microfossils has sought to remedy this knowledge gap while demonstrating the utility of plant microfossils at sites where comparatively little is known aside from lithic and ceramic assemblages. Analyses of plant microfossils in carbonized food residues adhering to pottery sherds from Whitefish Lake by Boyd et al. (2014) sites found a strong co-occurrence of wild rice and maize in vessels suggesting the two foods were frequently cooked and consumed together. The presence of maize in vessels from Whitefish Lake represents one of the more northerly areas of precontact maize consumption in North America (Boyd & Surette 2010). Whitefish Lake has an interesting story to be told, particularly involving the role of domesticated plant foods and the interplay between domesticates and wild plant resources in the Eastern Woodlands seasonal round. The limited recovery of organic plant remains coupled with the general lack of emphasis on the plant component of paleodiets in past archaeological work in the region (Boyd et al. 2014) has left many unanswered questions related to plant use by Woodland peoples in Northwestern Ontario and other Boreal Forest sites in the region. The durability and relatively good preservation of plant micrfossils and the immobility of phosphorus in soil (Holliday & Gartner 2007) make both proxies well-suited to study such sites with few organic plant remains and poor stratigraphy in order to obtain interesting and informative plant and land-use patterns. With continued archaeological exploration using subtle lines of evidence, a new narrative of the archaeology of the Eastern Subarctic can begin to form.

The research in this thesis was guided by several objectives: (1) Do economic plant microfossils in soil, and soil P values, at the Martin-Bird site allow for the identification of food processing or other activity areas involving plants?; and (2) Do plant microfossils recovered from soil differ from assemblages recovered from archaeological residues such as carbonized encrustations on pottery or residues on grinding stones? The results of the plant microfossil analyses and Total P testing relating to the first objective revealed several correlations between the datasets. Economic plant microfossils of maize and wild rice appeared to be clustered around a specific area of the site, among the four southernmost samples of Area B (denser archaeological zone) (Figure 5.5) and the Total P values here were consistenly among the highest of all samples for each depth. These four locations also had some of the highest microscopic charcoal counts. As elevated concentrations of soil P are often associated with areas of concentrated organic remains from a range of human behaviours, and given the clustering of maize and wild rice microfossils and higher charcoal counts, this area was interpreted as a possible food processing feature or midden. To the north of Area B, samples showed a decline in Total P and microfossil recoveries which may indicate that his area had less traffic or was less intensely occupied. The area may also represent one of ritual activity and as such, would have been kept comparatively clean and free of accumulations of organic debris.

Addressing the second research objective involved comparisons between the economic plant microfossil recoveries from soil samples analyzed in this thesis and the total microfossil assemblage from other contexts (food residues on pottery and grinding stones), derived from previous research at Whiteish Lake (Boyd et al. 2014; Boyd et al. in prep). This analysis of the microfossil assemblages from different archaeological contexts revealed an overall scarcity of economic plant microfossils from soil samples, an observation that may be attributed to their exposure to agents of decay like fungi, bacteria and enzymes in the soil while microgrooves on artifacts like pottery and grinding stones can better protect microfossils. Wild rice rondel phytoliths were slightly better represented in soil samples as expected, given the discarded chaff portion of the plant that produces these diagnostic phytoliths would be less likely to be consumed thus limiting their recovery in food residues. Evaluating multiple contexts for economic plant microfossils can provide a more rounded look at plants in both paleoecological and paleodietary contexts.

Future studies of the sort would benefit from greater spatial resolution and more intensive sampling but these results have shown that the proxies and methodologies used can be highly effective prospecting tools to direct more focused archaeological exploration and excavation. The application of soil chemistry and microfossil analyses can be very informative and reveal distribution patterns as well as specific aspects of plant and land use that would otherwise be undetectable at Boreal Forest sites using conventional methods.

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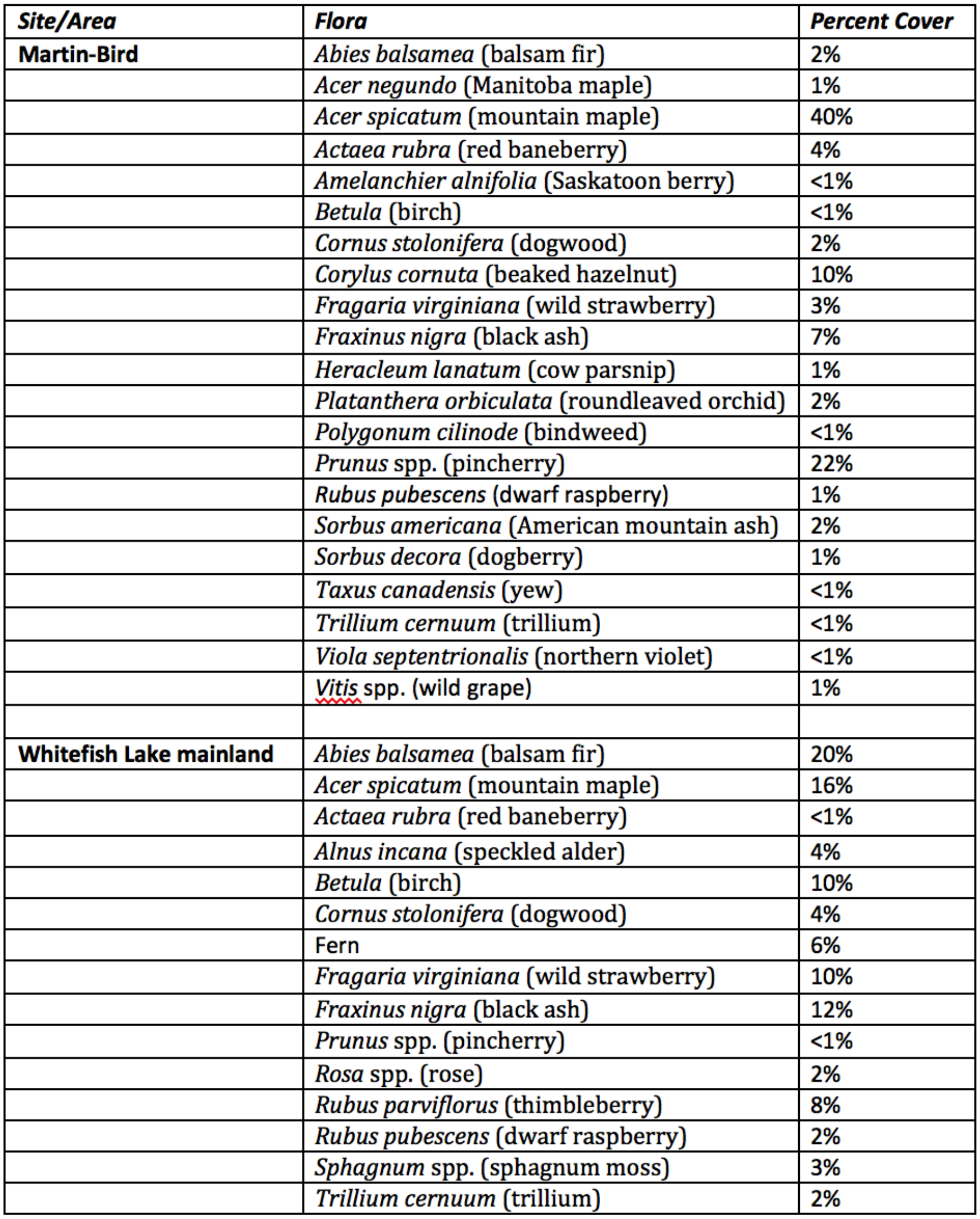
APPENDICES

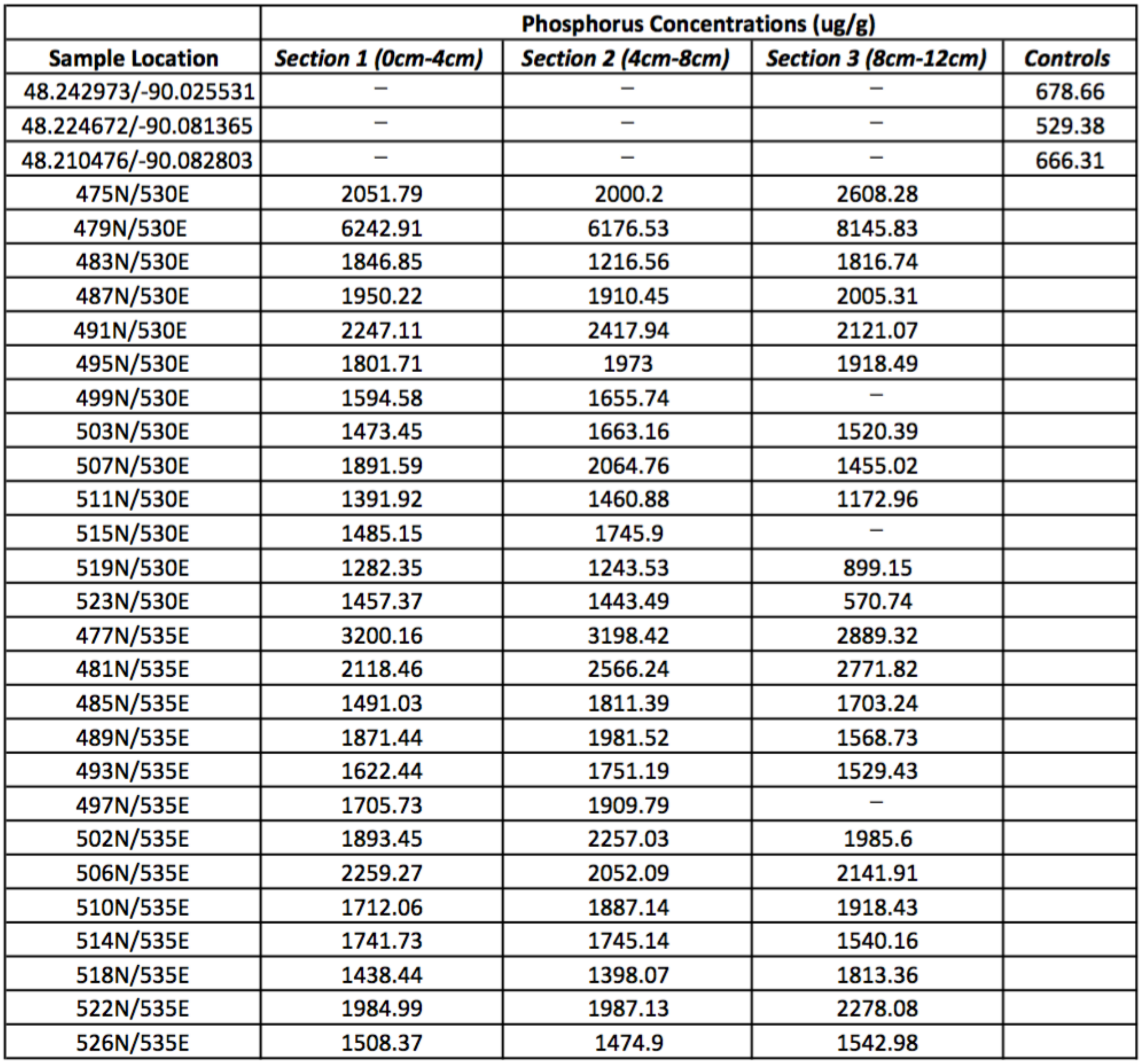


Site/Area	***Flora***	***Percent Cover***
Martin-Bird	*Abies balsamea* (balsam fir)	2%
	Acer negundo (Manitoba maple)	1%
	Acer spicatum (mountain maple)	40%
	Actaea rubra (red baneberry)	4%
	Amelanchier alnifolia (Saskatoon berry)	<1%
	Betula (birch)	<1%
	Cornus stolonifera (dogwood)	2%
	Corylus cornuta (beaked hazelnut)	10%
	Fragaria virginiana (wild strawberry)	3%
	Fraxinus nigra (black ash)	7%
	Heracleum lanatum (cow parsnip)	1%
	Platanthera orbiculata (roundleaved orchid)	2%
	Polygonum cilinode (bindweed)	<1%
	Prunus spp. (pincherry)	22%
	Rubus pubescens (dwarf raspberry)	1%
	Sorbus americana (American mountain ash)	2%
	Sorbus decora (dogberry)	1%
	Taxus canadensis (yew)	<1%
	Trillium cernuum (trillium)	<1%
	Viola septentrionalis (northern violet)	<1%
	Vitis spp. (wild grape)	1%
Whitefish Lake mainland	*Abies balsamea* (balsam fir)	20%
	Acer spicatum (mountain maple)	16%
	Actaea rubra (red baneberry)	<1%
	Alnus incana (speckled alder)	4%
	Betula (birch)	10%
	Cornus stolonifera (dogwood)	4%
	Fern	6%
	Fragaria virginiana (wild strawberry)	10%
	Fraxinus nigra (black ash)	12%
	Prunus spp. (pincherry)	<1%
	Rosa spp. (rose)	2%
	Rubus parviflorus (thimbleberry)	8%
	Rubus pubescens (dwarf raspberry)	2%
	Sphagnum spp. (sphagnum moss)	3%
	Trillium cernuum (trillium)	2%

Appendix 1: Vegetation survey results from the Martin-Bird and Whitefish Lake mainland. Ten plots from both areas were analyzed for percent cover.

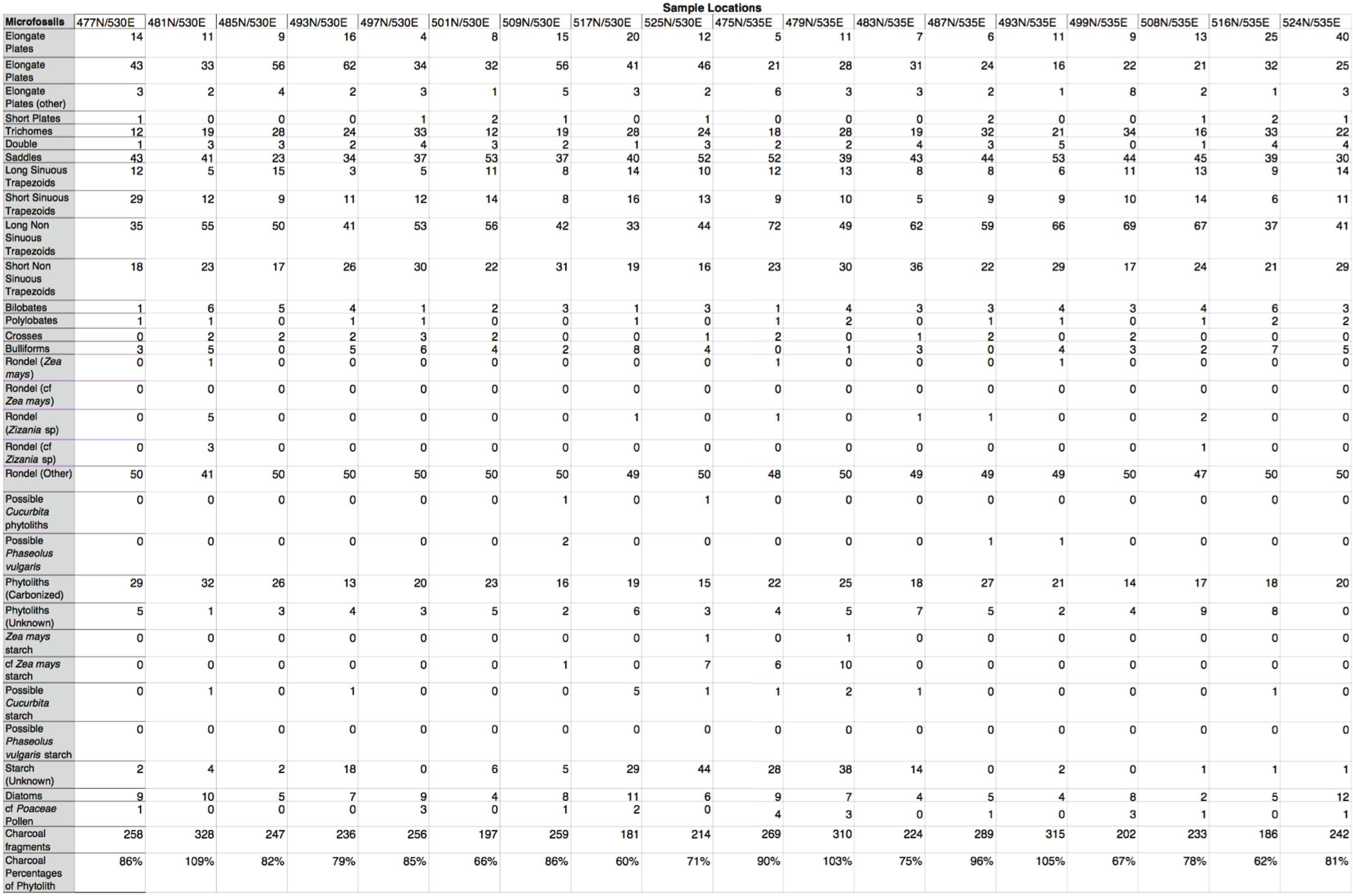
				Calibrated Age			
Site	**Material Dated**	**Lab I.D.**	**Conventional Radiocarbon Age (BP)**	**1 Sigma**	**2 Sigma**	**Associated Material**	**Source/Comments**
Martin-Bird	Charcoal	S-774	180 ± 140	A.D 1647 - post 1950	A.D 1485 - post 1950	Blackduck ceramics and historic trade goods from Area A.	Dawson 1987
Martin-Bird	Charcoal	S-775	660 ± 70	A.D 1277 - 1393	A.D 1228 - 1419	Blackduck ceramics and lithics and some Selkirk ceramics from Area A.	Dawson 1987
Martin-Bird	Charcoal	S-851	890 ± 130	A.D 1028 - 1246	A.D 884 - 1389	Blackduck ceramics from Area A.	Dawson 1987
Martin-Bird	Wood charcoal	S-772	1470 ± 120	A.D 428 - 660	A.D 259 - 858	No associated material. Area A.	Dawson 1987
Martin-Bird	Charcoal layer	S-773	3480 ± 70	B.C 1889 - 1695	B.C 1973 - 1626	Roasting pit feature from Area A.	Dawson 1987
Martin-Bird	Wood charcoal	S-852	320 ± 90	A.D 1470 - 1649	A.D 1421 - post 1950	Top stratum occupation from Area B.	Dawson 1987
Martin-Bird	Lime and charcoal	S-891	1150 ± 60	A.D 777 - 968	A.D 718 - 1015	Copper cache pit from Area B.	Dawson 1987
Martin-Bird	Charcoal	S-853	1750 ± 210	A.D 66 - 535	B.C 345 - A.D 673	Blackduck cultural refuse from Area B.	Dawson 1987
Martin-Bird	Charcoal	S-890	2280 ± 150	B.C 728 - 117	B.C 776 - 1	Laurel ceramics from Area B.	Dawson 1987
Martin-Bird	Charcoal	S-892	1320 ± 90	A.D 619 - 854	A.D 556 - 944	Near burial mound from Area C.	Dawson 1987
Martin-Bird	Carbonized residue	MB-FCRV-1	110 ± 30	A.D 1693 - 1919	A.D 1681 - 1938	Blackduck pottery from fire-cracked rock feature.	Boyd 2012
Martin-Bird	Carbonized residue	MB-SURFACE	640 ± 30	A.D 1292 - 1388	A.D 1283 - 1396	Selkirk/Rainy River pottery.	Boyd 2012
Martin-Bird	Carbonized residue	MB-SEL-390	1500 ± 30	A.D 543- 601	A.D 433 - 638	Clearwater Lake Punctate rim sherd.	Boyd 2012
Martin-Bird	Carbonized residue	MB-SEL-172	980 ± 30	A.D 1018 - 1147	A.D 994 - 1154	Clearwater Lake Punctate rim/neck sherd.	Boyd 2012
Martin-Bird	Carbonized residue	MB-BD-275	850 ± 30	A.D 1163 -1220	A.D 1053 - 1260	Kathio Series rim sherd.	Boyd 2012
Martin-Bird	Carbonized residue	MB-BD-327	1010 ± 30	A.D 992 -1031	A.D 975 - 1149	Blackduck rim sherd.	Boyd 2012
Macgillivray	Pure carbon lens	Gak-1278	2240 ± 80	B.C 392 -204	B.C 474 - 53	Eastern edge of burial mound.	Dawson 1980. No association with cultural material; dated sample deemed to from a forest fire.
Macgillivray	Wood sample	Gak-1942	1930 ± 200	B.C 170 -A.D 327	B.C 391 - A.D 535	Log crib area of mound.	Dawson 1980. Mound thought to represent early Laurel settlement
McCluskey	Charcoal	Gak-1282	1990 ± 90	B.C 106 - A.D 123	B.C 341 - A.D 235	Pottery cache and possible roasting pit.	Dawson 1974. Although site is primarily identified as Blackduck village site, date older than expected and may reflect Laurel occupation or dated sample was simply from a forest fire.
Mound Island	Charcoal	S-1476	0	N/A	N/A	Laurel rim sherd.	Dawson 1978. Date procured was modern and the disturbance may have been the result of campers or fisherman in the area.

Appendix 2: All radiocarbon dates for Whitefish Lake sites.



	Phosphorus Concentrations (ug/g)			
Sample Location	***Section 1 (0cm-4cm)***	***Section 2 (4cm-8cm)***	***Section 3 (8cm-12cm)***	***Controls***
48.242973/-90.025531	–	–	–	678.66
48.224672/-90.081365	–	–	–	529.38
48.210476/-90.082803	–	–	–	666.31
475N/530E	2051.79	2000.2	2608.28	
479N/530E	6242.91	6176.53	8145.83	
483N/530E	1846.85	1216.56	1816.74	
487N/530E	1950.22	1910.45	2005.31	
491N/530E	2247.11	2417.94	2121.07	
495N/530E	1801.71	1973	1918.49	
499N/530E	1594.58	1655.74	–	
503N/530E	1473.45	1663.16	1520.39	
507N/530E	1891.59	2064.76	1455.02	
511N/530E	1391.92	1460.88	1172.96	
515N/530E	1485.15	1745.9	–	
519N/530E	1282.35	1243.53	899.15	
523N/530E	1457.37	1443.49	570.74	
477N/535E	3200.16	3198.42	2889.32	
481N/535E	2118.46	2566.24	2771.82	
485N/535E	1491.03	1811.39	1703.24	
489N/535E	1871.44	1981.52	1568.73	
493N/535E	1622.44	1751.19	1529.43	
497N/535E	1705.73	1909.79	–	
502N/535E	1893.45	2257.03	1985.6	
506N/535E	2259.27	2052.09	2141.91	
510N/535E	1712.06	1887.14	1918.43	
514N/535E	1741.73	1745.14	1540.16	
518N/535E	1438.44	1398.07	1813.36	
522N/535E	1984.99	1987.13	2278.08	
526N/535E	1508.37	1474.9	1542.98	

Appendix 3: Total P levels (ug/g) from on-site samples and off-site controls.

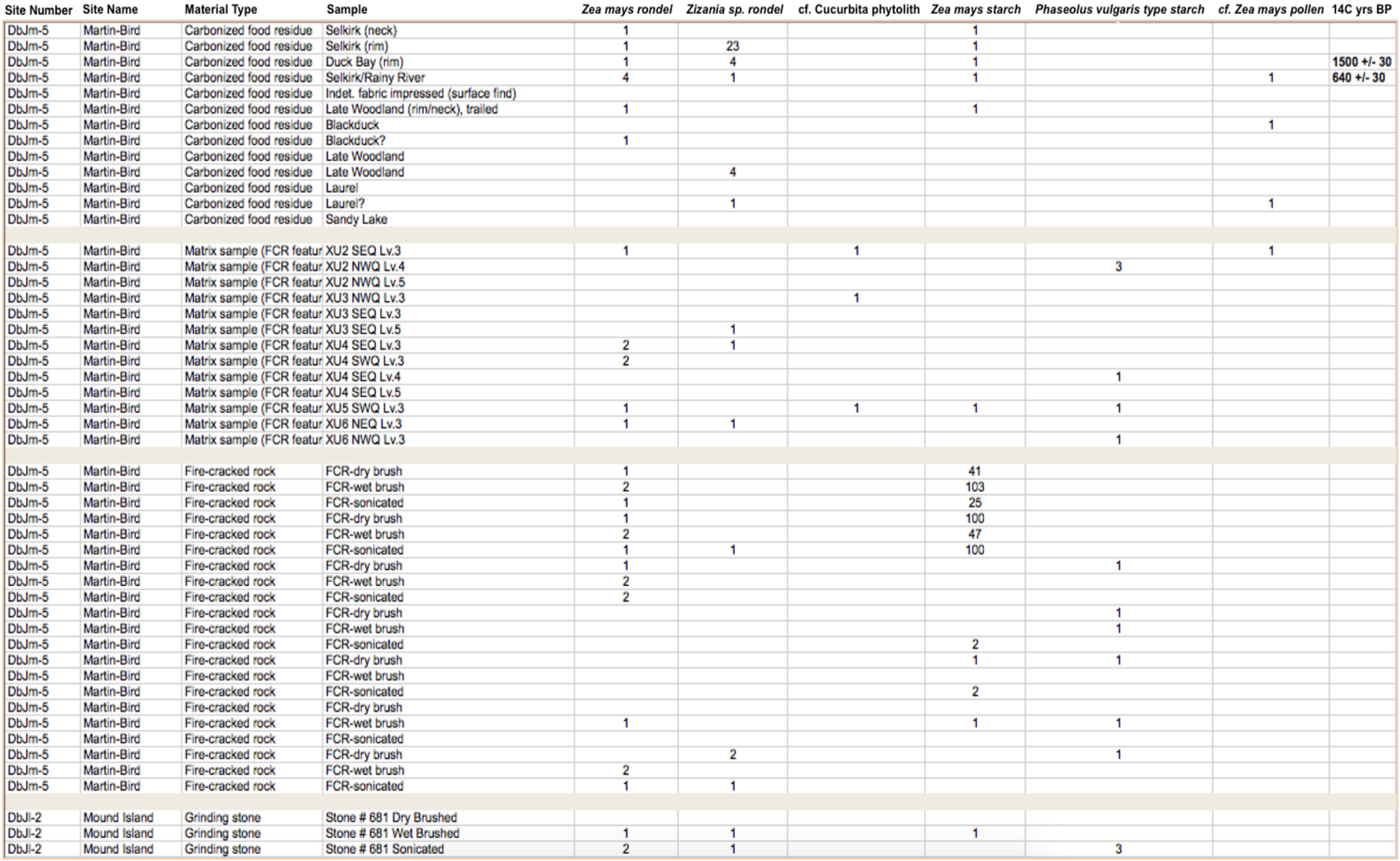


	Sample Locations																	
Microfossils	477N/530E	481N/530E	485N/530E	493N/530E	497N/530E	501N/530E	509N/530E	517N/530E	525N/530E	475N/535E	479N/535E	483N/535E	487N/535E	493N/535E	499N/535E	508N/535E	516N/535E	524N/535E
Elongate Plates	14	11	9	16	4	8	15	20	12	5	11	7	6	11	9	13	25	40
Elongate Plates	43	33	56	62	34	32	56	41	46	21	28	31	24	16	22	21	32	25
Elongate Plates (other)	3	2	4	2	3	1	5	3	2	6	3	3	2	1	8	2	1	3
Short Plates	1	0	0	0	1	2	1	0	1	0	0	0	2	0	0	1	2	1
Trichomes	12	19	28	24	33	12	19	28	24	18	28	19	32	21	34	16	33	22
Double	1	3	3	2	4	3	2	1	3	2	2	4	3	5	0	1	4	4
Saddles	43	41	23	34	37	53	37	40	52	52	39	43	44	53	44	45	39	30
Long Sinuous Trapezoids	12	5	15	3	5	11	8	14	10	12	13	8	8	6	11	13	9	14
Short Sinuous Trapezoids	29	12	9	11	12	14	8	16	13	9	10	5	9	9	10	14	6	11
Long Non Sinuous Trapezoids	35	55	50	41	53	56	42	33	44	72	49	62	59	66	69	67	37	41
Short Non Sinuous Trapezoids	18	23	17	26	30	22	31	19	16	23	30	36	22	29	17	24	21	29
Bilobates	1	6	5	4	1	2	3	1	3	1	4	3	3	4	3	4	6	3
Polylobates	1	1	0	1	1	0	0	1	0	1	2	0	1	1	0	1	2	2
Crosses	0	2	2	2	3	2	0	0	1	2	0	1	2	0	2	0	0	0
Bulliforms	3	5	0	5	6	4	2	8	4	0	1	3	0	4	3	2	7	5
Rondel (*Zea mays*)	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
Rondel (cf *Zea mays*)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rondel (*Zizania* sp)	0	5	0	0	0	0	0	1	0	1	0	1	1	0	0	2	0	0
Rondel (cf *Zizania* sp)	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Rondel (Other)	50	41	50	50	50	50	50	49	50	48	50	49	49	49	50	47	50	50
Possible *Cucurbita* phytoliths	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Possible *Phaseolus vulgaris*	0	0	0	0	0	0	2	0	0	0	0	0	1	1	0	0	0	0
Phytoliths (Carbonized)	29	32	26	13	20	23	16	19	15	22	25	18	27	21	14	17	18	20
Phytoliths (Unknown)	5	1	3	4	3	5	2	6	3	4	5	7	5	2	4	9	8	0
Zea mays starch	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0
cf *Zea mays* starch	0	0	0	0	0	0	1	0	7	6	10	0	0	0	0	0	0	0
Possible *Cucurbita* starch	0	1	0	1	0	0	0	5	1	1	2	1	0	0	0	0	1	0
Possible *Phaseolus vulgaris* starch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Starch (Unknown)	2	4	2	18	0	6	5	29	44	28	38	14	0	2	0	1	1	1
Diatoms	9	10	5	7	9	4	8	11	6	9	7	4	5	4	8	2	5	12
cf *Poaceae* Pollen	1	0	0	0	3	0	1	2	0	4	3	0	1	0	3	1	0	1
Charcoal fragments	258	328	247	236	256	197	259	181	214	269	310	224	289	315	202	233	186	242
Charcoal Percentages of Phytolith	86%	109%	82%	79%	85%	66%	86%	60%	71%	90%	103%	75%	96%	105%	67%	78%	62%	81%

Appendix 4: Total microfossil assemblage from Martin-Bird soil samples.

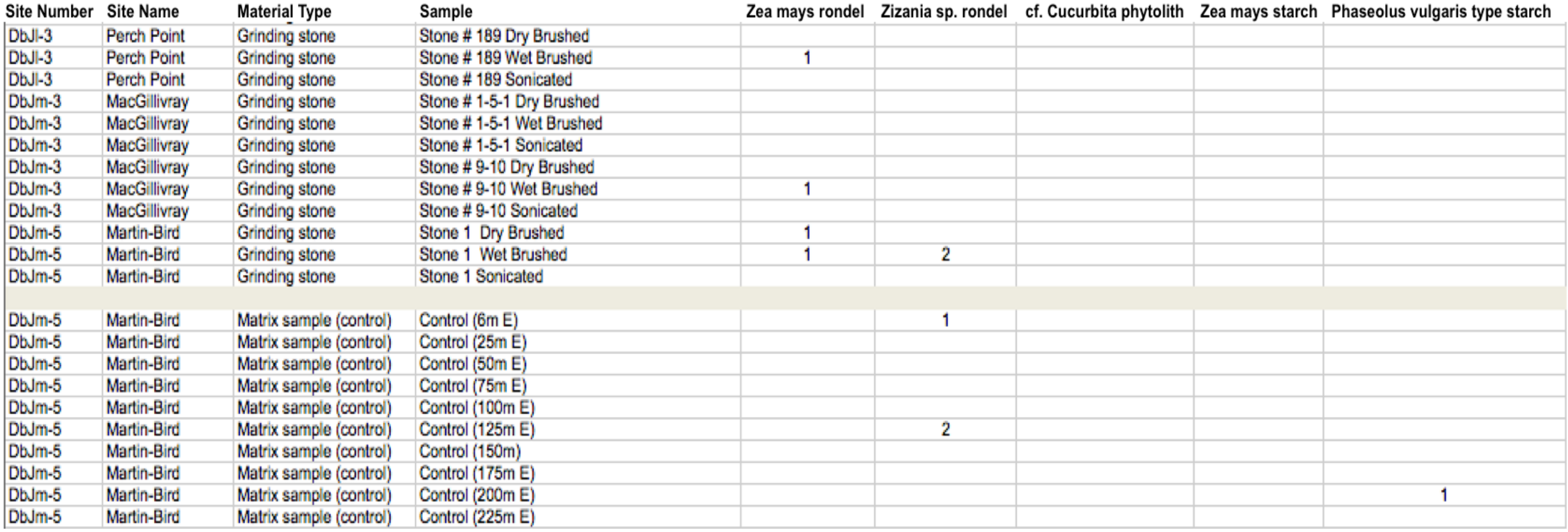
Site Number	Site Name	Material Type	Sample	*Zea mays* rondel	*Zizania* sp. rondel	cf. *Cucurbita* phytolith	*Zea mays* starch	*Phaseolus vulgaris* type starch	cf. *Zea mays* pollen	14C yrs BP
DbJl-1	East Road	Carbonized food residue	Selkirk					1		
DbJl-2	Mound Island	Carbonized food residue	Woodland	1	7		1	2		
DbJl-2	Mound Island	Carbonized food residue	Laurel							
DbJl-2	Mound Island	Carbonized food residue	Sandy Lake Plain							
DbJl-2	Mound Island	Carbonized food residue	Late Woodland					1		
DbJl-2	Mound Island	Carbonized food residue	Blackduck							
DbJl-3	Perch Point	Carbonized food residue	Blackduck							
DbJm-2	McCluskey	Carbonized food residue	Blackduck		2					
DbJm-2	McCluskey	Carbonized food residue	Blackduck		2					
DbJm-2	McCluskey	Carbonized food residue	Blackduck	1	2		1			
DbJm-2	McCluskey	Carbonized food residue	Blackduck							
DbJm-2	McCluskey	Carbonized food residue	Late Woodland							
DbJm-2	McCluskey	Carbonized food residue	Late Woodland							
DbJm-2	McCluskey	Carbonized food residue	Late Woodland	1						
DbJm-2	McCluskey	Carbonized food residue	Late Woodland		6					
DbJm-2	McCluskey	Carbonized food residue	Blackduck		5					
DbJm-2	McCluskey	Carbonized food residue	Late Woodland							
DbJm-2	McCluskey	Carbonized food residue	Laurel							
DbJm-3	MacGillivray	Carbonized food residue	Laurel	3	3					
DbJm-3	MacGillivray	Carbonized food residue	Laurel							
DbJm-4	Fisherman's Point	Carbonized food residue	Blackduck	3	1			1		
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck Mortuary Vessel	4	6		5	5		
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck (rim)	1	4			1		
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck (rim)	1	1		1			
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck (rim)		1		1			
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck complete vessel (FCR feature), rim	1			6			**110 +/- 30**
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck complete vessel (FCR feature), body				3			
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck (rim)	1			3			
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck (rim)	2	3					**1010 +/- 30**
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck/Laurel transitional							
DbJm-5	Martin-Bird	Carbonized food residue	Brainerd Parallel Grooved							
DbJm-5	Martin-Bird	Carbonized food residue	Kathio Series (rim)	1	1					**850 +/- 30**
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland	1		1	1	1		
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland				1			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)	1					1	
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)	1	1		1			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)				1			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)	1			3			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)				2			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)							
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)	1	3			1	1	
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)	2	1		1			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)							
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (body)	3						
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland fabric impressed (body)	2	1		1			
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland refit (body, n=4)	4	1		2		3	
DbJm-5	Martin-Bird	Carbonized food residue	Laurel (body), wide CWT impressions	2	4		2			
DbJm-5	Martin-Bird	Carbonized food residue	Middle Woodland? net-impressed sherd	3						
DbJm-5	Martin-Bird	Carbonized food residue	Selkirk (Clearwater Lake Punctate) rim/neck	5	7		19	2		
DbJm-5	Martin-Bird	Carbonized food residue	Selkirk (neck)							**980 +/- 30**

Appendix 5: Total microfossil assemblage from Boyd (N.D) from various samples and sites at Whitefish Lake.



Site Number	Site Name	Material Type	Sample	*Zea mays rondel*	*Zizania sp. rondel*	cf. Cucurbita phytolith	*Zea mays starch*	*Phaseolus vulgaris type starch*	*cf. Zea mays pollen*	14C yrs BP
DbJm-5	Martin-Bird	Carbonized food residue	Selkirk (neck)	1			1			
DbJm-5	Martin-Bird	Carbonized food residue	Selkirk (rim)	1	23		1			
DbJm-5	Martin-Bird	Carbonized food residue	Duck Bay (rim)	1	4		1			**1500 +/- 30**
DbJm-5	Martin-Bird	Carbonized food residue	Selkirk/Rainy River	4	1		1		1	**640 +/- 30**
DbJm-5	Martin-Bird	Carbonized food residue	Indet. fabric impressed (surface find)							
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland (rim/neck), trailed	1			1			
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck						1	
DbJm-5	Martin-Bird	Carbonized food residue	Blackduck?	1						
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland							
DbJm-5	Martin-Bird	Carbonized food residue	Late Woodland		4					
DbJm-5	Martin-Bird	Carbonized food residue	Laurel							
DbJm-5	Martin-Bird	Carbonized food residue	Laurel?		1				1	
DbJm-5	Martin-Bird	Carbonized food residue	Sandy Lake							
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU2 SEQ Lv.3	1		1			1	
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU2 NWQ Lv.4					3		
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU2 NWQ Lv.5							
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU3 NWQ Lv.3			1				
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU3 SEQ Lv.3							
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU3 SEQ Lv.5		1					
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU4 SEQ Lv.3	2	1					
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU4 SWQ Lv.3	2						
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU4 SEQ Lv.4					1		
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU4 SEQ Lv.5							
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU5 SWQ Lv.3	1		1	1	1		
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU6 NEQ Lv.3	1	1					
DbJm-5	Martin-Bird	Matrix sample (FCR featur	XU6 NWQ Lv.3					1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush	1			41			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush	2			103			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated	1			25			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush	1			100			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush	2			47			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated	1	1		100			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush	1				1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush	2						
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated	2						
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush					1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush					1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated				2			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush				1	1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush							
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated				2			
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush							
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush	1			1	1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated							
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-dry brush		2			1		
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-wet brush	2						
DbJm-5	Martin-Bird	Fire-cracked rock	FCR-sonicated	1	1					
DbJl-2	Mound Island	Grinding stone	Stone # 681 Dry Brushed							
DbJl-2	Mound Island	Grinding stone	Stone # 681 Wet Brushed	1	1		1			
DbJl-2	Mound Island	Grinding stone	Stone # 681 Sonicated	2	1			3		

Appendix 5 continued: Total microfossil assemblage from Boyd (N.D) from various samples and sites at Whitefish Lake



Site Number	Site Name	Material Type	Sample	Zea mays rondel	Zizania sp. rondel	cf. Cucurbita phytolith	Zea mays starch	Phaseolus vulgaris type starch
DbJl-3	Perch Point	Grinding stone	Stone # 189 Dry Brushed					
DbJl-3	Perch Point	Grinding stone	Stone # 189 Wet Brushed	1				
DbJl-3	Perch Point	Grinding stone	Stone # 189 Sonicated					
DbJm-3	MacGillivray	Grinding stone	Stone # 1-5-1 Dry Brushed					
DbJm-3	MacGillivray	Grinding stone	Stone # 1-5-1 Wet Brushed					
DbJm-3	MacGillivray	Grinding stone	Stone # 1-5-1 Sonicated					
DbJm-3	MacGillivray	Grinding stone	Stone # 9-10 Dry Brushed					
DbJm-3	MacGillivray	Grinding stone	Stone # 9-10 Wet Brushed	1				
DbJm-3	MacGillivray	Grinding stone	Stone # 9-10 Sonicated					
DbJm-5	Martin-Bird	Grinding stone	Stone 1 Dry Brushed	1				
DbJm-5	Martin-Bird	Grinding stone	Stone 1 Wet Brushed	1	2			
DbJm-5	Martin-Bird	Grinding stone	Stone 1 Sonicated					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (6m E)		1			
DbJm-5	Martin-Bird	Matrix sample (control)	Control (25m E)					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (50m E)					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (75m E)					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (100m E)					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (125m E)		2			
DbJm-5	Martin-Bird	Matrix sample (control)	Control (150m)					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (175m E)					
DbJm-5	Martin-Bird	Matrix sample (control)	Control (200m E)					1
DbJm-5	Martin-Bird	Matrix sample (control)	Control (225m E)					

Appendix 5 continued: Total microfossil assemblage from Boyd (N.D) from various samples and sites at Whitefish Lake.